DEVELOPMENT OF GLUTEN-FREE BREAD FORMULATIONS FOR BAKING IN INFRARED-MICROWAVE COMBINATION OVEN

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İLKEM DEMİRKESEN MERT

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DEVELOPMENT OF GLUTEN-FREE BREAD FORMULATIONS FOR BAKING IN INFRARED-MICROWAVE COMBINATION OVEN

submitted by **İLKEM DEMİRKESEN MERT** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Food Engineering Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen ________________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Alev Bayındırlı ________________
Head of Department, **Food Engineering Dept., METU**

Prof. Dr. Servet Gülüm Şumnu ________________
Supervisor, **Food Engineering Dept., METU**

Prof. Dr. Serpil Şahin ________________
Co-Supervisor, **Food Engineering Dept., METU**

Examining Committee Members:

Prof. Dr.Hamit Köksel ________________
Food Engineering Dept., Hacettepe University

Prof. Dr. Servet Gülüm Şumnu ________________
Food Engineering Dept., METU

Prof. Dr. Alev Bayındırlı ________________
Food Engineering Dept., METU

Prof. Dr. Esra Yener ________________
Food Engineering Dept., METU

Assist. Prof. Dr. İlkay Şensoy ________________
Food Engineering Dept., METU

Date: 05.07.2013

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: İlkem Demirkesen Mert

Signature:

ABSTRACT

DEVELOPMENT OF GLUTEN-FREE BREAD FORMULATIONS FOR BAKING IN INFRARED-MICROWAVE COMBINATION OVEN

Demirkesen Mert, İlkem
Ph.D., Department of Food Engineering
Supervisor: Prof. Dr. Servet Gülüm Şumnu
Co-Supervisor: Prof. Dr. Serpil Şahin

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The main objective of this study was to formulate gluten free breads based on different flours, gums, and emulsifiers for baking in infrared-microwave combination oven. In the first part of the study, the rheological properties of different gluten-free bread dough formulations containing only rice flour and rice-chestnut flour blend with different gums, gum blends and/or emulsifiers were evaluated. Power law model and Herschel–Bulkley models were found to explain the flow behaviors of rice and chestnut-rice dough formulations, respectively. The formulations with the chestnut:rice flour ratio of 30:70 promoted the desired quality parameters of gluten-free breads. Using tigernut flour in formulations improved the color of gluten-free rice breads. Furthermore, gum blend and emulsifier DATEM addition were found to be the necessary ingredients to obtain the desired physical properties in gluten-free bread formulations.

In the second part of the study, Response Surface Methodology (RSM) was used to optimize formulations and infrared-microwave baking conditions for gluten-free breads. Breads containing 46.5% chestnut flour and 0.62% emulsifier and baked using 40% infrared and 30% microwave power for 9 min had comparable quality with conventionally baked ones.

The effects of different flours, gums, and emulsifiers on macro- and micro-structures of the gluten-free breads baked in different ovens were studied by using image analysis technique and Scanning Electron Microscope (SEM). The highest pore area fraction values were obtained in breads prepared by replacement of 46% of rice flour with chestnut flour containing xanthan–guar gum blend–DATEM mixture and baked in an infrared–microwave combination oven. The addition of different gums and gum blends on the crumb structures of gluten-free breads were evaluated by using X-ray microtomography (X-ray μCT) and gluten-free breads prepared with the addition of xanthan, carboxyl methyl cellulose (CMC), xanthan-guar, xanthan-LBG and HPMC had higher number of smaller pores with finer crumb structure.

Lastly, the effects of different formulations and storage time on staling of conventionally and infrared-microwave baked breads were studied. Firmness, moisture loss and retrogradation enthalpy values for all bread samples increased significantly during storage. Retrogradation enthalpies and total crystallinity values of breads did not show significant differences with baking method. Using chestnut flour and xanthan-guar gum blend-DATEM mixture in formulations significantly delayed staling of gluten-free breads by decreasing moisture loss, firmness, retrogradation enthalpy, and total mass crystallinity.

Keywords: Chestnut flour, Emulsifier, Gluten-free bread, Gum, Infrared–microwave combination baking, Rice flour, Tigernut flour.

ÖZ

KIZILÖTESİ-MİKRODALGA KOMBİNASYONLU FIRIN İÇİN GLUTENSIZ EKMEK FORMÜLASYONLARININ GELİŞTİRİLMESİ

Demirkesen Mert, İlkem
Doktora, Gıda Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Gülüm Şumnu
Ortak Tez Yöneticisi: Prof. Dr. Serpil Şahin

Temmuz 2013, 425 sayfa

Bu çalışmanın ana amacı kızılötesi-mikrodalga kombinasyonlu fırında pişirilmek üzere farklı unlar, gamlar ve emülgatörler içeren glutensiz ekmeklerin tasarlanmasıdır. Çalışmanın ilk kısmında, sadece pirinç unu ve pirinç-kestane unu karışımlarıyla farklı gamlar, gam karışımları ve/veya farklı emülgatörler içeren glutensiz ekmek hamurlarının reolojik özellikleri incelenmiştir. Power yasası ve Herschel-Bulkley modelleri sırasıyla pirinç ve kestane-pirinç hamuru formülasyonlarının akış davranışlarını açıklamakta uygun bulunmuştur. Kestane:pirinç unu oranı 30:70 olan formülasyonlar istenilen kalite parametrelerini sağlamıştır. Formülasyonlarda yer bademi unu kullanımı glütensiz pirinç ekmeklerinin renklerini geliştirmiştir. Ayrıca, glutensiz ekmek formülasyonlarında istenilen fiziksel özelliklerin elde edilebilmesi için gam karışımları ve emülgator DATEM ilavesinin gerekli olduğu bulunmuştur.

Çalışmanın ikinci kısmında, glutensiz ekmekler için formülasyonları ve kızılötesi-mikrodalga kombinasyonlu fırınlarda pişirme şartlarını optimize etmek amacıyla Yanıt Yüzey Metodu kullanılmıştır. %46.5 kestane unu ve %0.62 emülgatör içeren ve %40 kızılötesi ve %30 mikrodalga gücü kullanılarak 9 dakikada pişirilen ekmekler konvansiyonel fırınlarda pişirilen ekmeklerle karşılaştırılabilir kaliteye sahip olmuşlardır.

Görüntü analiz tekniği ve taramalı elektron mikroskobu kullanılarak farklı unların, gamların ve emülgatörlerin farklı fırınlarda pişirilen glutensiz ekmeklerin makro ve mikro yapıları üzerine etkileri incelenmiştir. En yüksek gözenek alan oranı pirinç ununun % 46'sı yerine kestane unu eklenerek elde edilen ve ksantan−guar gam−DATEM karışımı içeren ekmek formülasyonlarının kızıl ötesi−mikrodalga kombinasyonlu fırınlarda pişirilmesiyle elde edilmiştir. Farklı gam ve gam karışımları ilavesinin glutensiz ekmeklerin iç yapısına etkisi X-ray mikrotomografi (X-ray μCT) kullanılarak değerlendirilmiştir ve ksantan, karboksi metil selüloz

(CMC), ksantan-guar, ksantan-LBG ve HPMC ilavesi ile hazırlanan glutensiz ekmekler yüksek sayıda küçük gözeneklerle iyi ekmek iç yapısı niteliğine sahip olmuşlardır.

Son olarak, farklı formülasyonların ve saklama sürelerinin konvansiyonel ve kızıl ötesi-mikrodalga kombinasyonlu fırınlarda pişirilen ekmeklerin bayatlamaları üzerine etkileri belirlenmiştir. Ekmek örneklerinin sertlik, nem kaybı ve retrogradasyon entalpi değerleri saklama sırasında önemli bir şekilde artmıştır. Ekmeklerin retrogradasyon entalpileri ve toplam kristalleşme değerleri pişirme yöntemine göre bir farklılık göstermemiştir. Formülasyonda kestane unu ve ksantan-guar gam-DATEM karışımının kullanılması ekmeklerin bayatlamasını nem kaybını, sertlik değerini, retrogradasyon entalpisini ve toplam kütle kristalleşmesini azalmak suretiyle önemli bir şekilde geciktirmiştir.

Anahtar kelimeler: Kestane unu, Glutensiz ekmek, Gam, kızıl ötesi-mikrodalga kombinasyonlu pişirme yöntemi, pirinç unu, yer bademi unu

To My Grandmother's Memory

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CHAPTER 1

INTRODUCTION

1.1 Celiac Disease

Celiac disease (gluten sensitive entropathy), is a multi-symptom, autoimmune disorder is which is triggered by the response of the body's immune system to prolamins found in wheat (gliadin), rye (secalin), barley (hordein), and their crossbreeds (Bower, 2006). This gluten-sensitive enteropathy is controlled by a combination of genetic and environmental risk factors. Hence a permanent withdrawal of gluten from the diet of celiac patients is required throughout their life-span. Recent studies showed that not only high molecular weight glutenin and sub-units of gluten proteins but also the gliadin parts of glutens have also toxic effects to celiac patients (Ellis et al., 2006). When people with celiac disease consume gluten, their immune system generates antibodies against this protein causing damage to the tiny hairlike projections in the small intestine, in severe cases the lesion extends to the ileum colon. The inflammation of the small intestine causes the malabsorption of nutrients such as iron, calcium, folate, and fat-soluble vitamin. Moreover, celiac patients are prone to the nutrient-related deficiencies such as osteoporosis, anaemia, and failure to thrive due to their nutritionally unbalanced diet (Mendoza, 2005, Arendt et al., 2008).

Since the symptoms of celiac disease show similarities with many common chronic intestinal disorders, such as irritable bowel syndrome, Crohn's disease, and ulcerative colitis, it is frequently misdiagnosed (Mendoza, 2005). Moreover, it remains undiagnosed because it is often a typical or even silent on clinical grounds that lead to the risk of long-term complications such as osteoporosis, infertility and cancer. Although it is difficult to calculate of the true extent of celiac disease occurrence, the prevalence of celiac disease in the United States is estimated to be at least 1:133 and it is approximately present in 1:150–300 in Europe (Fasano et al., 2003; McLoughlin et al., 2003; Tandoruk, 2005). However, recent studies showed that celiac disease is more common than previously reported and the incidence is 1:100-30:100 in the general population of Europe and United States (Catassi et al., 2002). Although, there is not a certain percentage for Turkey, it is estimated that there are 500000 celiac patients and due to insufficient diagnosis, only 1% of them have been diagnosed until now (http://www.xn--lyak-zoa4g.com/haber/45-2colyak-hastaligi-bilimsel-toplantisi-bursa39da-ya.html. Last visited: May, 2013). However, according to recent national scientific researches, the occurrence of celiac disease is much higher than supposed and 1 in every 100 people has celiac disease in Turkey.

1.1.1 The Difference between Wheat Sensitivity and Celiac Disease

Celiac disease differs from wheat sensitivity. There are four classes of protein in wheat: albumin, globulin, gliadin, and glutenin. People who have sensitivity to exposure of albumin and globulin are called as wheat sensitive and they have an IgE-mediated response to these wheat proteins. In an IgE-mediated allergy, at least two binding sites must be present on the epitope. The occurrence of this sensitivity is not frequent and is often diagnosed in early childhood. People with wheat sensitivity must avoid wheat, but they may consume barley, rye and oats. On the other hand, celiac disease is caused by the exposure of glutenin and gliadin. In celiac disease only a single binding peptide is present (Hamer, 2005). Therefore, celiac disease is not categorized as an allergy. In addition, the onset of intestinal damage symptom of celiac disease is not as fast as the onset of allergy, which typically occurs within an hour. Thus, it is often misdiagnosed or undiagnosed.

1.1.2 Symptoms of Celiac Disease

Indigestion, abdominal pain, bloating and gas production, bulky fatty bowel motions, sometimes pale and offensive smelling, failure to thrive, vomiting, muscle wasting are general symptoms, while hypoprotein anemia comprising possible ascites, general irritability and unhappiness are general signs of celiac disease. However, the classical picture of celiac disease includes intestinal malabsorption, chronic diarrhea, weight loss, abdominal distension and anaemia (Catassi et al., 2002). In infants and children symptoms consist of muscle cramps due to low calcium levels, slowed growth rate, itchy or painful rashes and in untreated conditions, symptoms can be more severe including nervous system damage. On the other hand, adults do not usually present with malabsorption unlike children (Niewinski and RD, 2008). In addition, in adults, the disease has non-specific symptoms such as fatigue, vague abdominal pains, intermittent diarrhea, tiredness, upper abdominal pain and constipation. Moreover, because of damage of intestinal mucosa, lactose intolerance can also occur in adults. In untreated conditions, adults with celiac disease have long-term risks such as osteoporosis, anaemia and gastrointestinal malignancy (Hamer, 2005). More specifically, women with untreated celiac disease are prone to miscarriages and mothers are at increased risk for having low birth weight babies (Ciclitira and Moodie, 2003).

1.1.3 Screening for Celiac Disease

Blood test is used to screen celiac disease. Antibodies to gliadin, which is toxic to celiac patients, are elevated in celiac patients. However, if high levels of anti-gliadin are detected, they may not certainly show celiac disease. Nevertheless, anti-gliadin antibody levels are useful in monitoring response to treatment since these antibodies return to normal level within several months when a gluten-free diet is initiated. Other antibodies produced by the body against itself and responsible for the damage induced by gluten in the small bowel, are EmA (anti-endomysial antibodies) and anti-Ttg (tissue transglutaminase antibodies). These antibodies are more sensitive than antigliadin antibodies. Elevated levels of these antibodies almost certainly reflect celiac disease (Niewinski and RD, 2008). Similar to antigliadin antibodies, they begin to fall normal levels when gluten is removed from the diet. A positive blood test requires tissue confirmation. A tissue biopsy is used not only to confirm the diagnosis but also to measure the degree of damage. A small intestinal biopsy is performed by the help of esophagogastroduodenoscopy (EGD), the tissue samples for loss of villi and other features of celiac disease, which are screened by a pathologist (http://www.webmd.com/digestive-disorders/celiac-disease/celiac-disease-diagnosis-tests). With the introduction of a gluten-free diet, the damage to the small bowel returns to normal over a period of a few months to 1–2 years in the majority of patients.

1.1.4 The Gluten-free Label Requirements

Celiac patients should read all food labels to ensure the gluten-free status of a food item. In 2004, The Food Allergen Labeling and Consumer Protection Act has intended to provide consumers with sufficient information so that they can avoid potentially life-threatening allergic reactions to food or an ingredient in food. After 2006, it has been stated that all food products manufactured must be clearly labeled to indicate the presence of any of the top eight food allergens which are milk, eggs, fish, crustacean shellfish, tree nuts, peanuts, soybeans, and wheat (Köksel, 2009).

There are certain groups of foods, which are not allowed in a gluten-free diet

a) Any bread, cereal or other food produced from wheat, rye, barley, triticale, kamut and oat flour or ingredients, and by-products made from those grains

b) Processed foods that comprise wheat and gluten-derivatives as thickeners and fillers, such as hot dogs, salad dressings, canned soups/dried soup mixes, processed cheese and cream sauces

c) Medications that use gluten as pill or tablet binders (Gallagher et al., 2004).

However, there is still a debate around the world in labeling of gluten-free foods. Since the protein component of wheat can not be completely removed from its starch component and thus, completely removal of gluten from gluten-free products is impossible.

US Food and Drug Administration is suggesting to determine food-labelling term “gluten-free” to mean that a food bearing this claim does not contain any of the following;

a) An ingredient that is a “prohibited grain”, which includes any species of wheat (such as durum wheat, spelt wheat or kamut), rye, barley or their crossbred hybrids;

b) An ingredient (e.g. wheat flour) that is derived from a "prohibited grain" and that has not been processed to remove gluten;

c) An ingredient (e.g. wheat starch) that is derived from a "prohibited grain" that has been processed to remove gluten, if the use of that ingredient results in the presence of 20 ppm (6 mg equivalent) or more gluten in the food;

d) 20 ppm or more gluten.

Most European countries use The Codex Standard for gluten-free foods that were adopted by the Codex Alimentarius Commission of the World Health Organization (WHO) and by the Food and Agricultural Organization (FAO). "Gluten free" food products are defined in Codex Alimentarius guidelines as containing <200 ppm gluten for cereal derived and <20 ppm for non-cereal derived foods (Codex Standard 118, 1979). AOAC (1995) method 991.19 is the formally authorized method for the determination of relatively high levels of gluten in food and its raw materials. For this purpose, contamination tests can be done by using gluten assay kits and these kits are used for the detection and quantification of gluten at very low concentrations in uncooked and cooked foods and the assay uses antibodies to gliadin protein in a non-competitive, sandwich type ELISA. The ready to use standards provide accurate quantification in parts per million (ppm).

Due to the lack of federal standards, the Gluten Intolerance Group has also established a voluntary program of testing and monitoring gluten-free food products. The Gluten-Free Certification Organization, which identifies qualifying foods with a "gluten-free" certification mark, was established in 2005. In order to meet the highest standards for gluten-free ingredients and safe processing environment, this organization uses strict standards to certify (Niewinski and RD, 2008). In Turkey, the standard for gluten-free foods, which was adopted by Turkey Standards Institution (TSE) are used (TS 13143, 2005).

1.2 Gluten and Its Role in Breadmaking

Bread is one of the most important basic items of the human diet. Wheat, which is the major cereal in breadmaking, comprises of starch (70–75%), water (14%), proteins (10–12%), non-starch polysaccharides (2–3%), particularly arabinoxylans and lipids (2%) (Goesaert et al., 2005). Wheat flour consists of two groups of proteins; the non-gluten proteins, which have either no or just a minor role in bread making, and the gluten proteins, which have a major role. The non-gluten proteins, which consist of 15 and 20 % of total wheat protein, are mainly present in the outer layers of the wheat kernel. These proteins are mostly structural proteins and genetically related to the major storage proteins in legumes and in the cereals of oats and rice. Gluten is the major storage protein of wheat and contributed of 80-85% of the total wheat protein. They are found in the endosperm cells of the mature wheat grain where they form a continuous matrix around the starch granules (Van Der

Borght et al., 2005). It is essential to form a strong protein network for the desired viscoelasticity to obtain high quality from breads. Therefore, the quality and quantity of gluten have critical role in quality of breads. Since gluten proteins are largely insoluble in the water, it can be purified by washing away from the associated starch and the water soluble components. When it is isolated from flour, it is composed of 80% protein and 8% lipids (on a dry basis), with the remainder being ash and carbohydrate (Hoseney, 1986). Glutenin and prolamin are the major fractions of the gluten. Glutenin molecule is linked by intermolecular disulfide bonds giving a network structure. In contrast, monomeric gliadin molecule is linked by intramolecular disulfide bonds, creating the proteins a globular confirmation (Tronsmo et al., 2002). Therefore, while prolamin provides viscous properties and extensibility in a dough system, polymeric glutenin is responsible for elastic and cohesive properties of dough (Gujral and Rosell, 2004). Together, the two are important for crumb structure of cereal-based products and the relative proportions of gliadin and glutenin affect the quality of products. When flour is mixed with water, gluten proteins provide cohesive viscoelastic properties to dough that is responsible of retaining gas produced during fermentation and oven-rise, so the high volume and soft texture can be obtained from the products.

1.3 Gluten-free Flour Types

Since gluten provides the viscoelastic properties to dough, absence of gluten significantly impairs the quality of products. Therefore, most of the gluten-free products have low volume, poor texture and flavor and stales faster. In addition, they do not have adequate amount of vitamins, minerals and fiber that worsens the nutritionally unbalanced diet of celiac sufferers (Bardella et al., 2000). To fulfill the expectations of celiac disease sufferers, many scientists and manufacturers seek alternative flour types to wheat flour such as rice, corn, chickpea, soy, soybean and sorghum flour and pseudocereals such as buckwheat and amaranth. However, it is difficult to obtain desired quality without using some additives such as gums, emulsifiers, dairy ingredients or dietary fiber.

1.3.1 Rice Flour

Rice is the most important staple food in Asia and India and it has the second or third-highest worldwide production rate after maize and/or wheat (Rosell and Marco, 2008). Rice flour is the most suitable cereal flour for preparing gluten-free products due to its several significant properties such as natural, hypoallergenic, colorless, and bland taste. It has also very low level of protein, sodium, fat and high amount of easily digested carbohydrates. Rice has very little prolamins (2.5-3.5%). It can be used alone or in combination with other types of flours. Despite of its numerous advantages, rice proteins have poor functional properties. Moreover, they are insoluble because of the hydrophobic nature and this prevents the formation of viscoelastic structure in dough (Rosell and Collar, 2007). As a consequence, rice products have low volume, firm texture, short shelf-lives and stales rapidly. Therefore, many studies were conducted on the usage of ingredients in bread formulations to overcome the problems associated with rice flour.

Several studies in the literature have demonstrated the potential use of rice flour for the development of gluten-free breads. In these studies, researchers used different gums, enzymes, and dietary fibers to develop gluten-free bread formulations. Cato et al. (2004) investigated the effect of guar gum, HPMC and CMC on gluten-free breads using rice flour mixed with potato starch. Lopez et al. (2004) optimized gluten-free bread formulation using rice flour, corn starch and cassava starch. Sivaramakrishnan et al. (2004) studied the effect of HPMC on rheological properties of rice dough and the quality of rice bread for the production of gluten-free bread. Ahlborn et al. (2005) prepared and evaluated gluten-free breads using rice flours, milk proteins, egg proteins, xanthan gum, and HPMC. McCarthy et al. (2005) optimized a gluten-free bread formulation based on rice flour, potato starch, skim milk powder and HPMC using a response surface methodology. Lee and Lee (2006) showed that the addition of xanthan gum decreased crumb firmness of fresh and stored rice flour based breads. Moore et al. (2006) conducted a study to show the effect of xanthan gum on gluten free breads that were prepared using rice flour, corn starch and potato starch. Lazaridou et al. (2007) prepared gluten-free bread formulations based on rice flour, corn starch, sodium caseinate, and different gums and found that there was an improvement in dough rheological characteristics and bread quality when pectin and CMC combination was used. Phimolsiripol et al. (2012) investigated the physical, nutritional and sensory quality and shelf life of rice-based gluten-free bread by using different fractions of rice bran and different ratios of insoluble to soluble dietary fibers.

A technological approach for the production of gluten-free breads that meet the unique nutritional and sensory requirements of celiac patients is a growing need. Using blends of different flours with rice flour in the presence of hydrocolloid has the potential to give gluten-free breads with good sensory attributes.

1.3.2 Chestnut Flour

According to FAO statistics, The Republic of Korea and China are the top producers of chestnut with their production about 43% of the world's chestnuts. Other major chestnut-producing countries are Italy and Turkey with their production about more than 25% of the world's chestnuts (FAO, 1999). Turkey's production rate is about 49000 tons per year. Chestnut flour has high quality proteins with essential amino acids (4-7%), relatively high amount of sugar (20-32%), starch (50-60%), dietary fiber (4-10%), and low amount of fat (2-4%). It also includes some important vitamins such as vitamins E, C, B group and minerals such as potassium, phosphorous, magnesium, calcium, copper, iron, manganese and sulfur (Sacchetti et al., 2004, Chenlo et al., 2007). In addition, it has some important phenolics (gallic and ellagic acid) that have various positive health effects (Blaiotta et al., 2012). Most of the gluten-free products do not contain sufficient amount of Vitamin B, Vitamin D, magnesium, calcium, iron, folate, and dietary fiber since they are not enriched and fortified (Arendt et al., 2008). Therefore, it may be advantageous to use chestnut flour due to its nutritional value. Besides its health and nutritional benefits, the ingredients of chestnut flour may provide some functional properties to the dough. While fiber content of chestnut flour may assist emulsifying, stabilizing, texturizing and thickening properties to dough, the sugar content of chestnut flour may improve the color and flavour properties of gluten-free products when it is used at a certain level.

The studies on chestnut flour are limited in literature. Sacchetti et al. (2004) determined the effects of extrusion temperature and chestnut flour composition on the functional and physical properties of snack-like products. They reported that the relatively high sugar to starch ratio of chestnut flour resulted in insufficient expansion of the extruded products. It was also reported that blending chestnut flour with rice flour resulted in better quality products. Chenlo et al. (2007) determined the influence of water content and temperature on the rheological behavior of chestnut flour pastes. Correia et al. (2009) studied the effect of the drying temperature on morphological, physical and chemical properties of the dried chestnut flours. In 2010, Moreira and coworkers determined the influence of particle size on the rheological properties of chestnut flour doughs. There is no available study on the production of gluten-free breads by using chestnut flour yet.

1.3.3 Tigernut Flour

Tigernut (*Cyperusesculentus*), also known as chufa, is an underutilized crop grown extensively in Mediterranean regions (Coskuner et al., 2002). Tigernut flour is a rich source of high quality oil and contains appreciable quantities of the fatty acids such as myristic acid, oleic acid and linoleic acid (Chinma et al., 2010). For satisfying adult needs, it has moderate amount of proteins with higher essential amino acids than those proposed in the protein standard by the FAO/WHO (1985) (Ade-Omowaye et al., 2008). Furthermore, it is an excellent source of some useful minerals and vitamins such as phosphorus, potassium, iron, calcium, and vitamins E and C.

Tigernut flour has high amount of dietary fiber, which is an important role in the human health because of the prevention, reduction, and treatment of some disease such as colon cancer, coronary heart diseases, obesity, diabetics and gastro intestinal disorders. Moreover, high dietary fiber consumption enhances blood circulation, aids in weight loss and appears to improve immune function. Tigernut has also been reported to be used in the treatment of flatulence, indigestion, diarrhea, dysentery, and excessive thirst (Sánchez-Zapata et al., 2010). In addition to its health effects, fiber content of tigernut flour also responsible for providing some functional and technological properties. Therefore, it can improve volume and texture of breads when they are used as certain quantities.

Studies on the usage of tigernut flour in bakery products are limited in literature. Oladele and Aina (2007) compared chemical composition and functional properties of flour produced from two varieties of tigernut. Chinma et al. (2010) studied the usage of tigernut and wheat flours at different proportions (0:100, 10:90, 20:80, 30:70, 40:60 and 50:50) in cakes and found that cakes were acceptable in terms of volume and batter density when 30% tigernut flour substitution was used. Ade-Omowaye et al. (2008) produced breads by substituting wheat with tigernut flour at different proportions (0:100, 10:90, 20:80, 30:70, 40:60 and 50:50) and evaluated these breads for proximate composition and physico-chemical properties. It was found that breads with qualities similar to 100% wheat bread were produced from 10% tigernut flour addition. Chinma and co-workers (2012) investigated the effects of the addition of germinated tigernut and moringa flour on the quality characteristics of wheat-based bread. It has been demonstrated that blending wheat flour with germinated tigernut and moringa flour blends improved the proximate composition and affected their pasting properties. It has also been suggested that such composite flour would help reduce protein–energy and micronutrient deficiency prevalent in developing countries. All these studies have been shown that tigernut flour has a potential to be used in the development of gluten-free products alone or in combination with the gluten-free flours such as rice flour.

1.4 Ingredients Used in Gluten-free Baked Products

Nowadays, the use of additives, which have the ability to mimic the viscoelastic properties of gluten has commonly been applied in gluten-free industry. Food hydrocolloids are one of the most extensively used functional ingredients in the food industry. In the gluten-free baked goods, hydrocolloids have been used for improving rheological properties of doughs as well as the quality of the fresh products and for retarding the staling. The most used hydrocolloids in the gluten-free industry included in this kind of substances are xanthan gum, guar gum, locust bean gum (LBG) and hydroxypropylmethylcellulose (HPMC) and carboxymethylcellulose (CMC). Emulsifiers are frequently added to commercial bakery products to improve bread quality as well as dough handling characteristics. Some widely applied emulsifiers are diacetyl tartaric acid esters of monodiglycerides (DATEM) and sodium stearoyl-2- lactylate (SSL), which are known as dough improvers. Monoacylglycerols, however, are used as antistaling agents or crumb softeners (Kohajdová et al., 2009).

1.4.1 Gums

Hydrocolloids, commonly named gums, are hydrophilic polymers obtained from vegetable, animal, microbial or synthetic material, which are composed of hydroxyl groups and sometimes polyelectrodes. Hydrocolloids have been widely used in food industry because of their functions such as thickening and gelling aqueous solutions, stabilizing foams, emulsions and dispersions (Arendt et al., 2008). Furthermore, they can improve viscoelastic properties of dough, enhance moisture retention ability, texture and shelf life of bakery products, retard retrogradation of the starch, modify starch gelatinization and act as fat replacer in formulations. The textures of frozen foods are also improved by hydrocolloids since they can affect ice-crystal formation and growth. In recent years, there has been growing interest in the usage of hydrocolloids as gluten-substitutes in gluten-free bread formulations (Acs et al., 1997; Gambus et al., 2001; Ribotta et al., 2004a; Anton and Artfield, 2008; Rosell and Marco, 2008; Brites et al., 2010; Leray et al., 2010; Peressini et al., 2011). Thus, the use of hydrocolloids in gluten-free baking industry appears to be a promising alternative for the development of high-quality foods for consumers. Hydrocolloids mimic the viscoelastic properties to dough, so the gas holding ability, texture and shelf-life of gluten-free products may be improved. Nevertheless, the function and hydration rate of hydrocolloids depend on many factors, such as chemical nature of the gum, temperature and pH range, electrolyte concentration, particle size, thermal treatment, presence of other inorganic ions and chelating agents and storage ability. Thus, selection of the particular hydrocolloid for a specific purpose is the task of product developers.

1.4.1.1 Guar Gum

Guar gum derives its name from the ground endosperm of the guar plant "*Cyamopsistetragonoloba"*, a plant of the Leguminosae family. It is soluble in water, nonionic, salt tolerant and its solutions are little affected by ions or pH. It exhibits synergism with agar, kappa-type carrageenan, and xanthan gum. Galactomannans are organized by entirely of linear (1, 4)-β-D-mannan chains with changing amounts of single D-galactose substituents linked to the main backbone by (1-6)-α-glycosidic bonds. There are 1.5 to 2 mannose residues for every galactose unit as presented in Figure 1.1. The degree of substitution of galactose strongly affects the properties of guar gum. Higher mannose amounts increase the stiffness of the polymer but they also decrease the extensibility and the radius of gyration for every isolated chain (Ptaszek et al., 2007).

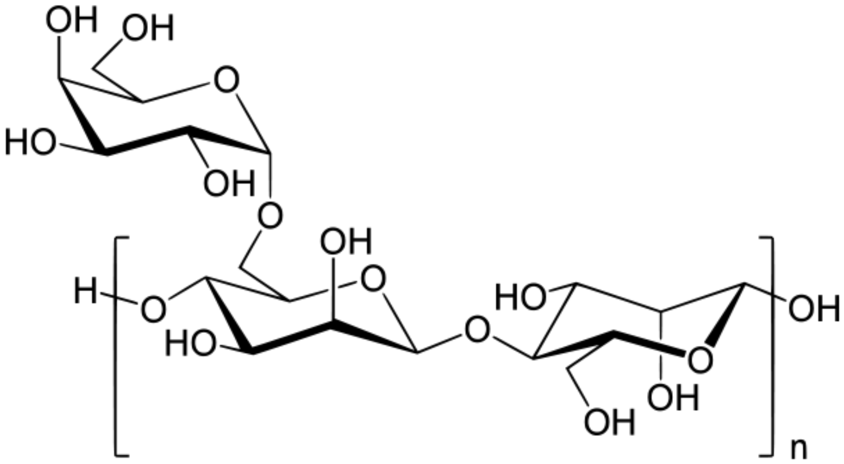

Figure 1.1. Primary structure of guar gum

Since its aqueous solutions exhibit high viscosity even at low concentrations, it is extensively used in the food industry. In addition, it is used as a food stabilizer and source of dietary fiber. The strong hydrophilic character of guar gum makes it suitable additive for salad dressings, ice cream mixes and bakery products (Berk, 1976). Moreover, the hydrophilic nature of guar gum is important to prevent of water release and polymer aggregation during refrigeration. Since guar gum preferentially binds to the starch, amylopectin retrogradation can be delayed, which can be explained by the influence on the amylose network formation avoiding the creation of a spongy matrix. Thus, the softening effect of guar gum has a critical role in the retardation of bread staling.

1.4.1.2 Locust bean Gum (LBG)

LBG, which is also known as carob gum is extracted from the seeds of carob tree "*Ceratoniasiliqua* L." after the removal of testa (seed coat) (Bonaduce et al, 2007). Its structure shows similarities with guar gum. It is also a natural hydrocolloid and flour made from the endosperm of the seed of a legume. However, it shows important property differences from guar gum. As opposed to most of the hydrocolloids, LBG is only slightly soluble in room-temperature water. To obtain a required dissolution, it is necessary to heat suspensions to about 85°C. Solutions of LBG by itself can not form gel, but hot solutions of LBG with agar, kappa-carrageenan, and xanthan can form gel when cooled below the gelling temperature. LBG is also a galactamannan but it has fewer branch units and more irregular structure compared to guar gum. It has ability to form junction zones with its long "naked chain" sections (BeMiller and Whistler, 1996). It is constituted of galactomannan polysaccharides (together with guar gum), which are neutral polysaccharides with a 1,4-linked β-D-mannopyranosyl backbone partially substituted with a single 1,6-linkedα-D galactopyranosyl side group (Kök et al., 1999) (Figure 1.2).

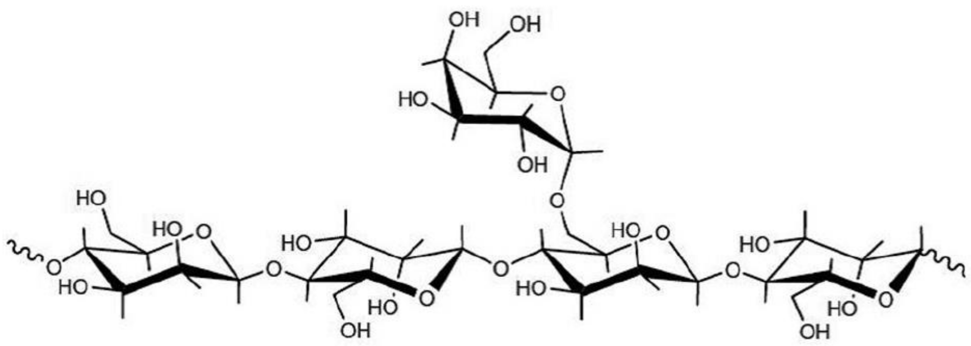

Figure 1.2. Primary structure of (LBG)

LBG is generally used in combination with other gums, such as HPMC, CMC, carrageenan, xanthan, guar gum, in dairy products including frozen products (ice cream), soft drinks, fruit juices, bread, pastry, fruit preserves, baby food and as household gelling agents in puddings, flans and pudding powder, as dietary fibers, and in pet foods. The thickening and gelling ability of LBG provides to products to be more appealing and attractive to the consumer. It improves the shelf life and texture of products by binding water, enhances the freeze-thaw behavior, prevents crystallization, creaming or settling, syneresis and retrogradation of starch products and maintains turbidity in soft drinks and juices (Wielinga and Maehall, 2000).

1.4.1.3 Xanthan Gum

Xanthan gum is an extracellular polysaccharide derived from the microorganism "*Xanthomonas campestris*". It is soluble in both hot and cold water and its solutions shows highly pseudoplastic flow that are unaffected by variations in temperature, pH, or salt concentration. It provides very high viscosity and its viscosity exhibits excellent mechanical, chemical and enzymatic stability. Although, it is not a gelling hydrocolloid, it forms gel with the combination agarose, kappa-type carrageenans, konjac glucomannan, or LBG (BeMiller, 2008). The synergic interactions between xanthan gum and galactomannans increase of the viscosity of solutions (Sworn, 2000). Chemical structure of xanthan can be explained as a cellulose backbone in Figure 1.3. It contains glucose units linked with β-1,4-glycoside bond, with branching at carbon-3 atoms. The branches composed of D-mannopyranose-(2,1)-β-D-glucuronic acid-(4,1)-β-D-mannopyranose. Moreover, less than 40% of the terminal mannose units have a pyruvic acid group linked as a ketal to its 4 and 6 positions and the inner mannose units are 6-*O*-acetylated. The branches of xanthan gum are irregular and some of the branches could be missing (Ptaszek et al., 2007).

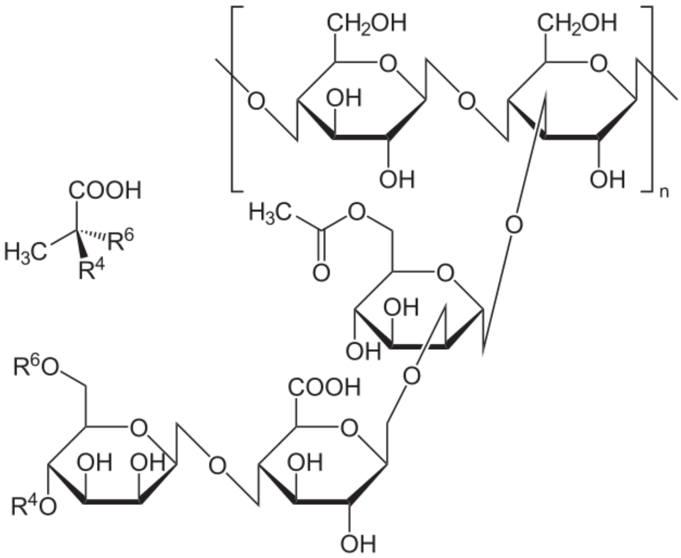

Figure 1.3. Primary structure of xanthan gum

Xanthan gum is one of the most preferred gums in food industry due to its highly shear thinning behavior. This characteristic behavior of xanthan gum provides good suspension properties and stability to colloidal suspensions. It is well known that even at low concentrations xanthan gum solutions exhibit high viscosity at relatively low shear rates (Sworn, 2000) which makes it easy to mix, pour, and swallow. This highly pseudoplastic flow characteristic of xanthan gum solutions may be explained by the complex aggregates formed by semi-rigid molecules. Xanthan gum also increases the water binding ability of gluten-free bread formulations because of its hydrophilic mannose and glucuronic side chains and thus higher moistness in the loaf are obtained (Urlacher and Noble, 1997). It provides smoothness and air incorporation and retention ability in cakes, muffins, biscuits and bread mixes. Therefore, baked products have higher quality with increased volume, moisture and shelf-life (Sworn, 2000).

A synergistic interaction occurs between xanthan gum and galactomannans such as guar gum, locust bean gum and cassia gum and glucomannans such as konjacmanan that provides enhancement of viscosity or gelation (Wielinga and Maehall, 2000).

Galactomannans are hydrocolloids in which the mannose backbone is partially substituted by single-unit galactose side chains. The degree and pattern of substitution varies between the galactomannans and this strongly affects the extent of interaction with xanthan gum. Galactomannans with smaller amount of galactose side chains and more unsubstituted regions can react more strongly (Wielinga and Maehall, 2000). Although the exact nature of this interaction has not been explained clearly, it is generally accepted that the xanthan gum interacts with the unsubstituted 'smooth' regions of the galactomannan molecules. However, the interaction of xanthan gum with galactomannans can easily change depending on the ratio of the mixture, pH, ionic environment and temperature of the solutions (Wielinga and Maehall, 2000).

1.4.1.4 Cellulose Derivatives

Cellulose is known as the most abundant organic substances existing in nature and cannot be digested by the human body. It is soluble in cold water and undergo reversible thermal gelation. Like xanthan gum, their solutions are pseudoplastic. Due to their interfacial activity, they can form films (BeMiller, 2008). The derivatives of cellulose are methylcellulose, hydroxypropyl cellulose, hydroxypropyl methylcellulose, methylethyl cellulose, and sodium carboxymethyl cellulose, which is frequently called simply carboxymethyl cellulose and also known as cellulose gumare obtained by chemical modification of cellulose.

HPMC is a chemically modified cellulose where hydroxyl groups are substituted by hydroxypropyl and methoxy groups (Figure 1.4). It is soluble in cold water to give solutions with a wide range of viscosity. It also binds water and shows shear thinning behavior. The hydroxypropyl groups are hydrophilic while the methoxy groups are hydrophobic that gives surfactant-like properties to HPMC. The etherification of hydroxyl groups of the cellulose increases its water solubility and also confers some affinity for the non-polar phase in doughs. Therefore, this bifunctional behavior permits a multiphase system like bread dough to provide its uniformity and to protect and maintain the emulsion stability during breadmaking (Selomulyo and Zhou, 2007). Although, hydrophobic groups present in the HPMC chain, it partially maintains the hydrophilic properties of cellulose (Sarkar and Walker, 1995; Barcenas and Rosell, 2005). HPMC undergoes reversible thermal gelation (gelling in cool water, then becoming amorphous upon heated, and after further cooling, it reverts back to a gel) (BeMiller, 2008).

The amount of hydrophilic and hydrophobic substitution can be changed in different varieties of HPMC. This property makes it a valuable hydrocolloid for challenging food applications. Due to its ether groups, methylcellulose can easily stabilize emulsions and foams. Since it provides fat like properties, it reduces the amount of fat in foods and the absorption of fat in fried products. Thus, they are used in low-calorie, yeast-leavened, wheat-flour-free baked products. It is also used in wheat based baked goods to improve crumb structure, loaf volume, crumb moisture and sensory properties. In addition to these properties, it is a good anti-staling agent and retards the crumb firming and amylopectin retrogradation (Guarda et al., 2004).

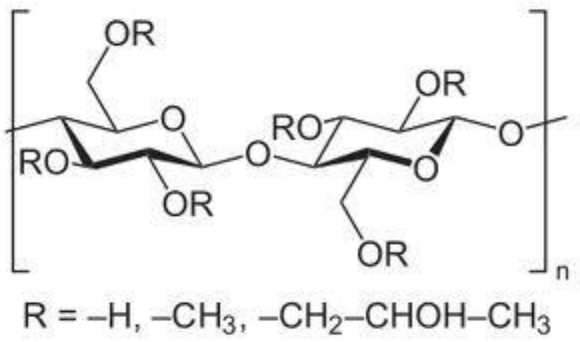

Figure 1.4. Primary structure of HPMC

CMC contains the carboxymethyl ether group in the sodium salt form (-O-CH 2-COO-Na +) giving ionic structure. While the other cellulose-derivatives are non-ionic, it is anionic polymer, and thus it does not dissociate in water due to their covalent bonds. Although, it hydrates rapidly, soluble in both cold and hot water and has water-holding ability, it can not form gel. It is thickener; form water-soluble films and is compatible with a wide variety of other ingredients. In addition, since it is an ionic polymer, it interacts with soluble proteins like soy protein, caseinate at around the isoelectric region of the protein. Although, most CMC solutions are pseudoplastic, some solutions of CMC types exhibit thixotropic behavior. Therefore, it is important to select the proper type of CMC (degree of substitution with carboxymethyl groups, viscosity grade, pseudoplastic or thixotropic type) among the available several types to obtain desired quality from products (BeMiller, 2008). CMC improves the volume yield of certain doughs as a result of its viscosity drop during baking. It is used in bakery goods to improve moistness of products, to improve consumer acceptability by increasing volume and uniformity, to control sugar and ice crystallization and to retard staling (Kohajdová et al., 2009).

Methylcellulose (MC) products contain only methyl ether groups rather than both methyl and hydroxypropyl ether groups, as present in HPMC. Properties of MC and HPMC products are both similar. It forms a firm gel when it is heated. For this reason, many bakeries add it to their pie fillings to ensure that they don't spill out of their pastry shells when cooking. In addition, they are also used to improve rheological properties of dough and quality (Onyango, 2009) and sensory properties of gluten-free products (Toufeili et al., 1994).

1.4.1.5 Agar

Agar is a hydrophilic colloid derived from seaweeds of "*Rhodopyceae",* including "*Gelidiales"* (Gelidium *and Pterocladia)* and "*Gracilariales"* (Gracilaria and *Hydropuntia).* It is composed of agarose (agaran), which is gel forming component and agaropectin. Agar gels have ability to hold large amount of soluble solids such as sugar without allowing crystallization becoming opaque, or losing adhesive properties. Therefore, they are generally used in the preparation of bakery glazes, icings and toppings and in the formulation of piping jellies for fillings in doughnuts and filled cakes (Kohajdová et al., 2009). However, it is rather expensive than other hydrocolloids, which limits its usage in food products.

1.4.1.6 Pectin

Pectin is a natural product, which can be found in the cell wall of all plants and many fruits in variable amounts and qualities. Pectin substances are primarily soluble fiber. Pectin substances contain a wide variety of materials based upon poly-α-1,4-D-galacturonic acid, with some side chains of galactose, rabinose, xylose, rhamnose or glucose and with varying degrees of esterification of the carboxylicacid with methyl groups compositions. Pectin may either a high degree (high methoxyl pectin, HMP) or a lower degree (low methoxyl pectin, LMP) of esterification. While HMP is naturally found in the fruit, LMP is a chemically modified pectin (Stauffer, 1990; Edwards, 2007). HMP readily forms film gels at low concentrations and is widely used rapid-setting jellies and similar products. On the other hand, LMP gels are less reactive and used for the usual consumer jellies and similar products in which a softer jells is required. It is used jellifying, thickening and stabilizing agent in the production of jams, confectionery, baked and dairy products. Pectin is also used as an ingredient in aerated products and adds moistness to the bread and used as a fat replacer (Stauffer, 1990; Edwards, 2007).

1.4.2 Emulsifiers

In addition to hydrocolloids, emulsifiers are also commonly used in bakery products to assist blending and emulsification of ingredients, to enhance the properties of the shortening, and to obtain a softer crumb. Moreover, they enhance dough handling ability, improve rate of hydration and water absorption, provide greater tolerance to resting and fermentation, improve crumb structure and loaf volume, increase uniformity in cell size, advance gas retention resulting in lower yeast requirements, better oven spring and faster rate of proof and provide longer shelf-life of bread (Stampfli and Nersten, 1995). Interaction of an emulsifier with the protein can improve the strength and allow better retention of CO_2. They can also inhibit the firming of the crumb, associated with staling. Their interaction with starch and blocking effect of moisture migration between gluten and starch prevents starch from adsorbing water. This property provides anti-staling mechanism to emulsifiers (Arendt and Moore, 2006).

Emulsifiers are amphilic substances. Their hydrophilic and lipophilic groups allow the interaction between the emulsifiers and other components of dough such as starch, protein, water and shortening and thus contribute to the increased stability of a thermodynamically unstable system. The hydrophilic/lipophilic balance number

(HLB) is very critical to determine the emulsification property. For example, while emulsifiers with low HLB (3-8) have ability to form water in oil emulsions, emulsifiers with intermediate HLB (8-18) have ability to form oil in water emulsions (Sahin and Sumnu, 2006).

According to their potentials for ionization, which are determined based on the electrochemical charge of the emulsifiers in aqueous systems, they are categorized either as ionic or nonionic. While nonionic emulsifiers (monoglycerides (MG), distilled monoglycerides (DMG), epoxylated monoglycerides (EMG), sucrose esters of fatty acids (SE)) do not dissociate in water due to their covalent bonds, ionic emulsifiers are classified as anionic (DATEM, sodium stearoyl-2-lactylate (SSL)) or cationic. However, cationic emulsifiers are not used in foods. Amphoteric emulsifiers like lecithin contain both anionic and cationic groups and their surface-active properties are pH-dependent. Classification of emulsifiers is presented in Table 1.1.

Table 1.1. Classification and abbreviation of emulsifier. Derived from Stampfli and Nersten (1995).

Classification	Emulsifier	Abbreviation	EEC No	Softening	Strengthening
Ionic					
Amphoteric	Lecithin	None	E322	Good	None
Cationic	Not used in foods				
Anionic	Diacetyl tartaric acid esters of monodiglycerides	DATEM	E 472e	Fair	Excellent
	Sodium stearoyl-2-lactylate	SSL	E481	Very good	Excellent
	Calciumstearoyl-2-lactylate	CSL	E 482	Good	Excellent
Nonionic	Monodiglycerides	MDG	E 471	Excellent	None
	Distilled monodiglycerides	DMG	E 471	Excellent	None
	Ethoxylated monoglycerides	EMG	E 488	Poor	Very good
	Sucrose esters of fatty acids	SE	E 473	Good	Excellent
	Esters of fatty acids Polysorbate-60	Poly-60	E 435	Fair	Very good

According to the required properties in bread making, the emulsifiers are normally classified as dough strengtheners and crumb softeners. However, some emulsifiers such as SSL exhibit both dough strengthening and crumb softening properties. DATEM, lecithin, monodiglycerides (MDG), DMG, SSL, calciumstearoyl-2-lactylate (CSL), EMG, SE, polysorbate-60 (Poly-60), sodium stearoylfumarate, sodium lauryl sulfate, dioctyl sodium sulfosuccinate, polyglycerol esters, and sucrose esters are some of the frequently used emulsifiers in wheat based bakery products (Orthoefer, 2008). Emulsifier Purawave^{TM} has also been shown to improve quality of microwave baked wheat based breads and gluten-free cakes (Ozmutlu et al., 2001; Turabi et al., 2008a). Although, the synergic interaction between hydrocolloids and emulsifiers are well known, there is limited number of study on the use of both hydrocolloids and emulsifiers in gluten-free bread formulations. Onyango et al. (2009) conducted a study on the effect of cellulose-derivatives and emulsifiers on the creep-recovery behavior of gluten-free dough and quality of gluten-free breads prepared from gelatinized cassava starch and sorghum. Nunes et al. (2009) studied the impacts of the emulsifiers (lecithin (LC), DATEM, DMG or SSL) on the rheological properties of rice bread dough and final quality of bread formulated with xanthan gum.

1.4.2.1 Dough Strengthener

The rheological properties of the dough plays critical role in the production of bread. Emulsifiers are generally used as dough conditioners to obtain a good machine tolerance from dough. DATEM, SSL, CSL and polysorbate are the most widely used dough strengtheners in baking industry. These emulsifiers are effective during mechanical handling, fermentation, shaping, transport and the first part of the baking period. Their positive effect on specific volume and texture of breads has been demonstrated in different studies (Stampfli and Nersten, 1995). Although, the mechanism of dough strengthening of emulsifiers is not fully understood, several theories exist to explain their positive effect as dough strengthener (Krog, 1981; Tamstorf, 1983). One of the explanations is that emulsifiers promote strength to wheat dough due to the complex formation between emulsifier and gluten proteins. The emulsifier may bind to the protein hydrophobic surface that assists aggregation of gluten proteins in dough and formation of a strong protein network and therefore better texture and increased volume of bread were obtained. Another theory is based on the ability of polar emulsifiers to form liquid–crystalline phases in water, which associates with gliadin and provides dough elasticity allowing gas cell to expand resulting in an increased volume.

DATA ESTERS or DATEM is anionic oil-in-water emulsifier. It enhances mixing tolerance, gas retention, and resistance of the dough to collapse, improves loaf volume and endows the crumb with a good texture, fine grain and good slicing properties like SSL. DATEM may form hydrogen bonds with starch and glutamine, which have ability to promote the aggregation of gluten proteins in dough by binding to the protein hydrophobic surface. This provides the formation of a strong protein network resulting in better crumb texture and increased volume. It has been also reported that DATEM may also form lamellar liquid-crystalline phases in water, which associates with gliadins and the formation of such structures allows the expansion of gas cells and contributes to dough elasticity resulting in improvement of bread volume. When it is used in frozen dough, DATEM provides bread with increased loaf volume and form ratio (i.e. height/width) values, lower firmness and delays staling. Its interaction with starch, particularly with the linear amylose molecules and also with amylopectin offers crumb-softening effect. The formations of such complexes also avoid bread staling either by preventing amylose or amylopectin retrogradation or by having fewer ß-type amylose nuclei that also could promote amylopectin retrogradation (Kohajdová et al., 2009).

SE contains a hydrophilic sugar head and one or more lipophilic fatty acid tails. It provides high volume, fine and soft crumb structure, extends shelf life, raises dough mixing tolerance, and enhances freeze–thaw stability. It interacts with the amylose molecules to form inclusion complexes with the helical amylose molecules during gelatinization and such complex formations inhibit starch retrogradation resulting in a baked product with longer freshness. It avoids wheat protein denaturation during freezing and thus damage to the baking properties of the frozen dough is minimized.

1.4.2.2 Crumb Softeners

Crumb softeners have ability to produce a long-term softness in the crumb of bread by interacting with the flour components and retarding the staling. One of the most used crumb softeners is the monoglycerides. The generally accepted model about the mechanism by which crumb softeners retard the firming process is based on the ability of monoglycerides to form complexes with amylose. Tamstorf (1983) stated that the amylose-monoglyceride inclusion complex was insoluble in water and did not participate in the gel formation, which typically happens during baking. In addition, this complex neither recrystallizes nor contributes to the staling of the bread crumb upon cooling. Nevertheless, it has been stated that the ability of different emulsifiers to form complexes with amylose varies; hence their contributions to reduction of the staling rate changes.

SSL, an anionic oil-in-water emulsifier, is used to improve the quality of products in baking industry. It improves mixing tolerance and resistance of the dough to collapse. In addition, it offers the gas-dough interface with certain properties, which are favorable for the stability of the gas bubbles in bread dough throughout the breadmaking process and thus it enhances loaf volume, provides improved texture, fine grain, and slicing properties. It has been also observed that it can decrease the effects of frozen storage on rheological properties. However, it has not been found to be effective in reducing the dough proofing time (Kohajdová et al., 2009).

Monoacylglycerol is extensively used fat-based emulsifiers in breads to delay staling and as crumb softeners. The ability of monoglycerides to form complexes with amylose offers retardation of the firming effect. Upon cooling, the complexed amylose is not recrystallize as well as not contributes to staling of the bread crumb (Kohajdová et al., 2009). Their combination with DATEM may be also used in baking industry and such combinations provide a dough conditioner and crumb softener effects to emulsifiers (Kohajdová et al., 2009).

1.5 Rheological Properties of Gluten-free Dough Formulations

Rheological information is critical to determine molecular interactions such as starch-emulsifier, starch-gum interactions, which are important to optimize acceptability, stability and textural properties of baked products. Rheological analysis is also essential for dough studies since dough behavior is predictive of baking performance (Dobraszczyk et al., 2001). Since dough undergoes stress during mixing, proofing and baking, the final quality attributes such as loaf volume and crumb texture can be correlated with dough handling ability (Dobraszczyk et al., 2001). The direct correlation between dough handling ability and final bread quality can be observed in wheat dough. However, the predictability of relationship between rheological properties of gluten-free dough and final bread quality is not as easy as in the case of wheat dough.

In food industry, rheology defines a relationship between the stress acting on a given material and the resulting deformation and/or flow. Deformation (strain), which occurs due to a force or stress, is the change in arrangement of the material (response) (Malkin and Isayev, 2006) and this measures the resistance to flow of a material (Steffe, 1996). In nature, there are no true elastic solids or liquids; but there are complex materials that have behaviors with solid-like and liquid-like properties (Malkin and Isayev, 2006). A material’s deformation behavior is determined as elastic response, viscous response, and the ratio of viscous to elastic response. Elastic modulus (G') shows the material’s solid (elastic) behavior while the viscous modulus (G") reflects liquid (viscous) behavior. Wheat dough has a nonlinear viscoelastic behavior, which is shear-thinning with a small yield stress (Dobraszczyk et al., 2001). When the low shear is applied, the dough will slowly flow with a fluid like behavior. On the other hand, when it is rapidly stretched with high shear, it will recoil back with elastic like behavior. However, gluten-free dough flows at low shear due to their high G", but at higher shear, the deformation will be permanent. Most dough rheology focuses on large deformation in the non-linear region such as with a farinograph, mixograph, or extensograph. However, testing is conducted with the intent of destruction of the dough structure, which only determines single-point measurements and does not reflect fully physical behavior of the dough. In addition, the stress applied during the rheological measurements is much greater than that of proofing and oven rise. Thus, it is important to determine rheological behavior of dough within the linear viscoelastic region since the linear viscoelastic region is the small range of applied stress where a material‘s response is independent of the stress applied. Dynamic measurements reflect the flow and deformation of substances and, in particular, their behavior in the transient area between solids and fluids. Thus, it defines a relationship between the stress acting on a given material and the resulting deformation and/or flow that occur (Crockett, 2009).

Recent studies have focused on the rheological properties of gluten-free doughs and in these studies; researchers have tried to find a relationship between rheological properties of gluten-free dough and final bread quality. The effects of hydrocolloids on dough rheology and bread quality in gluten-free formulations based on rice flour, corn starch, and sodium caseinate were studied by Lazaridou et al. (2007). The influences of enzymes such as cyclodextrin glycosyl transferase, oxidase and protease addition on rice flour dough rheology and bread quality were also investigated (Gujral et al., 2003a; Gujral and Rosell, 2004; Renzetti and Arendt, 2009). Turabi et al. (2008a) determined rheological properties of rice cake batters formulated with different gums (xanthan gum, guar gum, LBG, kappa-carrageenan, HPMC, xanthan–guar gum blend and xanthan–kappa-carrageenan gum blend)and an emulsifier blend (Purawave™).In the study of Sivaramakrishnan et al. (2004), it has been reported that rice dough containing HPMC had similar rheological properties as that of wheat flour dough and thus, gluten-free rice dough supplemented with HPMC was suitable for making rice bread. Sciarini et al. (2012) determined the effect of emulsifiers, hydrocolloids and enzymes on gluten-free dough rheology and thermal properties and bread quality and they related dough properties parameters to bread quality. The impacts of addition of both xanthan gum and different type of emulsifiers on the rheological behavior of gluten-free rice dough were studied by Nunes et al. (2009). Rheological properties of chestnut dough samples were also worked in different studies, the effects of hydrocolloids, gelling agents and particle size on rheological properties of chestnut dough were determined (Moreira 2010; 2011a; 2011b).

1.6 Infrared-Microwave Combination Baking of Foods

Although microwave heating has a number of advantages such as energy efficiency, faster heating, space saving, precise process control, selective heating, and food with high nutritional quality, microwave-baked products do not meet with consumer acceptance due to their unacceptable quality (Sumnu, 2001). Infrared-microwave combination heating includes infrared and microwave heating mechanisms together. In combination heating, infrared heating can operate at different times and at different locations compared to microwave heating which offers more uniform and higher overall rate of heating (Datta et al., 2005). The combination heating provides selectivity that improves moisture distribution inside food by heating the surface of a food faster. Therefore, moisture can be easily removed from the surface of the product and the food remains crisp (Datta et al., 2005). Thus, this technology combines the browning and crisping advantages of near-infrared heating and the time-saving and energy efficiency advantages of microwave heating.

The advantages of infrared–microwave combination heating over the microwave heating have been realized over the past few years. This baking technology may be an alternative to conventional baking to produce gluten-free breads with comparable quality but in shorter times (Sumnu, 2001). In order to understand the mechanism of infrared-microwave combination heating, it is important to review the mechanisms of microwave and infrared heating separately.

1.6.1 Mechanism of Microwave Heating

Microwaves are electromagnetic waves of radiant energy at frequency range of 300 MHz to 30 GHz, which belongs to the non-ionizing radiations (Giese, 1992) (Figure 1.5). The frequency range of microwaves belongs to the range of radio frequencies, which is used in broadcasting and also applied for telecommunications such as mobile phones and radar transmissions. In order to prevent interference problems, special frequency bands within this range of the electromagnetic spectrum are reserved by the International Telecommunications Union for industrial, scientific, medical (so-called ISM) and domestic use. These special frequency bands are 915 MHz and 2450 MHz for industrial applications and home-type microwave ovens, respectively (Meda et. al, 2005).

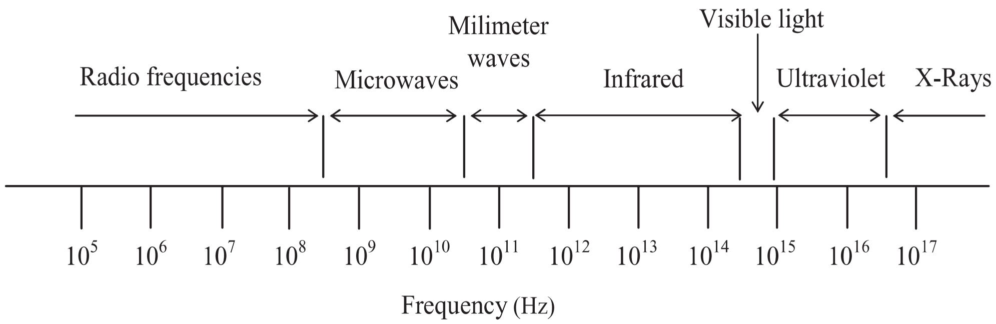

Figure 1.5. The electromagnetic spectrum (Sahin and Sumnu, 2006).

The second microwave heating mechanism involves microwave interaction with polar molecules like water and it is the dominant microwave interaction for most of the foods except the highly salted foods. The water molecule, the major constituent of most food products, is the main source for microwave interactions due to its dipolar nature. The structure of water molecule is in the form of V, with the two hydrogen atoms each involve of a positive charge attached to the oxygen atom that consists of negative charge making an angle of approximately 105°. These charges are physically separated and in this form they are called as a dipole. In the presence of a region of an oscillating electric field such as microwave electric field, the polar molecules experience a torque or rotational force attempting to line up them in the direction of field. The microwave field is reversing its polarity in millions of times each second. The water molecules only begins to move in one direction when they must reverse themselves and move to the other direction, hence considerable kinetic energy are taken out from the oscillating electric field by the dipoles and is transferred to other molecules by the collisions. Therefore, heating occurs in a very short time.

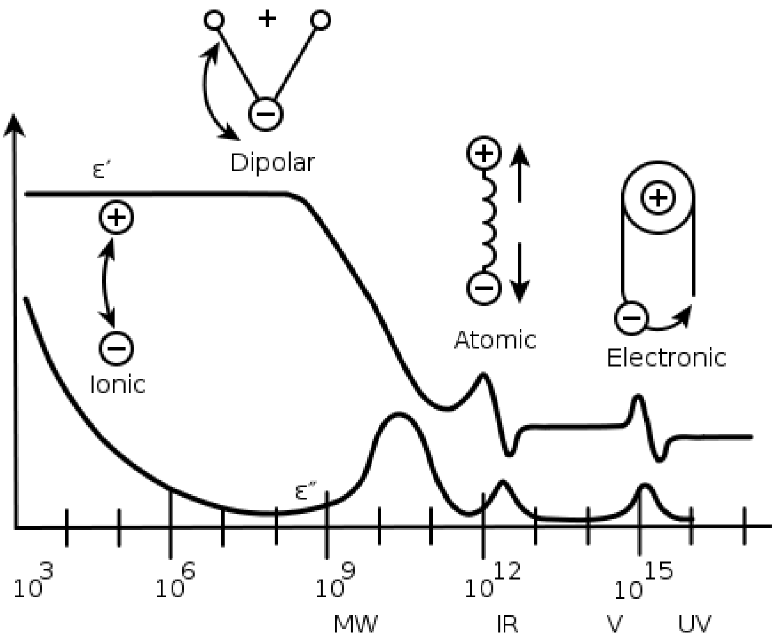

Figure 1.6. Schematic representations of dipolar rotation and ionic conduction mechanisms

Dielectric properties (dielectric constant and dielectric loss factor) are the physical properties of food that influence the behavior of the product during microwave heating. While the dielectric constant (ε') influences the ability of a material to store electrical energy in an electromagnetic field, the dielectric loss factor (ε") influences the conversion of electromagnetic energy into thermal energy (Tang, 2005). These properties of foods depend on food composition, temperature and frequency. Thus, information about the dielectric properties of food materials provides knowledge about the heating patterns during microwave heating of foods and it helps to develop products, processes and equipment with consistent and predictable properties (Sumnu and Sahin, 2005a).

In microwave heating the energy equation includes a heat generation term as presented in

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T + \frac{Q}{\rho c_p} \quad (1.1)$$

where, "T" (^oC) is temperature, "t" (s) is time, "α" is thermal diffusivity, "ρ"($kg.m^{-3}$) is density, "C_p" ($J.kg^{-1}.^oC^{-1}$) is specific heat of the material and "Q"($J.m^{-3}.s^{-1}$) is the rate of heat generated per unit volume of material per unit time. Q represents the conversion of electromagnetic energy into heat and its relationship to the electric field intensity (E) at that location can be derived from Maxwell's equations of electromagnetic waves (Metaxas and Meredith, 1983) where the magnetic losses of the food have been ignored which shown in Equation 1.2;

$$Q = 2\pi\varepsilon_0\varepsilon'' f E^2 \qquad (1.2)$$

where "ε_0" is the dielectric constant of free space (8.854×10^{-12}), "ε''" is the dielectric loss factor of the food, "f" (Hz) is the frequency of oven and E (V/m) is the electric field intensity (Meda et. al, 2005).

In microwave heating, internal heat generation due to the absorption of electrical energy from the microwave field as well as heat transfer by conduction, convection and evaporation are the major reasons of time-temperature profiles within the product when heated by microwave (Mudgett, 1982).

1.6.2 Mechanism of Infrared Heating

Infrared radiation is the part of the sun's electromagnetic spectrum that is mainly responsible for the heating effect of the sun. The region of wavelengths of infrared radiation is between visible light and microwaves. The relative position of infrared region of electromagnetic spectrum is in the wavelength range of 0.75 to 100μm and can be divided into three different classes, namely, near-infrared radiation (NIR, 0.75-3μm), mid-infrared radiation (MIR, 3-25μm) and far-infrared (FIR, 25-100μm) radiation (Figure 1.7) (Ranjan et al., 2002).

Foods are heated directly with infrared radiation with the help of infrared sources such as infrared lambs, rods and plates. These sources provide near-infrared radiation and its region in the electromagnetic spectrum is near the visible light with higher frequency and lower penetration depth than the other infrared radiation categories (Mujumdar, 2007). Interactions of food materials in the near- and mid- infrared range of electromagnetic waves primarily include vibrational energy levels of molecules, but in the far infrared range, their interaction largely involves rotational energy levels of molecules. The infrared sources often have high temperatures (500-3000°C). Infrared radiation has poor penetration because of its higher frequency range; hence, it impacts only on the surface of the body. Heat transfer through the body proceeds by mainly radiation as well as by conduction and convection (Sepulveda and Barbosa-Canovas, 2003). The penetration depth of infrared radiation reflects how much the surface temperature increases or the level of surface moisture that builds up over time and it can vary significantly for different foods. It has been suggested that as penetration depth is decreased, infrared energy will be absorbed closer to the surface; hence the surface temperature of the products will be increase (Datta and Ni, 2002).

The advantages of infrared radiation are the versatility of infrared heating, simplicity and compactness of the required equipment, fast transient response, reduced heating time, rapid processing, decreased change of flavor loss, preservation of vitamins in food products, absence of solute migration from inner to outer regions and also energy saving effect (Ranjan et al., 2002; Mujumdar, 2007). Olsson et al. (2005) investigated the effects of air jet impingement and infrared radiation on crust formation of par-baked baguettes during post-baking. It has been stated that infrared radiation and jet impingement increased the rate of color development of the crust and reduced the heating time as compared conventional heating. The fastest color development was obtained when infrared and impingement heating were combined. Although combination baking increased moisture loss rate because of the high rate of heat transfer, the total moisture loss was reduced due to the shorter heating time. In the study of Shyu et al. (2008), bun bread, toast, pound cake, and sponge cake were baked in a far infrared oven as well as in an electrical oven in order to evaluate the influences of far infrared radiation on quality of baked products. It was found that there were no significant differences in these products in terms of volume, water activity, staling rate and sensory scores. Sumnu et al. (2005) determined the effects of different baking methods (microwave, infrared and infrared-microwave combination) on the quality of cakes. Researchers suggested that using only infrared heating was not advisable since the cakes had a very thick crust and baking time was not less than infrared-microwave baking.

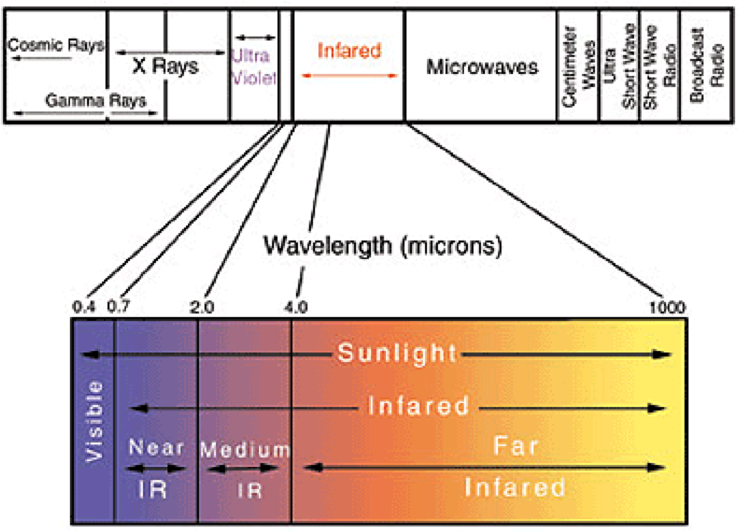

Figure 1.7. The electromagnetic spectrum

1.6.3 Studies on Infrared-microwave Combination Baking of Foods

Although the use of microwave baking introduces some advantages over conventional baking such as energy efficiency, faster heating, space saving, precise process control, selective heating and food with high nutritional quality, there are quality problems in these products which do not meet the expectations of the customers (Sumnu, 2001). Common quality problems of microwave-baked products are high moisture loss, firm structure, rapid staling and lack of surface browning, flavor and crust formation.

One of the reasons for the problems related to microwave heating is the short baking time in microwave oven, which does not allow the completion of physicochemical changes and interactions of major ingredients. However, these reactions are completed over a lengthy period in a conventional system (Sumnu, 2001). Specific interactions of each component in the formulation with microwave energy are also the cause of undesired texture of microwave-baked products (Sumnu, 2001).

Microwave ovens baking can neither promote browning reactions nor crust formation. Because of the cool ambient temperature inside a microwave oven, the surface temperature can not reach sufficient temperature to promote browning reactions during the microwave baking (Decareau, 1992; Hegenbert, 1992). As a result, the desired color and flavor are not obtained from microwave-baked products. The color problems related to microwave baking may be overcome by using of chestnut-rice flour and/or tigernut-rice flour blends. The problems associated to crustless or unacceptable color of products baked using microwave can also be eliminated by combining of microwaves with infrared heating.

Breads baked in microwave oven stale faster as compared to conventionally baked one. During the microwave baking, more amylose is leached out of starch granules that increases amount of starch gel (Sumnu and Sahin, 2005b). Moreover, this amylose is more disoriented and contains less bound water in microwave-baked bread as compared to conventionally baked one. Upon cooling, the surrounding amylose molecules align and increased crumb firmness. Since amylose fractions of microwave-heated bread have higher ability to realign into a more crystalline structure than conventionally heated one, they have firmer texture (Sumnu, 2001). Previous attempts have been made to overcome the problems associated with microwave baking and in these studies the combination of microwave heating with infrared heating has been successfully used by several researchers (Demirekler et al., 2004; Keskin et al., 2004; Keskin et al., 2005; Sumnu et al., 2005; Demirkol, 2007; Datta et al., 2007; Turabi et al., 2008b).

According to Demirekler et al. (2004) breads baked in infrared-microwave combination oven had comparable quality with conventionally baked ones. Moreover, the desirable color and crust formation in breads were obtained by the help of infrared mechanism. However, the microwave power was found to be the dominant factor on the weight loss and textural properties of wheat breads during the infrared-microwave combination baking (Keskin et al., 2004). Sumnu et al. (2005) compared the quality of microwave, infrared and infrared-microwave combination baking of cakes and found that cakes baked in infrared-microwave combination oven had similar color and firmness values with conventionally baked ones. Furthermore, infrared-microwave combination oven reduced conventional baking time by about 75%. Keskin et al. (2007) determined the effect of different gums on quality of infrared-microwave baked breads and found that xanthan-guar blend addition improved bread quality in terms of specific volume, porosity and firmness. Sakiyan et al. (2011) conducted a study on the gelatinization of cakes baked in microwave and infrared-microwave combination oven and found that infrared-microwave combination baking increased gelatinization degree as compared to microwave baking and resulted in cakes comparable with the conventional baked ones. The gluten-free rice cakes baked in infrared-microwave combination oven had comparable quality with those baked in conventional oven in the study of Turabi et al. (2008b). Sumnu et al. (2010) studied the effects of xanthan and guar gums on staling of gluten-free rice cakes and found that xanthan-guar gum blend decreased firmness, weight loss and retrogradation enthalpy of cakes baked in infrared-microwave combination and conventional ovens. The studies on gluten-free products baked in infrared-microwave combination oven are limited and there is a need for a broader research about the infrared-microwave combination baking of gluten free breads as well as their quality during storage**.**

1.7 Structural Analysis of Foods

Quality of a baked product depends on appearance, texture, loaf volume, and sensory properties (Zghal et al., 1999). These properties are significantly affected by structure of foods varying from the molecular to macroscopic levels. Thus, knowledge of macro- and micro-structure is essential. However, examining food microstructure is difficult, since food materials are complex and the majority of structural elements are below the 100-μm range (Aguilera, 2005). Several microscopy, scanning, and spectrometric techniques that allow visualization of changes in structure at different levels without intrusion have been proposed as useful tools for image acquisition (Falcone et al. 2006). In recent years, image analysis based on a large variety of macroscopic and microscopic techniques has been applied as quantitative tool for characterization of bread crumbs and digital scanners to capture bread crumb two dimensions (2D) high-resolution images. Size, distribution, wall thickness, and number of cells were determined in these studies (Zayas, 1993; Sapirstein et al., 1994; Zghal et al., 2002; Rouille et al., 2005; Datta et al., 2007; Sanchez-Pardo et al., 2008; Ozkoc et al., 2009a; Polaki et al., 2010; Rosell and Santos, 2010; Farrera-Rebollo et al., 2012).

1.7.1 Macro-structure of Bakery Products

Image analysis methods based on a large variety of macroscopic techniques such as scanning have widely been applied for quantitative evaluation of morphology and macro-/micro-structure of food products. Quantitative examination of bread crumb, such as measuring gas cell sizes and their distribution, can be done by image analysis to provide information on structural system. The obtained data from image analysis is useful to convert the complex food system to numerical data that improves the understanding of structure-function relationships of foods (Falcone et al., 2006)

The most widely applied imaging techniques in macro-structural food research is scanning. The use of scanner for image acquisition and for the assessment of appearance and/or colour offers all the advantages of previously investigated camera based systems. In addition, the acquisition of 2D images by flatbed scanning offers some advantages over camera based systems such as being fast, easy to use, economical, robust, independent of the external light conditions and with good accuracy. However, one of the disadvantages of this technique is the lack of a standardized technique for this evaluation. The differences in methodologies such as scanning resolution also result in different data for similar breads. Hence, comparing information among published report is a challenging issue. The most of image analysis applications in the area of cereal research were focused on the characterization of dough and bread-crumb structure (Zghal et al., 1999; Schober et al., 2005; Tlapale-Valdivia et al., 2010, Van Riemsdijk, 2011, Farrera-Rebollo et al., 2012)

1.7.2 Micro-structure of Bakery Products

Sensory (size, shape and color) and texture characteristics of bakery products are strongly affected by structural organization of foods at molecular, microscopic, and macroscopic levels. In particular, microstructure and interactions of food components critically contribute to transport, physical and sensory properties of foods; hence determine the texture of foods.

Studies on food structure at a microscopic level can be performed by using a large variety of microscopic techniques including light microscopy (LM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and confocal laser scanning microscopy (CLSM). Up to date, image analysis techniques such as LM, CSLM and electron microscopy (EM) have been applied to evaluate the relationship between microstructure and physical properties of bread. LM offers the specific staining of the different chemical components of a food (proteins, fat droplets, and so on), which make it a suitable imaging technique for the research of multicomponent or multiphase foods such as cereal-based foods. However, as compared to electron microscopy techniques, the magnification of this technique is modest. Different characteristics of particulate structures can be determined by combining of different imaging techniques (Falcone et al., 2006). In the study of

Langton et al. (1996), different imaging techniques were used to analyze the structure of microporous, particulate gels. In this study, LM was used to visualize pores, TEM was applied to evaluate particle size, while SEM allowed to detect how the particles were linked together (Falcone et al., 2006). Compared to LM, SEM and TEM allow a higher resolution, but sample preparation procedures such as freezing and dehydration are required and that may cause artifacts. SEM is one of the most important image analysis techniques, since it provides the combination of higher magnification, larger depth of focus, greater resolution, and ease of sample observation. SEM studies have been assessed to determine the changes that occur during baking qualitatively (Sanchez-Pardo et al., 2008; Ozkoc et al., 2009a; Polaki et al., 2010; Rosell and Santos, 2010). In a recent study by Turabi et al. (2010), SEM has been used to obtain quantitative information on macro- and micro-structure of gluten-free rice cakes. Concerning sample preparation, CLSM represents a suitable alternative imaging technique since it requires a minimum sample preparation. CLSM can be used to investigative the 3D structure of the protein network of doughs, breads, pasta samples, or high-fat foods (Moore et al., 2004; Renzetti et al., 2004; Moore et al., 2007; Schober et al., 2007). One of the other advantages of this method is presenting the optical slicing of the sample. The use of X-ray microtomography (X-ray μCT), which is usually used in medical applications, introduces some advantages over other image analysis techniques. This new imaging technique creates 3-D representation of the inside structure of food from 2-D image slices allowing a set of projection measurements recorded from a certain number of points of view in non-destructive and non-invasive way. The visualization of the final image results can be recorded by 3-D rendering, by 2-D slices, or projections following arbitrary directions. It has an ability to create the contrast-enhanced imaging without any sample preparation that helps to overcome typical artifacts in the visualization of structure. In very recent studies, X-ray μCT has been used for quantitative characterization of bread crumbs by creating 3-D representation of the inside structure of bread from 2-D image slices (Falcone et al., 2004, Falcone et al., 2005; Primo-Martín et al., 2010; Wang et al., 2011).

1.8 Staling in Gluten-free Breads

Staling is a complex process that encompasses many of the physical, chemical and sensory changes occurring in bakery products during storage, which cause large economic losses and decreases in consumer acceptance. Dough formulations include various components each undergoing complicated changes during the breadmaking process as well as during storage of bread, which make staling an extremely complex phenomenon to describe (Gray and BeMiller, 2003). Starch retrogradation/crystallization, moisture diffusion and redistribution among the protein-starch components and crumb-crust fractions of the bread as well as reorganization of starch polymers within the amorphous region have been related to bread staling (Ozkoc et al. 2009b).

Staling has been related to starch retrogradation in many studies. However, the role of gluten in bread staling has also been mentioned by different researchers since starch might be able to interact with gluten fibrils and crosslink them (Martin and Hoseney, 1991). Nevertheless, recent studies showed that the interactions between the gluten and starch may not be the essential factor for staling because starch retrogradation alone can also cause the staling of breads (Morgan et al., 1997).

During staling, bread undergoes many structural changes such as crust toughing (especially for gluten containing breads), crumb firming, and loss of moisture and flavor. Although crumb and crust of the bread change, the increase in crumb firmness has mostly been used by investigators following staling. According to some studies, changes in starch structure, namely, gelatinization and retrogradation of starch contribute to texture from soft to firm and it is the main causes of bread staling (Bloksma and Bushuk, 1988). Since firming of the crumb is caused by starch crystallization and moisture transfer from the bread crumb, most of the studies on bread staling have focused on the retrogradation behavior of the starch fraction, predominantly amylopectin (Pateras, 2007). However, other changes such as flavor loss, decrease in water absorption capacity, amount of soluble starch and enzyme susceptibility of the starch, increase in starch crystallinity and opacity and the changes in X-ray diffraction patterns have also been worked (D'Appolonia and Morad, 1981).

Among the components of bread dough, gluten forms a viscoelastic network that is responsible for slowing down the movement of water and retaining gas produced from yeast fermentation and oven-rise. Therefore gluten-free breads lacking gluten have low volume, poor texture and flavor and stale faster. In order to overcome the problems associated with the lack of viscoelasticity in gluten-free dough, modifications in formulations by using alternative flours to wheat flours and ingredients such as hydrocolloids (starches and gums), emulsifiers, sugars, shortening, enzymes and fibers have mostly been established by the gluten-free baking industry (Ribotta et al., 2004a; Purhagen et al., 2012; Roccia et al., 2012; Van Riemsdijk et al., 2011).

Infrared-microwave combination baking may be an alternative to conventional baking to produce breads with comparable quality but in shorter times. However, it has been difficult to clarify the phenomenon of staling of infrared-microwave baked bread by comparing changes in the physical properties of infrared-microwave baked and conventionally baked breads, because they have different degrees of gelatinization and moisture contents. The reason of rapid firming of microwave-baked product is mainly leaching out of more amylose during microwave baking as compared to conventional baking (Seyhun, 2002). Moreover, microwave heating increases the staling rate of bread and this is caused primarily by a decrease in moisture content of the bread. Since crumb firmness and moisture loss of breads baked in infrared-microwave combination ovens were found to be relatively higher when compared to those of breads prepared in conventional ovens (Keskin et al., 2004), the focus of recent studies has been to prevent staling of breads baked in infrared-microwave combination ovens by modifying the bread formulation and by adjusting processing conditions (Ozkoc et al. 2009b). Ozkoc et al. (2009b) studied staling of breads baked in different ovens (microwave, infrared-microwave combination and conventional) by mechanical (compression measurements), physicochemical (DSC, X-ray, FTIR) and rheological (RVA) methods and the retrogradation enthalpy values and FTIR outputs related to starch retrogradation of breads baked in combination oven were not found to be statistically different than that of conventionally baked ones. In literature, there are a limited number of the studies on staling of gluten-free products. Addition of xanthan-guar gum blend was found to be effective on the retardation of staling of gluten-free cakes baked in infrared-microwave oven (Sumnu et al., 2010).

Different techniques have been used to characterize and gain an understanding of the staling phenomenon. Rheological techniques, differential scanning calorimetry (DSC), X-ray diffractometry, fourier transform infrared spectroscopy (FTIR), nuclear magnetic resonance (NMR) and vibrational spectrophotometry have been widely used to monitor changes in certain physical properties of breads as indicators of retrogradation at the macroscopic level and in starch polymer conformation and water mobility in starch gels at the molecular level. To obtain an adequate description of retrogradation, it is also important to determine retrogradation characteristics of gluten-free breads at both macroscopic and molecular levels (Karim et al., 2000). However, the staling parameters of gluten-free breads baked in infrared-microwave combination oven have not been studied yet.

1.9 Optimization by Response Surface Methodology (RSM)

Optimization means improvement of the performance of a system, a process, or a product to gain the maximum benefit from it. Generally as an optimization technique, one-at-a-time is used to monitor the influence of one factor at a time on experimental response. It means that while only one factor is varied at a time, all other variables are fixed to their central or baseline values. However, one-factor optimization is problematic since this technique does not involve the interactive effects among the variables studied; hence it does not represent the complete effects of the parameter on the response. Another disadvantage of one-factor optimization is the increase in the number of experiments needed to conduct, which results in an increase of time and expenses and increase in the consumption of reagents and materials. Thus, in order to overcome this problem, multivariate statistic techniques are applied in the optimization. Among the most applicable multivariate techniques utilized in optimization is response surface methodology (RSM).

RSM includes a group of mathematical and statistical procedures based on the fit of a polynomial equation to the experimental data. It is a helpful tool to examine the relationship between the responses and factors. It is used to minimize the number of trials and to provide multiple regression approach for optimization of ingredient levels, formulations and processes in food technology (Myers and Montgomery, 2002). Basically the application of RSM includes some stages as an optimization technique are as follows: (1) the selection of independent variables (2) the selection of the experimental design and using the experiments according to the selected experimental matrix; (3) the mathematical–statistical treatment of the obtained experimental data through the fit of a polynomial function; (4) the evaluation of the model's fitness; (5) the verification of the necessity and possibility of performing a displacement in direction to the optimal region; and (6) obtaining the optimum values for each studied variable.

If the response (y) is to be maximized in a two variables (x_1, x_2) system and the response is a function of the levels of variables, as follows:

$$y = f(x_1 + x_2) + \varepsilon \quad (1.3)$$

where ε represents the noise which is also called as standard deviation or error detected in the response y. If the expected response is presented by

$$E(y) = f(x_1, x_2) = \eta \quad (1.4)$$

then the surface is represented by

$$\eta = f(x_1, x_2) \quad (1.5)$$

which is called a response surface.

The response can be represented graphically either in 3-D space or as contour plots, where expected response (η) is plotted versus the levels of variables x_1 and x_2. This assist visualizes the shape of the response surface. In this method, dependent variables are described as arbitrary functions of independent variables. Figure 1.8 shows three-dimensional and the contours of the response surface. In the contour plot, lines of constant response are drawn in the x_1-x_2 plane and each contour corresponds to a particular height of the response surface.

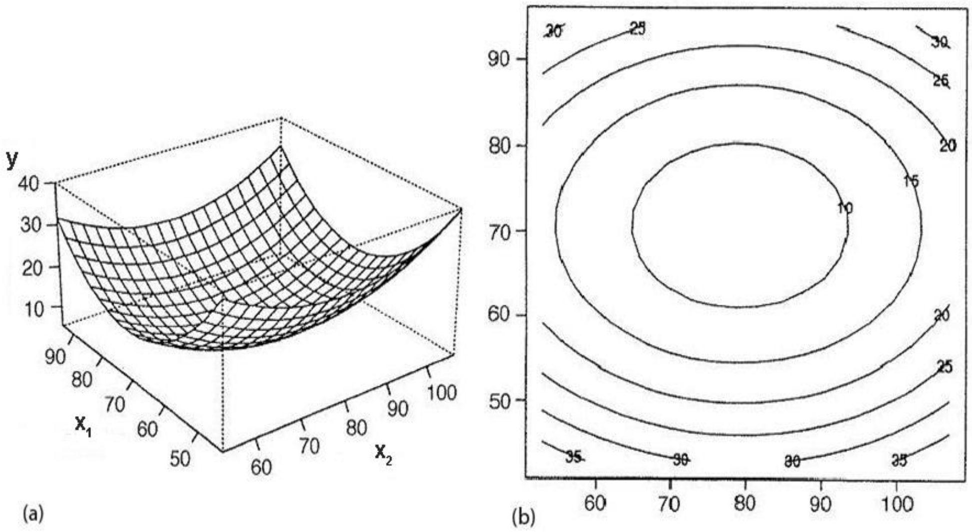

Figure 1.8. a) Three-dimensional response surface indicating the response as a function of x_1 and x_2 and b) the corresponding contour plot of a response surface (Turabi, 2010).

In RSM problems, since the form of the relationship between the response and the independent variables is mostly unknown, the first step is to find a suitable approximation for the true functional relationship between y and the set of independent variables. Two types of models, first order and second order models, are frequently used in RSM studies. First order models rarely applied for biological phenomena. Therefore, second order models are preferred in such cases, which have the advantage of being easy to fit using multiple regressions (Sumnu, 1997). The general form of the second order polynomial equation presented in equation 1.7 is often chosen.

The response variables were fitted to a second-order polynomial model equation in order to correlate the response variables to the independent variables. The general form of the second order polynomial equation was as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \beta_{11} {x_1}^2 + \beta_{22} {x_2}^2 + \cdots \beta_{kk} {x_k}^2 + \beta_{12} x_1 x_2 + \beta_{1k} x_1 x_k + \epsilon \quad (1.6)$$

where Y’s are the dependent variables, X_i’s are the independent variables, b_o is the constant coefficient, b_i’s are the linear, b_{ii}’s are the quadratic and b_{ij}’s are the interactions regression terms and ε is the error.

Central composite design (CCD), which was presented by Box and Wilson in 1951, is the most commonly applied experimental design in engineering purposes. The advantages of this design over the other designs is the reduction of the number of treatment combinations required to estimate the terms in the second order model (Anderson and Mc Lean, 1974). This design includes the following parts: (1) a full factorial or fractional factorial design; (2) an additional design, often a star design in which experimental points are at a distance from its center; and (3) a central point. Figure 1.9 (a and b) demonstrates the full central composite design for optimization of two and three variables.

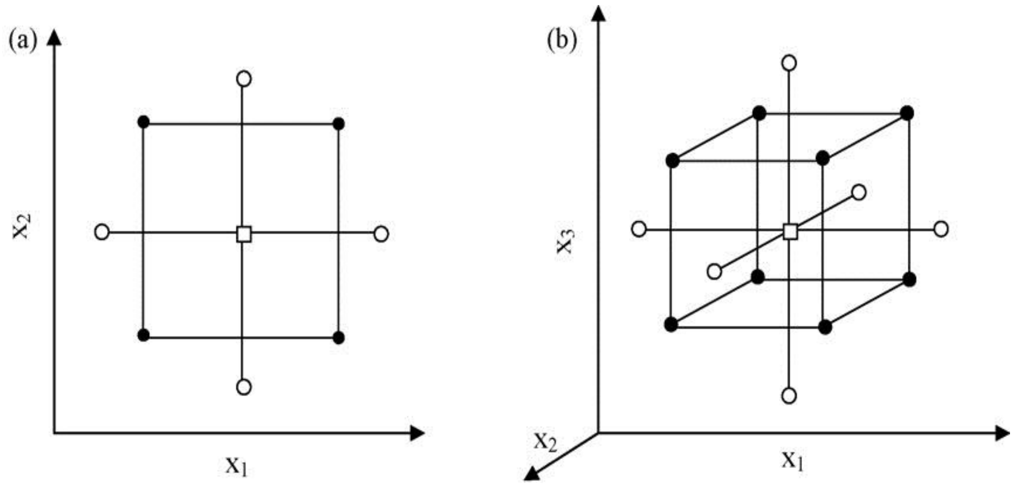

Figure 1.9. Central composite designs for the optimization of (a) two variables (α=1.41) and (b) three variables (α =1.68). (□): Points of factorial design, (O): axial points, (●): cube points and (□): central point (Bezerra et al., 2008).

Factorial points (n_c) are the number of points, which are located at the vertices of square. The coded independent variable levels for these points are ± 1.

$$n_c = 2^{k-m} \tag{1.7}$$

where k is the explanatory variables and m is defined as the power of one half representing the fractional replications.

Star points (n_a) have coordinates such as (α, 0, 0), (-α, 0, 0), (0, -α, 0) etc.

$$n_a = 2k \tag{1.8}$$

α is selected to make the design rotatable. By choosing an appropriate value for α and repeating the center point a number of times the design can be given the property of rotatability meaning that standard of dependent variable will be the same for all points that are the same distance from the center of the region. The rotatable condition is satisfied by the following equation:

$$\alpha = (n_c)^{1/4} \tag{1.9}$$

Center points (n_0) are the replicated points at the center of the design. These points have all coordinates (0,....,0). These points provide a mean for estimating the experimental error and provide a measure of lack of fit with one degree of freedom

$$n_0 = 4\left(2^{(k-m)/2} + 1\right) - 2k \qquad (1.10)$$

RSM has been broadly used in baking studies. The effectiveness of RSM in the development and optimization of gluten-free breads has also been efficiently used by several researchers (Toufeili et al., 1994; Sanchez et al., 2002; McCarthy et.al., 2005; Sanchez et al., 2004; Mezaize et al., 2009; Sabanis et al., 2009). Toufelli et al. (1994) optimized methylcellulose, gum arabic, and egg albumen levels by response surface methodology for production of gluten-free pocket type flat breads. Ingredient levels (corn starch, cassava starch, and rice flour) were optimized for production of gluten-free bread to maximize specific volume, crumb grain score and bread score (Sanchez et al., 2002). In another study, RSM was carried out to optimize gluten-free bread fortified with soy flour and dry milk (Sanchez et al., 2004). McCarthy et al. (2005) also used response surface methodology in the development of gluten-free bread. In the study of Sabanis et al. (2009), levels of ingredients (corn starch, rice flour and hydroxypropylmethylcellulose) were optimized for a fibre-enriched gluten-free bread formulation. In 2009, Mezaize et al. optimized formulations for the development of French-style gluten-free breads. Turabi et al. (2008b) optimized processing conditions and formulation for production gluten-free cakes to be baked in infrared-microwave combination oven. However, there is no study in the literature on optimization of formulations and processing conditions of gluten-free breads to be baked in infrared-microwave combination oven.

1.10 Objectives of the Study

People suffering from celiac disease, cannot consume products containing gluten. Therefore, many scientists and manufacturers seek alternative flour types to wheat flour to meet nutritional requirements of celiac patients. Since gluten is responsible for viscoelastic properties of the dough, it is necessary to use additional ingredients in gluten free baked products to provide required functional properties.

Infrared-microwave combination heating technology combines the time saving advantage of microwave heating with the browning and crisping advantages of infrared heating. The main objective of this study was to design gluten-free breads made from alternative flours (rice flour, rice-chestnut flour blend, rice-tigernut flour blend) with the addition of different gums, gum blends and different emulsifiers to be baked in infrared-microwave combination oven.

Rheological properties are critical for acceptability and stability of baked products. In the literature, there is no study on investigating the effect of combination of different hydrocolloids and emulsifiers on the rheological properties of gluten-free bread dough and final quality of bread. Therefore, one of the objectives of the present work was to study the rheological behavior of different dough formulations containing only rice flour and rice-chestnut flour blend with different gums and/or emulsifiers. In addition, the influences of these additives on bread quality were also investigated.

Analysis of macro- and micro-structure is essential since it provides valuable information about the quality of breads. SEM is one of the main instruments for qualitative structural analysis of foods. However, quantitative characterization of baked products using SEM images is very limited. In the present study, it was aimed to obtain both quantitative and qualitative information on macro- and micro-structure of different gluten-free breads baked in different ovens. The X-ray μCT introduces some advantages over other image analysis techniques. The application of X-ray μCT for quantitative characterization of gluten-free bread crumbs has not been studied yet. Thus, another objective of the present study was to point out microscopic changes of gluten-free breads by using X-ray μCT and to relate crumb micro-structure with physical properties of breads. Another objective of this research was to understand the influence of different gums or gum blends and emulsifier addition on crumb porous structure of gluten-free breads.

There is no study in the literature on optimization of formulations and processing conditions of gluten-free breads to be baked in infrared-microwave combination oven. Therefore, in this study it was not only aimed to optimize the baking conditions but also aimed to optimize formulations of gluten-free breads to be baked in infrared-microwave combination oven. Moreover, staling of gluten-free breads having different formulations and baked in different ovens were studied using different techniques.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

Rice flour (Knorr-Çapamarka, Istanbul, Turkey) with 10% moisture, 79.9% starch, 0.1% sugar, 1.3% fiber, 6.0% protein, 2.1% crude fat and 0.6% ash was obtained from a local market. Chestnut flour with 10.8% moisture, 47.8% starch, 21.5% sugar, 9.5% fiber, 4.6% protein, 3.8% crude fat and 2.0% ash was supplied by Kafkas Pasta Şekerleme San. & Tic. A.Ş. (Karacabey, Bursa, Turkey). The tigernut flour was composed of 4.8% moisture, 25.2% starch, 21.5% sugar, 22.3% dietary fiber, 3.6% protein, 20.5% fat, and 2.1% ash. Sugar (sucrose), salt, instant yeast (*Saccharomyces cerevisiae)* (Dr. Oetker, Istanbul, Turkey), and shortening (Becel, Unilever, İstanbul, Turkey) containing vegetable oil, water, non-fat pasteurized milk, emulsifier blend (vegetable mono/digliserides, soy lecithin), salt, lactic acid, potasyum sorbate, vitamins (B6, Folic acid, A, D and B12), butter aroma and color additive (β-carotene) were also purchased from local markets. Emulsifiers; Purawave™ which is composed of lecithin, soy protein, mono/diglycerides, and vegetable gums supplied from Puratos (İstanbul, Turkey) and DATEM (diacetyltartaric acid esters of monoglycerides) were obtained from Danisco Co., (Copenhagen, Denmark). Xanthan *(Xanthomonascampestris)*, guar gum, LBG (locust bean gum), agar, MC (methyl cellulose), CMC (carboxymethyl cellulose), HPMC (hydroxylpropylmethyl cellulose) and pectin gum from citrus peel were obtained from Sigma–Aldrich (Steinheim, Germany and St. Louis, MO, USA).

2.2 Methods

2.2.1 Breadmaking Procedure

2.2.1.1 Rice Breadmaking Procedure

Basic dough recipe on 100 g rice flour basis consists of 8% sugar, 8% shortening, 1% instant yeast, and 2% salt were used in the experiments. On flour basis, the amount of water (30°C) added to rice dough was 150%. For wheat dough, the used amount of water was 75% on flour basis. Water content used for each bread formulation was determined by conducting experiments based on the quality tests of breads in terms of specific volume and hardness.

Gums (xanthan, guar, LBG, HPMC and pectin) and/or gum blends (xanthan–guar and xanthan–LBG) and/or emulsifiers (Purawave™ and DATEM) were added at 0.5% of flour weight. The blends of xanthan-guar gum and xanthan–LBG were prepared by mixing equal amounts of each gum. Rice dough/bread and wheat dough/bread without any gum and emulsifier were used as controls. Before adding the gums or gum blends into dough mixture, gums or gum blends were dispersed in half of the water to be used in the dough formulation using a high speed homogenizer (Ika T18 Ultra-Turrax, Staufen, Germany). During preparation of the bread, first dry ingredients (rice flour, instant yeast, sugar, salt and emulsifier) were mixed thoroughly, and then the melted shortening was added. Finally gum suspension and rest of the water were added slowly and mixed for 2 min at 85 rpm and then 1 min at 140 rpm using a mixer (Kitchen Aid, 5K45SS, ELKGROVE Village, USA). After complete mixing, the dough samples were placed in the cylindrical glass baking cups (diameter 8.7 cm and depth 4.8 cm) and fermented in an incubator (Nüve EN 400, Ankara, Turkey) at 30°C for 40 min. The fermentation time of wheat dough was determined as 110 min. Following fermentation, breads were ready for baking.

In order to characterize the structure of gluten-free breads by using X-ray microtomography, experiments were conducted in Purdue University, USA. Thus, brown rice flour was used during these analyses. Bob's Red Mill Organic Brown Rice Flour (Milwaukie, OR, USA) with 10% moisture, 76% starch, 3% protein, 8 % fiber, 2 % crude fat and 1% ash was obtained from a local market. Sugar (sucrose), salt, instant yeast (*Saccharomyces cerevisiae)* (Red Star Yeast & Products, Milwaukee, WI, USA), vegetable oil (Market Pantry® vegetable oil, MN, USA) were also purchased from local markets. The amount of water (30°C) added to rice dough was determined as 143% on flour basis. Gluten-free rice bread sample prepared without any additives (gums and emulsifiers) was used as control.

2.2.1.2 Chestnut-rice Breadmaking Procedure

Basic dough recipe on 100 g flour basis contained 8% sugar, 8% shortening, 1% instant yeast, and 2% salt. On flour basis, the amount of water (30 °C) added to dough varied between 150% and 210% for the different chestnut:rice flour ratios (0:100, 10:90, 20:80, 30:70, 40:60, 50:50, and 100:0). The water content used for the each formulation was determined by conducting many preliminary experiments. The water levels used for each bread formulations were determined based on the quality tests of breads in terms of specific volume and hardness and are shown in Table 2.1.

Dough samples containing only rice flour and chestnut flour without any gum and emulsifier were used as controls. For investigation of the effect of gum blends (xanthan–guar gum, xanthan–LBG) and emulsifier DATEM on the rheological behavior of dough and quality parameters of gluten-free breads, the dough samples with chestnut:rice flour ratio of 10:90, 20:70, 30:70, and 40:60 were chosen.

During dough preparation, the mixing of dry ingredients (chestnut flour, rice flour, instant yeast, sugar, salt and emulsifier) was followed by addition of melted shortening. Then the gum blend suspension and water were added slowly and mixed for 3 min at 85 rpm and 2 min at 140 rpm using a mixer (Kitchen Aid, 5K45SS, ELKGROVE Village, USA). The mixing time was the time at which lumps disappeared and a homogenous structure was obtained. After complete mixing, the doughs were placed in the cylindrical glass baking cups (diameter 8.7 cm and depth 4.8 cm) and fermented in an incubator (Nüve EN 400, Ankara, Turkey) at 30 °C for 40 min. Following fermentation, gluten-free breads were ready for baking. Chestnut breads samples (chestnut:rice flour ratio of 100:0) and rice bread samples (chestnut:rice flour ratio of 0:100) without any gum and emulsifier were used as controls.

Table 2.1. Percentage of water (in flour basis) used in chestnut-rice bread formulations

Formulations	Water (%)
100:0 CF[a]:RF[b]	210
50:50 CF:RF	185
40:60 CF:RF	180
40:60 CF:RF–X[c]–LBG[f]–E[d]	183
40:60 CF:RF–X–G[e]–E	183
30:70 CF:RF	170
30:70 CF:RF–X–LBG–E	173
30:70 CF:RF–X–G–E	173
20:80 CF:RF	160
20:80 CF:RF–X–LBG–E	163
20:80 CF:RF–X–G–E	163
10:90 CF:RF	155
10:90 CF:RF–X–LBG–E	158
10:90 CF:RF–X–G–E	158
0:100 CF:RF	150

[a]Chestnut flour, [b]Rice flour, [c]Xanthan gum, [d]Emulsifier DATEM, [e]Guar gum, [f]Locust bean gum.

2.2.1.3 Tigernut-rice Breadmaking Procedure

Raw tigernut were harvested from the fields in Konya. In order to produce tigernut flour, tigernuts were washed, dried, and then ground into flour using attrition mill (Thomas Wiley, Model 4, Philadelphia, PA, USA). Finally, the flour samples were passed through a sieve having 0.45 mm mesh opening. It was then placed in a plastic bag and then into a glass jar then stored in a freezer at −18 °C. Basic dough recipe on 100 g flour basis contained of 8% sugar, 8% shortening, 1% instant yeast, and 2% salt. On flour basis, the amount of water (30 °C) added to dough was 150%, 160%, 170%, 180%, 190%, and 200% for different tigernut:rice flour ratios (0:100, 5:95, 10:90, 15:85, 20:80, and 25:75). Preliminary experiments were conducted to determine the appropriate water amounts for different tigernut:rice flour ratios. The gum blend (xanthan–guar gum) was prepared by mixing equal amount of each gum. The gum blend was dispersed in half of the water to be used in the dough formulation using a high-speed homogenizer (Ika T18 Ultra-Turrax, Staufen, Germany) before adding it into dough mixture. Both gum blend (xanthan–guar gum) and emulsifier (DATEM) were added as 0.5% (w/w) of flour amount.

During dough preparation, mixing of dry ingredients was followed by addition of melted shortening. Then, the gum blend suspension and water were added slowly and mixed for 4 min at 85 rpm and 3min at 140 rpm using a mixer (Kitchen Aid, 5K45SS, Elkgrove Village, St. Joseph, USA). After complete mixing, tigernut dough was placed in the cylindrical baking cups (diameter 8.7 cm and depth 4.8 cm) and fermented in the incubator (Nüve EN 400, Ankara, Turkey) at 30 °C for 70 min. Following fermentation, samples were baked in different ovens. Tigernut breads samples (tigernut:rice flour ratio of 100:0) and rice bread samples (tigernut:rice flour ratio of 0:100) without any gum and emulsifier were used as controls.

2.2.2 Baking

Following fermentation process, dough samples were baked in either conventional or infrared-microwave combination oven.

2.2.2.1 Conventional Baking

Conventional baking was performed in conventional oven (Arçelik A.Ş., İstanbul, Turkey) preheated to 200°C. Four bread samples (100g each) were baked at a time. Baking time for rice breads, wheat breads, chestnut-rice flour blend containing breads and tigernut-rice flour blend containing breads were 30, 30, 25 and 35 minutes, respectively.

2.2.2.2 Infrared-microwave Combination Oven Baking

Infrared-microwave combination oven (Advantium oven, General Electric Company, Louisville, KY, USA) combines microwave heating and infrared heating in the oven. The microwave power of the oven has been determined as 682 W by using IMPI 2-liter test (Buffler, 1993). In order to improve heating uniformity of samples, there is a rotary table in the oven. The oven has three halogen lamps, each having 1500 W. Two of the lamps were located at the top of the oven and one was at the bottom. To maintain the humidity in the oven, four beakers, each containing 400 ml water, were placed in the corners of the oven during baking. Four dough samples (100 g each) were placed at the center of the turntable and baked using 40% upper infrared and 30% microwave power for 9 min.

2.2.2.3 Analytical Tests

Protein content was determined by the LECO Nitrogen Determinator (Sweeney and Rexfod, 1987). The sugar and starch contents were determined in accordance with AOAC (1990) methods 982.14 and 978.17, respectively. Total fat content was determined by the Soxhlet extraction using petroleum ether as a solvent according to AOAC (1990) method 963.15. The fiber content was determined using AOAC (1990) method 991.43. The moisture and ash contents were determined according to AOAC (1990) methods 925.10 (air oven method) and 923.03, respectively.

2.2.2.4 Rheological Measurements

The rheological measurements were conducted using TA rheometer (RA 2000ex, Sussex, UK or ARG-2 Model, from TA Instruments, Newcastle, DE, USA). All measurements were done at 25°C, using parallel plate geometry (40 mm diameter and 2 mm gap). The dough samples were placed between the plates and the edges were carefully trimmed with a spatula. The flow experiments were conducted under steady-shear conditions with shear rate ranging from 1 to 50 1/s. For the relaxation of the residual stresses, the dough was rested at room temperature for 20 min before testing. The wheat dough samples were also characterized using the lubricated squeezing technique described by Campanella and Peleg (1987).The dough sample at 25°C was placed between two parallel plates (60 mm) lubricated with a silicon oil and allowed to rest until the normal force reading minimized and stabilized (RA 2000ex Rheometer, Sussex, UK). The biaxial deformations of 100 µm/s, 300 µm/s and 500 µm/s were applied until the dough was compressed 80% of its original thickness. In the case of the dynamic oscillatory experiments, first linear viscoelastic region of the samples were determined. Then, frequency sweep experiments were carried out at 0.5% strain rate between 0.1 to 10 Hz. Finally, results were expressed in terms of elastic (G') and loss (G") values. In order to avoid interference of bubble formation, dough samples for the rheological tests were prepared without adding any yeast to the formulation. All the rheological experiments were performed at least twice and their averages were reported in the study.

2.2.2.5 Weight Loss

The percentage weight loss (WL%) of the breads during the baking was calculated by measuring the weights of the bread samples before (W_{dough}) and after the baking process (W_{bread}). The weight loss expressed as the percentage of the initial value. The measurements were done in duplicate.

$$\text{WL}\ (\%) = \left[\frac{W_{dough} - W_{bread}}{W_{bread}}\right] \times 100 \tag{2.1}$$

where, W denotes weight (g).

2.2.2.6 Texture Analysis

After 1 h cooling at 25 °C, firmness, cohesiveness, springiness, chewiness and adhesiveness of bread samples were evaluated by the Texture Analyzer (TA Plus, Lloyd Instruments, UK and Texture Technologies Corp., Scarsdale, NY, USA). Samples in cubic shape having dimensions of 25 × 25 × 25 mm were taken from the center of bread and were compressed to 25% of thickness with a cylindrical probe (diameter 10 mm) (approved method 74–09, AACC, 2000). The measurements were done in duplicate.

2.2.2.7 Specific Bulk Volume

To determine specific volume, volume (cm^3) of bread sample with known weight (g) was determined by the rapeseed displacement method after 20 min cooling at 25°C. Then, specific volume was calculated as the volume/mass ratio (cm^3/g) of bread according to (approved method 10–05, AACC 2000). The measurements were done in duplicate.

2.2.2.8 Color Analysis

The crust color of the bread samples was measured using a Minolta CR-10 color reader (Osaka, Japan) using the CIE L*, a*, and b* color scale. Five readings were carried out from different positions of bread crust, and mean value was recorded. Total color change (ΔE) was calculated from the following equation;

$$\Delta E^* = [(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2]^{1/2} \qquad (2.2)$$

Color of rice dough was selected as reference point and its L*, a* and b* values were represented as L_0, a_0 and b_0 which were 78.32, 4.65, 32.43, respectively.

2.2.2.9 Sensory Analysis

Ten-member semi-trained panelists who are familiar with sensory analysis techniques were participated in sensory analysis of bread samples. The freshly baked breads were submitted for an acceptance test, applying a hedonic scale of 5 point (Resurreccion, 2008). Panelists were asked to assess the breads for acceptability of texture, taste, and crumb color and to rate samples from 0 to 5 (0 means unacceptable & 5 means very acceptable).

2.2.3 Analysis of Bread Macro-structure and Micro-structure

X-ray microtomography was used to determine microscopic changes of gluten-free breads containing different gums. Macro- and micro-structures of gluten-free breads containing different flour types and different gums baked in conventional and infrared-microwave combination ovens were investigated by using the images obtained by scanner and scanning electron microscopy (SEM).

2.2.3.1 X-ray Micro Computed Tomography (X-ray μCT) Analysis

MicroCT 40 (Scano Medical Inc.,PA) was used to study porous structure of gluten-free bread crumbs. The parameters of μCT were selected for foods to be most favorable at 45-kVp and 177μA intensity (Kelkar, et al., 2011). The largest sample cell having 35.6 mm diameter and medium resolution was selected for scanning the crumbs. Each of the bread samples was cut to fit into the sample cell with minimal damage to the structure using serrated cutter. Cotton was placed on top and bottom of the sample in the cell to avoid movement of sample during scanning. Then, the sample cell was covered with a paraffin film to avoid any possible moisture loss. To create a tomogram, a sample is placed on a rotary stage and the X-rays penetrate the sample, the stage is rotated. Each sample was scanned to obtain 100 slices of 0.036 mm thickness each.

2.2.3.2 Scanning of Bread

Gluten free breads were cut into two halves vertically by an electrical knife (Arzum AR 156 Colte, Ankara, Turkey). The cut side of one of the halves was placed over the glass of a scanner (CanoScan 3200F, Tokyo, Japan). Scanning was performed with a resolution of 300 dpi.

2.2.3.3 Scanning Electron Microscopy (SEM) Analysis

For SEM analysis, bread crumbs which were broken into small pieces (cubes in about 2.5 cm dimension), frozen in liquid nitrogen and then freeze dried. Freeze-dried samples were sputter coated with gold-palladium to render them electrically conductive by using HUMMLE VII Sputter Coating Device (Anatech Electronics, Garfield, N.J., USA). Samples were then examined and images were recorded with a scanning electron microscope (JSM-6400, JEOL, Tokyo, Japan) at an accelerating voltage of 20 kV. Samples were observed at magnification levels of 20× and 1000×. In the case of 1000× magnification level, both outside and inside of bread crumbs were examined.

2.2.3.4 Image Analysis

The scanned images of the samples were exported to a computer and Image J software (http://rsbweb.nih.gov/ij/) was used to quantify the results. The scans were segmented to obtain similar sized rectangular region of interest from the middle part of the sample to eliminate possible artifacts (Babin et al., 2007). Thresholding operation was performed using the Otsu's algorithm (Otsu, 1979) to divide the grayscale image into foreground (air) and background (bread). Porosity of the bread crumbs was determined from the ratio of the number of foreground (air) voxels divided by the total number of voxels in the image using Image J. The shape descriptors plugin was used to determine the number of pores, aspect ratio, roundness and the average size of the pores. Due to the resolution of the μCT, only pores greater than $0.05 cm^2$ were considered. Crumb structures of bread samples were analyzed calculating porosity, the number of pores and mean roundness values by this software. The equations for the roundness and aspect ratio are given below (Russ, 2004).

$$\text{Roundness} = \frac{4 \times \text{area}}{\pi \times \sqrt{(\text{major axis})}} \tag{2.3}$$

$$\text{Aspect ratio} = \frac{\text{Major axis}}{\text{Minor axis}} \tag{2.4}$$

where major axis is length and minor axis is width. Aspect ratio and roundness value of 1 indicates a perfect circle.

Crumb cell characteristics of the scanned images and SEM micrographs at magnification of 20× were analyzed using the software Image J (http://rsb.info.nih.gov/ij/). In the software, the contrast between two phases (pores and solid part) for each images were used. In the case of scanned images, each color image was first converted to gray scale (8 bit). Values of scanned images were obtained in pixels and converted into cm by using bars of known lengths. Segmentation was carried out using Image J software by applying the manual thresholding tool. The largest possible cross-section of the images (5 cm × 5 cm) was selected for each image. However, the whole area was analyzed without any cropping in the case of SEM micrographs. To determine the pore distribution in bread crumbs, the method and software used in the study of Impoco et al. (2007) was used. This software is in the form of a plug-in for Image J. The plug-in encompasses two commands: Binarise SEM and Compute Stats.

Binarise SEM segments the input image into "holes" and "structure". The command Compute Stats is used for the output of the previous application Binarise SEM to obtain image statistics about the distribution of pores.

2.2.4 Optimization by RSM

RSM was employed as an optimization tool to determine the effects formulations and processing conditions on the quality parameters of gluten-free breads baked in infrared-microwave combination oven.

2.2.4.1 Experimental Design

There were five independent variables each having five levels, which were chestnut:rice flour ratio (X_1; 0:100, 20:80, 40:60, 60:40 and 80:20), emulsifier content (X_2; 0.00, 0.25, 0.50, 0.75 and 1.00% of flour weight), upper halogen lamp power (X_3; 40, 50, 60, 70 and 80%), microwave power (X_4; 30, 40, 50, 60 and 70%) and baking time (X_5; 9, 11, 13, 15 and 17 min). The lower halogen lamp power was constant at 70%. The levels of these variables were determined by preliminary experiments.

In order to study the main effects and interactions, central composite design (CCD) having 36 experimental runs with different combination of factors and two blocks was conducted using MINITAB Release 14.1 (Minitab Inc., State College PA, USA). To provide uniform variance at any given radius from the center of the design mainly, rotatability and orthogonality the axial distance α was chosen to be 2. To make each run in the design independent of each other, MINITAB Release 14.1 (Minitab Inc. State College, PA, USA) tool of randomization was used. The assigned run order was taken into account during the experiments. For convenience, the actual values were converted into coded values. The coded and uncoded (actual) levels of the independent variables used in the experiments were given in Table 2.2. In this design, the experiments were randomized to minimize the effects of extraneous variables.

Table 2.2. The coded and actual values of the levels of the independent factor

Independent variables	Symbol	Coded levels -2	-1	0	1	2
		Uncoded levels				
Chestnut:rice flour ratio	X_1	0:100	20:80	40:60	60:40	80:20
Emulsifier content (%)	X_2	0.00	0.25	0.50	0.75	1.00
Upper halogen lamp power (%)	X_3	40	50	60	70	80
Microwave power (%)	X_4	30	40	50	60	70
Time (min)	X_5	9	11	13	15	17

2.2.4.2 Optimization

For the optimization, the second-order regression equations and coefficients were determined from the analysis of response surface design by using MINITAB Release 15 (Minitab Inc. State College, PA, USA). According to the results of ANOVA, only the factors affecting responses significantly were selected. Model selection for each response was made on the basis of the Anderson and Darling normality test and Bartlett's test. The optimization of the process conditions of infrared-microwave combination baking was calculated by optimization tool of MATLAB Package (Version: 7.4.0.278, R2007a, The Math Works Inc., Natick, MA, USA). A constraint optimization program was written by entering the models obtained for responses color and firmness of breads. The program was written to find the optimum point by considering a maximum specific volume, a minimum weight loss and constraint of color and firmness. Firmness and color constraint was obtained by using firmness and ΔE^* values of conventionally baked gluten-free breads. One-way ANOVA was used to determine whether oven type significantly affected quality parameters of bread formulations or not ($p \leq 0.05$).

2.2.5 Staling Analysis

2.2.5.1 Storage of Gluten-free Breads

After baking, breads were allowed to cool down for 1 h; then covered with a stretch film, and kept in a plastic bag at 22 ± 2 °C for different storage times (1, 24, 48, 72, and 96 h).

2.2.5.2 Analysis of Bread

DSC was used to measure the retrogradation enthalpies of amylopectin in gluten-free breads during storage. The crystallinity levels in the bread samples were determined by using X-ray diffraction and FTIR analyses. For DSC, X-ray and FT-IR measurements, gluten-free bread samples, which were stored at different times, were frozen at -80ºC (Beko, 7103 DF, Istanbul, Turkey) and then freeze-dried (Christ, Alpha 1-2 LD plus, Germany) for 48 h at a pressure below 1 mbar. Samples were ground in a coffee grinder (Sinbo, SCM-2909, Istanbul, Turkey) and sieved through a 212-μm screen.

2.2.5.3 Moisture Content

The moisture content of bread crumb samples was determined by drying bread samples in an oven at 105°C until constant weight was obtained (approved method 44-15, AACC, 2000). Results were expressed on a wet weight basis. Three replicates were done.

2.2.5.4 Firmness

Firmness of bread samples was evaluated with a Texture Analyzer (TA Plus, Lloyd Instruments, Hants, UK) equipped with a 50 N load cell. Samples taken from the center of the bread samples were cut into cubic shapes having dimensions of 25 mm × 25 mm × 25 mm and compressed to 25% of their thickness at a speed of 55 mm/min with a cylindrical probe (diameter 10 mm) (AACC approved method 74-09, 2000). The measurements were done in duplicate.

2.2.5.5 DSC (Differential Scanning Calorimetry) Analysis

Differential Scanning Calorimetry (TA Q20 model from TA Instruments, New Castle, DE, USA) was used to measure the retrogradation enthalpies of amylopectin in gluten-free breads during storage. Dry samples were weighed (3 ± 1 mg) into DSC pans. The samples were hydrated by adding water (water:dry sample =3:1) with a micro-syringe. The pans were hermetically sealed and allowed to equilibrate at 5±2ºC in the refrigerator for 24 h prior to analysis. An empty pan was used as a reference. The DSC cell was heated at a rate of 10°C/min from 10 °C to 130°C. The endothermic peaks at around 90–130^{o}C are due to amylose-lipid complexation for fresh samples. The retrogradation enthalpies of bread samples (ΔH_r) were computed as J/g by integration of the thermal curves using the analysis software supplied with the instrument. The measurements were done in duplicate.

2.2.5.6 X-ray Diffraction Analysis

X-ray diffraction analysis was done using CuKa (λ=1.54056) radiation on a D8 Focus X-ray diffractometer (Bruker, USA) at 40 kV and 40 mA. The equipment was managed through Difrac plus V4.02 (Bruker) software. The scanning region of the diffraction angle (2θ) was 10°–40° with the scanning speed of 4°/min. The analysis was performed using PeakFit version 4.12 software. The freeze–dried and ground samples were compressed to thin disks of 1–2 mm thickness and a diameter of 13 mm. The pressed samples were mounted on a sample holder. Two replicates were done. Crystalline peaks were analyzed as pseudo-Voight-form and the amorphous ones as Gaussian-form peaks. The crystallinity levels in the samples were determined by the separation and integration of the areas under the crystalline and amorphous X-ray diffraction peaks. The quantification of relative crystallinity was performed using total mass crystallinity grade (TC), the ratio of area of the crystalline fraction to the area of crystalline fraction plus the amorphous fraction, based on the method described by Ribotta et al. (2004c) and Ozkoc et al. (2009b).

$$\mathrm{TC} = \frac{\mathrm{I_c}}{\mathrm{I_c}+\mathrm{I_a}} \qquad (2.5)$$

I_c is the integrated intensity of crystalline phase, and I_a is the integrated intensity of the amorphous phase.

2.2.5.7 FT-IR (Fourier Transform Infrared Spectroscopy) Analysis

All spectra of freeze-dried breads were recorded on a Thermo Nicolet Nexus 670 FT-IR (Thermo Nicolet Analytical Instruments, Madison, Wis., USA) spectrometer equipped with a mercury cadmium telluride (MCT) detector and KBr beam splitter using anavatar Smart Multibounce HATR accessory (Smart ARK, Thermo Electron Corp) with a ZnSe crystal at an angle of incidence of 45°. The detector was cooled with liquid nitrogen for 60 min before data collection. Spectra were collected using 256 scans at 4 cm^{-1} resolutions over the entire 4000-400 cm^{-1} wave number region. Two spectra were collected for each sample and averaged. The analysis was performed using PeakFit version 4.12 software. The integral peak area ratios of peaks around 1041 cm^{-1} (A_1) and around 1150 cm^{-1} (A_2), the ratio of peak intensities bands (R) at 1041 cm^{-1} and 1022 cm^{-1} were made on spectra of gluten-free breads.

2.2.6 Statistical Analysis

Analysis of variance (ANOVA) was performed to determine whether there were significant differences between different gluten-free bread formulations (different flours, gums, and/or emulsifiers), storage time, and oven types. If significant difference is found out, Tukey multiple comparison test were used ($p \leq 0.05$) using MINITAB (Version 16) software.

CHAPTER 3

RESULTS AND DISCUSSION

In the first part of study, the rheological properties of different gluten-free bread dough formulations containing only rice flour and rice-chestnut flour blend with different gums (xanthan, guar, LBG, HPMC, pectin), gum blends (xanthan-guar, and xanthan-LBG blend) and/or emulsifiers (Purawave^{TM} and DATEM) were evaluated. The effects of these additives on the quality of rice breads, rice-chestnut and rice-tigernut breads (weight loss, specific volume, texture, color and sensory) baked in conventional oven were also determined.

As a second part of the study RSM was used to optimize formulations and infrared-microwave baking conditions for gluten-free chestnut-rice breads. The relationships between the responses of weight loss, firmness, specific volume and color change of the breads and independent variables, which were chestnut:rice flour ratio, emulsifier content, upper halogen lamp powers, microwave powers and baking time were determined by using second order models. The effects of different flours, gums, and emulsifiers on macro- and micro-structures of the gluten-free breads baked in different ovens were studied both qualitatively and quantitatively by using an image analysis technique and SEM. The addition of different gums (xanthan, guar, LBG, HPMC, MC, CMC and agar) and gum blends (xanthan-guar, and xanthan-LBG blend) on the crumb structures of gluten-free rice breads were evaluated by using X-ray μCT.

In the last part of the study, the effects of different formulations (different flours, gums, and/or emulsifiers) and storage time on staling of gluten-free rice breads baked in conventional and infrared-microwave combination ovens were studied. Staling properties of the bread were assessed using mechanical compression, DSC, X-ray diffraction, and FT-IR.

3.1 Bread Quality and Dough Rheology of Gluten-free Rice Bread Formulations

The rheological properties of rice bread dough containing different gums with/without emulsifiers were determined. In addition, the quality of rice breads (volume, firmness and sensory analysis) was evaluated. Different gums (xanthan gum, guar gum, LBG, HPMC, pectin, xanthan–guar, and xanthan–LBG blend) and emulsifiers (Purawave^{TM} and DATEM) were used to find the best formulation for gluten-free breads.

3.1.1 Rheological Measurements

Table 3.1 shows the Power Law parameters of gluten free dough samples. The shear stress (τ) versus shear shear rate ($\dot{\gamma}$) data for all formulations containing different kinds of gums with and without emulsifiers at 25°C were fitted well to the Power Law model (Eq.3.1.)

$$\tau = K\,(\dot{\gamma})^n \tag{3.1}$$

where K is the consistency index (Pa s^n), and n is the flow behavior index). Flow behavior indexes (n value) ranging from 0.33 to 0.68 (except pectin containing samples) showed that all dough formulations and gum solutions displayed a shear thinning (pseudoplastic) behavior (Table 3.1, Figure 3.1-Figure 3.3). For the pseudoplastic materials, the viscosity decreases as the shear applied to the liquid increases because the interactions between the components of the system break down under the action of shear.

The flow curves of dough samples containing different gums with or without emulsifiers are given in Figure 3.1, Figure 3.2 and Figure 3.3.

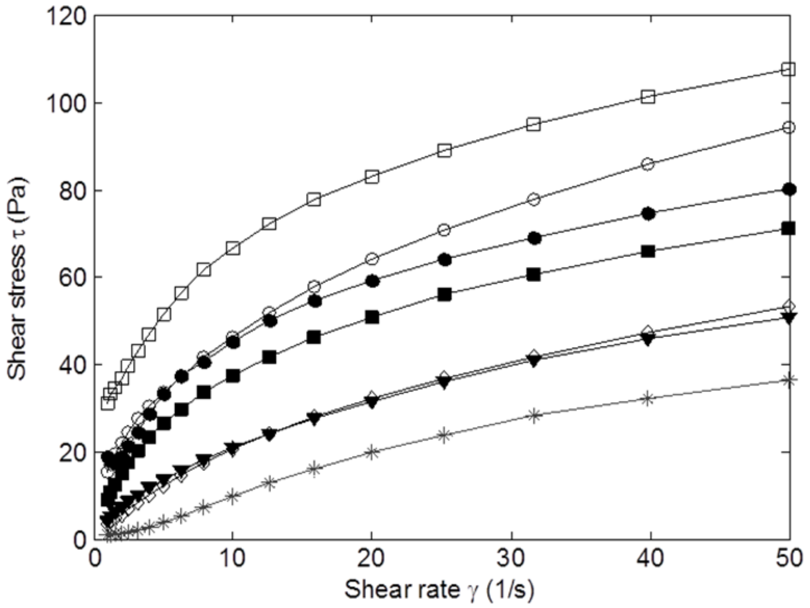

Figure 3.1. Flow curves obtained for rice flour dough containing gums: xanthan (□), xanthan-guar (○), LBG-xanthan (●), guar (■), HPMC (◊), LBG (▼), pectin (*).

The flow curve of the control sample prepared using only rice flour (without gum or emulsifier) couldn't be measured properly because of the quick phase separation during the experiment. Similar problem was also encountered with the pectin containing sample, causing high flow behavior index shown in Table 3.1. Furthermore, lubricated squeezing flow experiments were also conducted to give a sense of comparison between flow properties of a typical wheat dough and rice flour dough prepared in this study (Osorio et al., 2003). Most of the rice flour dough samples, especially the ones containing only gum and gum and Purawave, were soft for this methodology.

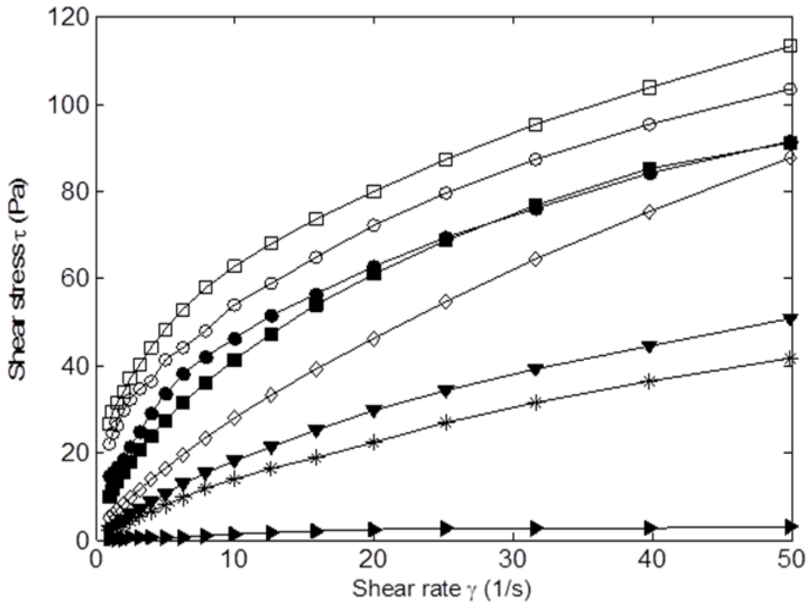

Figure 3.2. Flow curves obtained for rice flour dough containing Purawave™ and different gums: xanthan (□), xanthan-guar (○), LBG-xanthan (●), guar (■), HPMC (◊), LBG (▼), pectin (*) and purawave only (▶).

Table 3.1. Power law constants of the rice dough samples at 25°C, using parallel plate geometry.

	Samples containing only gum			Samples containing Purawave			Samples containing DATEM		
	K (Pa.s^n)	n	r^2	K (Pa.s^n)	n	r^2	K (Pa.s^n)	n	r^2
HPMC	3.50	0.55	0.98	4.90	0.74	0.99	4.80	0.68	0.99
Guar	10.80	0.53	0.98	10.20	0.59	0.99	50.80	0.39	0.98
Locust bean gum (LBG)	2.75	0.63	0.97	4.60	0.79	0.99	14.10	0.61	0.99
Xanthan-guar	15.70	0.46	0.99	21.80	0.39	0.99	61.70	0.35	0.99
Xanthan-LBG	15.80	0.43	0.99	14.10	0.51	0.99	46.10	0.39	0.99
Xanthan	26.50	0.37	0.99	30.10	0.33	0.99	61.40	0.33	0.99
Pectin	0.70	0.97	0.95	2.20	0.77	0.99	3.40	0.71	0.99
DATEM	-	-	-	-	-	-	1.14	0.77	0.96
Purawave	-	-	-	0.20	0.81	0.94	-	-	-

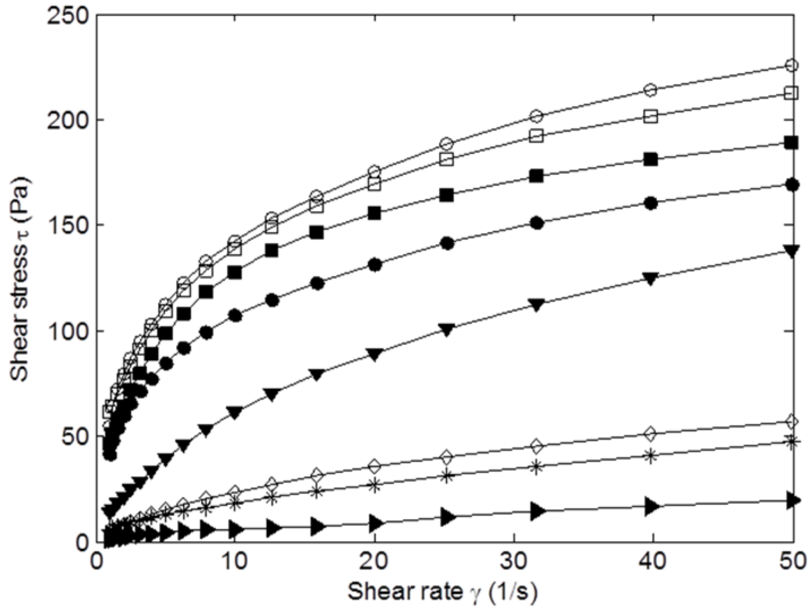

Figure 3.3. Flow curves obtained for rice flour dough containing DATEM and different gums: xanthan-guar (○), xanthan (□), guar (■), LBG-xanthan (●), LBG (▼), HPMC (◊), pectin (*), and DATEM only (▶).

As shown in Figure 3.4, wheat dough had significantly higher biaxial viscosity compared to the selected most viscous rice flour samples. The resistance to the extensional flow provides the highest specific volume of breads. In the case of rice flour dough, the extensional viscosity values, thereby extensibility, were relatively low resulting in low specific volume of the rice flour samples compared to wheat dough.

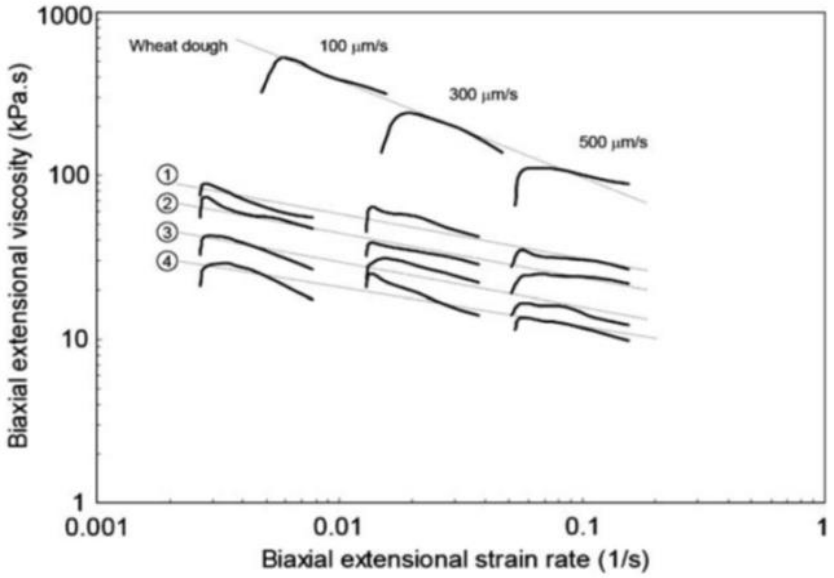

Figure 3.4. Biaxial extensional viscosity as a function of biaxial strain of wheat dough used in this study at 3 different compression velocities.

Among the rice dough samples containing different gums (without emulsifier), the highest consistency index and apparent viscosity values were obtained for xanthan containing samples (Table 3.1, Figure 3.1, Table A. 1, Table A. 2, Table A. 3). The samples containing xanthan-LBG and xanthan-guar gum mixtures had very similar flow curves with almost identical consistency and flow behaviour index (Table 3.1). Briefly, the observed apparent viscosities were in the following decreasing order; xanthan, xanthan–guar, xanthan–LBG, guar, HPMC, LBG and pectin containing rice dough samples. When the 1% solutions of the gums were tested at 25 °C, very similar order was also observed (Figure 3.5).

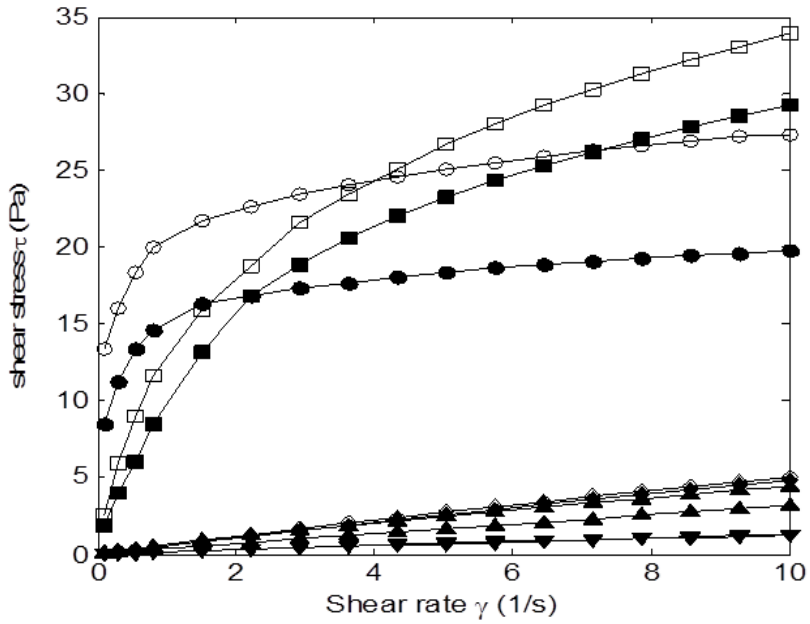

Figure 3.5. Flow curves of the gums (1% w/w) used in this study: xanthan (■), xanthan-DATEM (□), guar (●), guar-DATEM (○), HPMC (◊), HPMC-DATEM (♦), LBG (▲), LBG-DATEM (△), pectin (▼), pectin-DATEM (▽).

It is well known that even at low concentrations xanthan gum solutions exhibit high viscosity at relatively low shear rates. Xanthan gum results in high consistency and low flow behavior indexes due to the complex aggregates formed by semi-rigid molecules (Sworn, 2000, Mandala et al., 2004). This property of xanthan gum resulted in the relatively higher apparent viscosities in xanthan containing rice flour dough samples including xanthan-guar and xanthan-LBG. Guar gum is also widely used in food industry as a thickening agent. Therefore, addition of guar gum into rice dough also resulted in relatively higher apparent viscosities. As expected, the other gums (LBG, HPMC, and pectin) used in this study had smaller viscosities compared to xanthan and guar gums. The addition of these gums did not improve the consistency of rice dough as much as xanthan and guar.

The flow curves of dough samples containing gums and Purawave^{TM} are shown in Figure 3.2. Based on two-way ANOVA results, gum type and Purawave^{TM} addition affected the flow curves of dough significantly ($p \leq 0.05$) (Table A. 1). Addition of Purawave^{TM} caused an increase in the consistency index and apparent viscosity values of rice dough samples (Table 3.1 and Figure 3.2). However, when Purawave^{TM} was mixed with the gums used in this study, precipitation of Purawave^{TM} was observed. Therefore, addition of Purawave^{TM} did not change the flow curves of the gum solutions given in Figure 3.5. On the other hand, as shown in

Table 3.1 and Figure 3.2, Purawave^{TM}-gum addition resulted in higher apparent viscosities in rice dough samples compared to the ones with only gums. Similar to the results shown in Figure 3.1, when Purawave^{TM} was used as an emulsifier, xanthan containing sample had the highest consistency index and apparent viscosity values (Figure 3.2). In fact, the order of the flow curves was the same as those given in Figure 3.1. These results are in good agreement with the study of Turabi et al., 2008a, in which it was reported that among the rice cake batters formulated with various gums (xanthan, guar, LBG, kappa-carrageenan, HPMC, xanthan-guar gum blend and xanthan–kappa-carrageenan gum blend) and Purawave^{TM}, xanthan containing batters showed the highest apparent viscosity values (Table A. 1).

In the third group, DATEM was used as the emulsifier. The increase of the consistency index and apparent viscosities was higher than those observed when Purawave^{TM} was used. However, the order of flow curves (as shown in Figure 3.3) was slightly different than the order given in Figure 3.2. When DATEM was used, flow curve of the guar added sample had apparent viscosity higher than flow curve of xanthan-LBG. This may be explained by the increased apparent viscosities observed when DATEM (1 %) was added into guar (1%) or xanthan (1%) solution (Figure 3.5). Nevertheless, such an increase was not observed in other gums (LBG, HPMC, or pectin). When the effects of emulsifiers on xanthan containing samples were evaluated, the more pronounced effect of DATEM on consistency coefficient and apparent viscosity values can be easily seen in Figure 3.6.

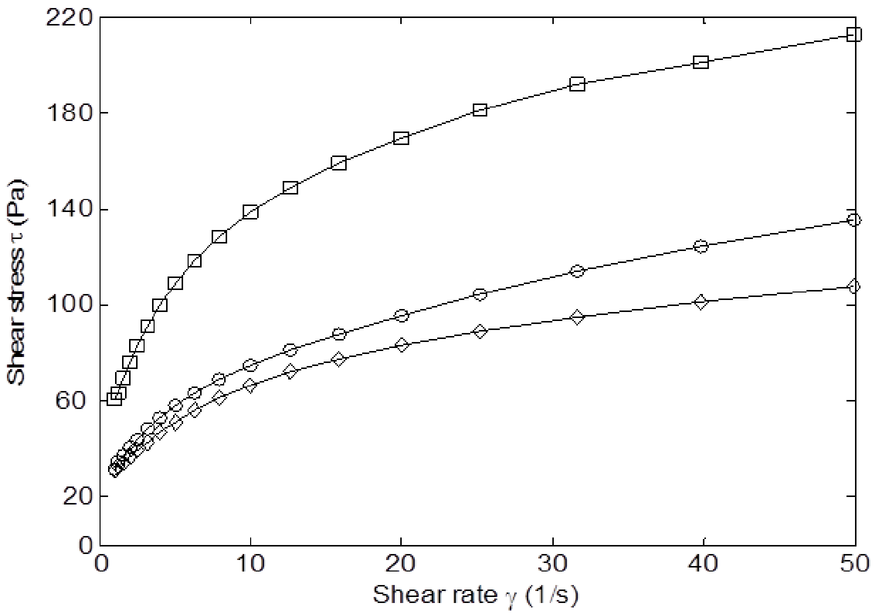

Figure 3.6. Flow curves obtained for rice flour dough containing xanthan and emulsifiers, where □: xanthan-DATEM, ○: xanthan-Purawave, and ◊: only xanthan.

There was an increase in the consistency index and apparent viscosity values of dough samples as shown in Figure 3.6 and Table 3.1. The highest consistency index and apparent viscosity values were obtained from xanthan-guar mixture and xanthan containing dough samples similar to Purawave^{TM} containing samples (Table A. 1, Table A. 2, Table A. 3).

Figure 3.7 - Figure 3.9 show the linear viscoelastic modulus of dough samples containing different gums with and without emulsifier. These figures also include viscoelastic moduli data obtained for wheat dough sample. All the samples showed solid like structure with elastic modulus (G') higher than the viscous modulus (G"). Since rice flour dough without any gum or emulsifier did not form a homogenous mixture and had a very quick phase separation, it was not possible to obtain any meaningful results for this sample. Similar problems were also experienced by Sivaramakrishnan et al. (2004). As shown in Figure 3.7, wheat dough had higher elastic and loss modulus values compared to the rice dough samples containing different hydrocolloids. Obviously, gluten was the main factor for the big difference between the rice and wheat dough. It is known that the gluten is responsible for the cohesive and viscoelastic property of wheat flour. Another important difference between the rice and the wheat dough was the frequency dependency of G' and G" values. Rice dough samples (even with the addition of gums) had strong frequency dependence as opposed to the wheat dough, indicating that the structure of rice flour dough did not have strong elastic structure as the structure of the wheat dough.

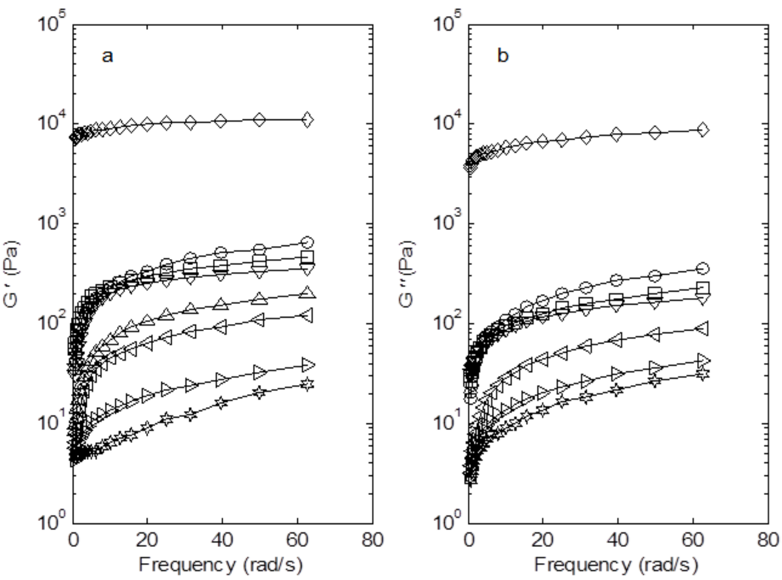

Figure 3.7. Linear viscoelastic moduli (a- storage modulus, b- loss modulus) of dough samples containing wheat flour (◊) and rice flour containing different gums: xanthan (□), xanthan-guar (○), LBG-xanthan (▽), guar (△), LBG (◁), HPMC (▷), and pectin (✯).

Figure 3.7 shows that the addition of xanthan provided the highest moduli values among the rice flour dough samples, which was followed by xanthan-guar and xanthan-LBG containing dough samples. These results agree with the previous studies conducted with rice flour dough containing different gums (Lazaridou et al., 2007). Guar and LBG resulted in relatively smaller increase in viscoelastic moduli compared to xanthan. Furthermore, HPMC and pectin had a very poor impact on the dynamic viscoelastic behavior of dough samples. Unlike wheat dough, lack of protein network in rice dough prevents the formation of a strong viscoelastic structure. However, using emulsifiers can significantly increase both viscous and elastic moduli of rice flour dough. Emulsifiers are amphiphilic substances. Therefore, the interaction between the emulsifiers and other components of rice dough such as water, oil could be obtained due to the hydrophilic and lipophilic groups. Figure 3.8 and Figure 3.9 show the significant increases observed in the viscoelastic modulus values when Purawave™ or DATEM was used in addition to hydrocolloids.

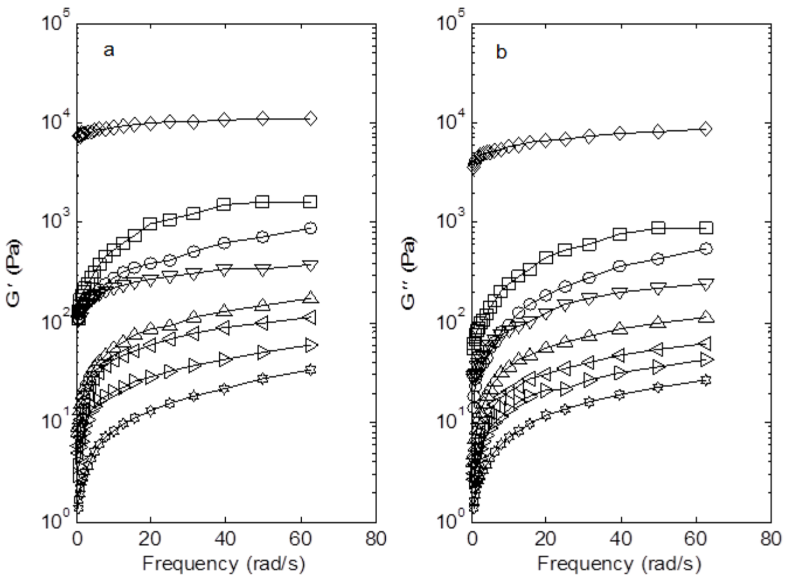

Figure 3.8. Linear viscoelastic moduli (a- storage modulus, b- loss modulus) of dough samples containing wheat flour (◊) and rice flour containing Purawave and different gums: xanthan (□), xanthan-guar (○), LBG-xanthan (▽), guar (△), LBG (◁), HPMC (▷), and pectin (✯).

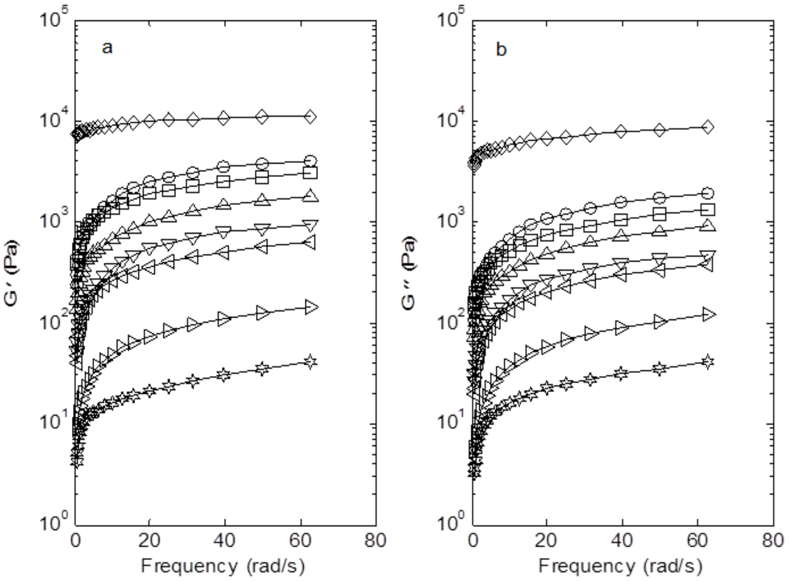

Figure 3.9. Linear viscoelastic moduli (a- storage modulus, b- loss modulus) of dough samples containing wheat flour (◊) and rice flour containing DATEM and different gums: xanthan-guar (○), xanthan (□), LBG-xanthan (▽), guar (△), LBG (◁), HPMC (▷), and pectin (✯).

Among the rice dough samples, the highest viscoelastic behavior was obtained when xanthan, xanthan-LBG and xanthan-guar mixture containing samples mixed with DATEM (Table A. 4, Table A. 5). Nevertheless, LBG, HPMC and pectin addition resulted in smaller increases in viscoelastic moduli of Purawave^{TM} or DATEM containing samples. If the viscoelastic values obtained from DATEM or Purawave^{TM} containing samples were compared, DATEM was clearly more effective in increasing viscoelastic moduli. The hydrophilic/lipophilic balance number (HLB) is very critical to determine the emulsification property. For example, while emulsifiers with low HLB (3–8) have ability to form W/O emulsions, emulsifiers with intermediate HLB (8– 18) have ability to form O/W emulsions (Sahin and Sumnu, 2006). Purawave^{TM} is composed of different emulsifying agents such as lecithin and mono/diglycerides. Both lecithin and mono/diglycerides have low HLB number. On the other hand, DATEM is more hydrophilic as compared to the mono/diglycerides or lecithin. Due to their larger hydrophilic part, they have a higher HLB value. Therefore, even in very low concentrations, DATEM may be able to reduce the surface tension of the dough which is important to obtain more strong dough structure. Thus, emulsifier DATEM had more significant effect on the viscoelastic properties of rice dough as compared to Purawave^{TM}. As shown in Figure 3.9 when xanthan–guar mixture was used with DATEM the highest elastic and loss modulus values were obtained for rice flour dough, however these values were still an order of magnitude less than those of wheat dough.

3.1.2 Baking Tests

The baked bread samples were evaluated in terms of firmness and specific volume as shown in Figure 3.10 and Figure 3.11, respectively. In general, the samples prepared without any emulsifier had relatively firm structure with undesirable physical appearance such as small pore sizes. In the case of pectin containing samples, the bread samples had very firm structure even with the addition of emulsifier and they had similar appearance as the rice control bread. Figure 3.10 also depicts the firmness values of the samples containing only emulsifier. These samples also had relatively firmer structure showing the necessity of addition of gum for the acceptable firmness values.

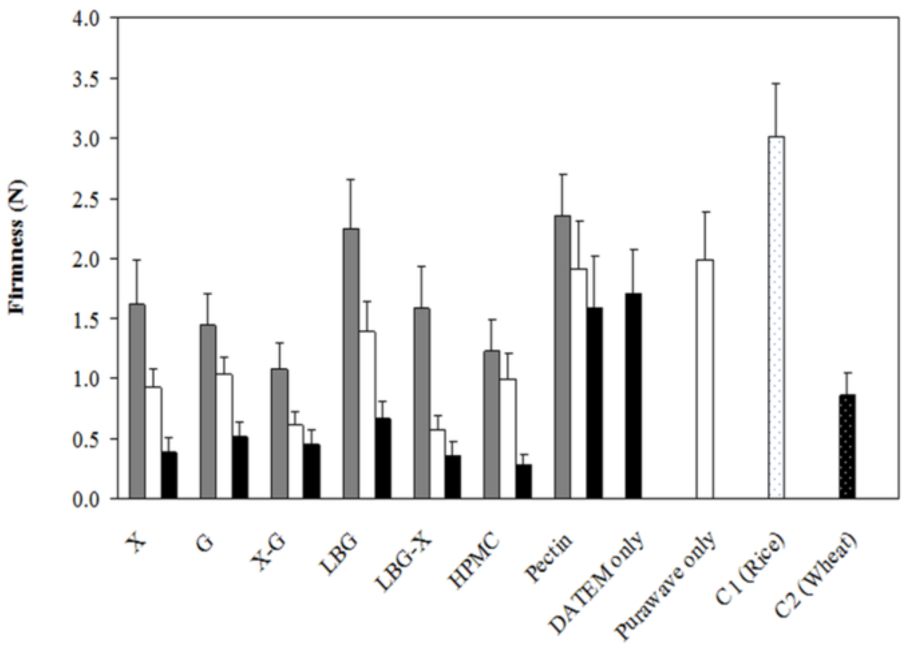

Figure 3.10. Firmness values of the bread samples prepared using different gums and emulsifiers (gray bar): Only gum containing bread samples, (white bar): Purawave containing bread samples, (black bar): DATEM containing bread samples, (dotted white bar): control rice bread samples, (dotted black bar): control wheat bread samples. Bars indicate standard deviation of the replicates.

Addition of gum together with an emulsifier resulted in bread samples with firmness values comparable to that of wheat bread. More specifically, firmness of bread samples decreased with the addition of gum and further decreased with addition of the Purawave^{TM} and DATEM. Especially DATEM and gum combinations lowered the firmness values and improved the texture. In fact, the firmness values of all the samples prepared with DATEM and gum combinations were comparable with the sample prepared with wheat dough. The positive effect of DATEM on firmness has been long recognized for wheat breads (Ribotta et al., 2004b) and also shown for the rice bread in this study. DATEM is mainly used for softening effect in wheat or rye based baked products (Goesaert et al., 2005). It facilitates the aggregation of gluten proteins, creating a gluten network that can improve the entrainment of air and result in better bread volume and crumb texture (Ribotta et al., 2004b). In this study, it was shown that DATEM can also be effective in providing increased water absorption and gas retention during fermentation and proofing in gluten free rice breads. These functions of DATEM in combination with hydrocolloids provided the most acceptable gluten free rice breads having similar firmness values to wheat dough bread (Table A. 6).

The specific volume values obtained from bread samples are given in Figure 3.11. As shown in figure, wheat bread had clearly higher volume value compared to all rice flour breads. The gluten proteins are responsible not only for this cohesive and viscoelastic property of wheat flour dough but also for the protein-starch interaction that is related to the dough's ability to retain gas during fermentation and partly for the setting of the dough during baking (Hoseney, 1986; Gan et al., 2001).

In the case of rice breads, addition of gums and emulsifiers clearly improved the volume of the breads by allowing the entrapment of air bubbles in dough and providing stability to the dough mixture during baking. There are a number studies showing that hydrocolloids improved the volume and texture of gluten-free breads (Nishitia et al., 1976; Acs et al., 1997; Kang et al., 1997; Gambus et al., 2001, Gan et al., 2001; Cato et al, 2004, Lopez et al., 2004; Moore et al., 2004; Sivaramakrishnan et al., 2004; Ahlborn et al., 2005; Ribotta et al., 2004a; Lazaridou et al., 2007).

Although breads prepared using only gums had softer texture than breads prepared without the addition of gums, these breads still had firmer texture values compared to wheat breads. Therefore, the addition of emulsifier is essential to ensure that gluten-free breads have comparable quality parameters with that of wheat breads. This study shows that the addition of Purawave^{TM} or especially DATEM is critical to obtain required volume of the rice flour based breads. When the emulsifiers are compared in terms of their impact on volume, all bread samples supplemented with DATEM had higher specific volume values compared to Purawave^{TM} added breads.

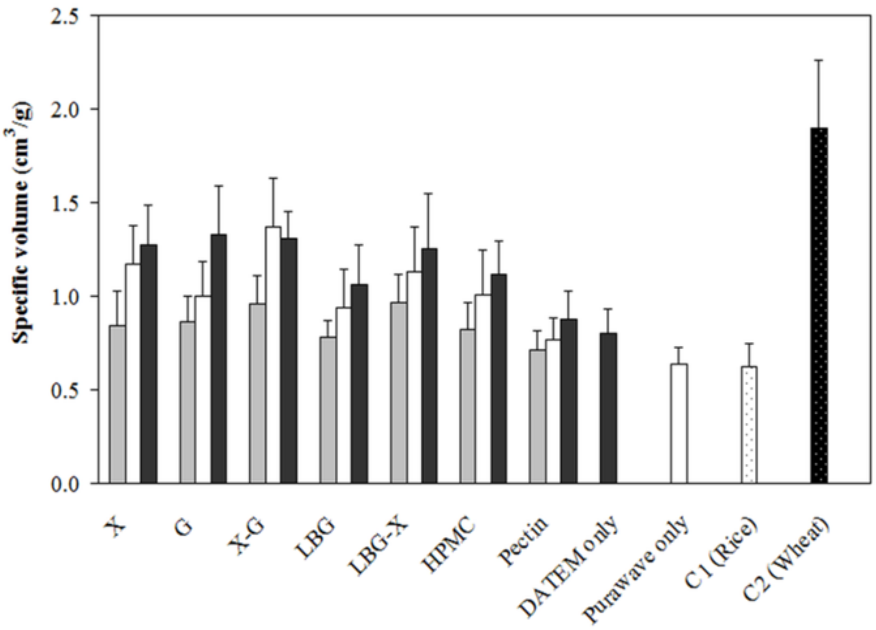

Figure 3.11. Specific volume values of the bread samples prepared using different gums and emulsifiers (gray bar): Only gum containing bread samples, (white bar): Purawave containing bread samples, (black bar): DATEM containing bread samples, (dotted white bar): control rice bread samples, (dotted black bar): control wheat bread samples. Bars indicate standard deviation of the replicates.

When DATEM was used in the formulations, there was a significant increase in the viscoelastic properties of dough which in turn resulted in less sticky and easy to handle surface (Figure 3.8 and Figure 3.9). While xanthan gum exhibited high viscoelastic properties without emulsifier blend, the specific volume values of breads containing xanthan gum were not high. This may be explained by making dough system too rigid to incorporate gases which also resulted in low specific volume values with the addition the addition of xanthan. Lazaridou et al. (2007) reported that, although xanthan had the most pronounced effect on viscoelastic properties of the wheat dough, the volume of breads increased with the addition of hydrocolloids except for xanthan.

A relation between the rheological properties of dough samples (power law and viscoelastic parameters) and the firmness of the rice bread samples was also sought in this study. The elastic and the loss moduli values shown in Figure 3.7, Figure 3.8 and Figure 3.9 indicated that the differences between the samples were amplified as the frequency increased. Thus the elastic and loss moduli values obtained at plateau regions (maximum measured frequency, 10Hz) were chosen to correlate with the firmness values of the bread samples. Figure 3.12 shows that there were good correlations between viscoelastic parameters of dough and firmness values. In general higher moduli values of dough samples resulted in lower firmness values of bread samples. Similar relations were also attempted to establish between the power law parameters (the consistency and flow behavior index values) and firmness, however the R^2 values were less than 0.5 and no meaningful correlation could be obtained.

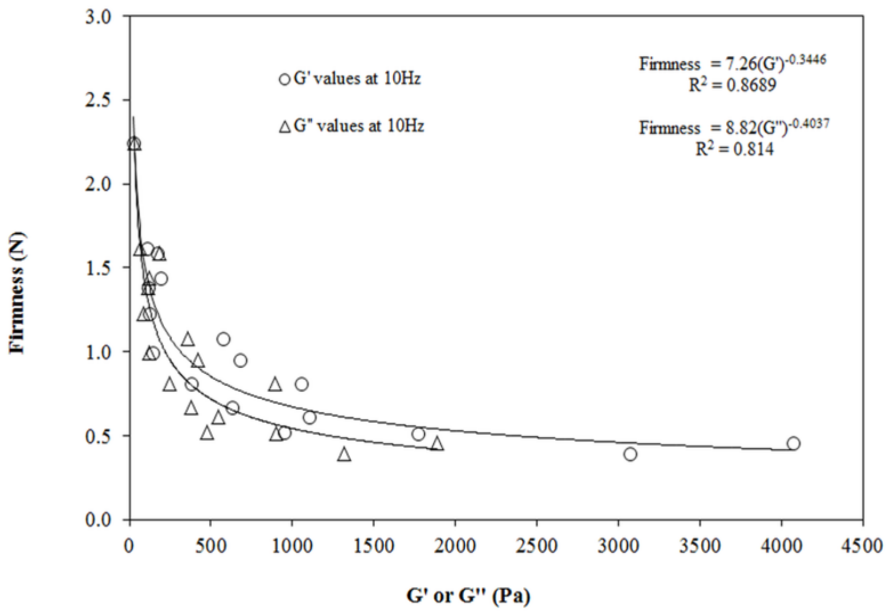

Figure 3.12. Power law relation between the firmness and the viscoelatic moduli of rice flour based breads.

The results of sensory analysis of the rice bread samples are given in Table 3.2. Since rheological, textural, and volume measurements showed that DATEM and xanthan, guar gum, xanthan-guar, xanthan-LBG blend provided the best final product, only these samples were tested. The sensory evaluations were performed according to ranking tests which were developed for measuring the food acceptability, in which higher score means higher acceptability.

Table 3.2. Effect of gum type and DATEM blend on the texture and taste of rice breads.

FORMULATION	Texture	Taste
Control (No gum & emulsifier)	2.3 [c]	3.5 [a]
X–E	2.7 [b, c]	4.0 [a]
G-E	3.1 [b]	3.6 [a]
X-G-E	4.5 [a]	4.0 [a]
X-LBG-E	4.5 [a]*	4.2 [a]

* Formulations having different letters (a, b and c) are significantly different ($p \leq 0.05$).

In Table 3.2, texture and taste scores of the breads are given. In general, the sensory analysis results agreed with the results of firmness measurements. According to sensory analysis, the bread samples differed significantly in texture. The highest scores for the texture were obtained when xanthan-guar and xanthan-LBG were used in rice breads in the presence of DATEM ($p \leq 0.05$) (Table A. 9). The control sample had the lowest texture score as expected based on firmness values. On the other hand, addition of gum and DATEM did not cause any significant difference ($p \leq 0.05$) in taste of rice breads.

3.2 Bread Quality and Dough Rheology of Gluten-free Chestnut-rice Bread Formulations

Gluten-free bread formulations using chestnut and rice flours at different ratios (0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0) were tested. As discussed in section 3.1, addition of xanthan–LBG and xanthan–guar gum blend and DATEM into bread formulations resulted in high quality of breads. Thus, the influence of hydrocolloid blend (xanthan–LBG and xanthan–guar gum blend) and emulsifier DATEM on the rheological properties of dough formulations and quality parameters of breads were investigated for the samples.

3.2.1 Rheological Measurements

The shear stress (τ)versus shear rate ($\dot{\gamma}$)data for all dough formulations (except for rice dough samples) at 25°C were fitted well to the Herschel-Bulkley equation (Eq.3.2);

$$\tau = \tau_0 + K\,(\dot{\gamma})^n \qquad (3.2)$$

where τ is the shear stress (Pa), τ_0 is the yield stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency index (Pa s^n), and $n$is the power-law index. Table 3.3 shows the Herschel-Bulkley model parameters for the dough samples. For the steady-state flow experiments a shear thinning behavior (pseudoplastic) was observed for all the samples with the power-law index values between 0.52 and 0.87. For the pseudoplastic materials, as the shear stress increases the viscosity decreases as a result of the disruption of interactions between the components (Malkin and Isayev, 2006).

Table 3.3. Herschel-Bulkley model constants of the dough samples at 25°C

Formulation	K ($Pa.s^n$)	n	τ_0(Pa)	r^2
100:0 CF:RF	79.0 ± 5.31	0.52 ± 0.041	85.9 ± 8.01	0.99
50:50 CF:RF	41.0 ± 4.62	0.56 ± 0.042	59.2 ± 6.37	0.99
40:60 CF:RF	8.4 ± 1.61	0.59 ± 0.053	18.1 ± 2.12	0.99
40:60 CF:RF- X-LBG-E	44.1 ± 5.10	0.54 ± 0.067	58.8 ± 3.43	0.98
40:60 CF:RF- X-G-E	59.5 ± 6.74	0.53 ± 0.073	68.4 ± 3.97	0.98
30:70 CF:RF	3.6 ± 0.82	0.75 ± 0.079	8.6 ± 1.43	0.99
30:70 CF:RF- X-LBG-E	28.9 ± 2.12	0.70 ± 0.041	38.0 ± 2.46	0.98
30:70 CF:RF-X-G-E	26.0 ± 1.97	0.61± 0.044	43.0 ± 3.38	0.99
20:80 CF:RF	1.7 ± 0.56	0.87 ± 0.054	4.8 ± 0.94	0.99
20:80 CF:RF- X-LBG-E	5.5 ± 0.84	0.81 ± 0. 171	11.0 ± 0.73	0.98
20:80 CF:RF-X-G-E	15.1 ± 1.12	0.78 ± 0.093	22.0 ± 2.51	0.99
10:90 CF:RF	1.1 ± 0.39	0.9 ± 0.057	3.2 ± 1.19	0.97
10:90 CF:RF-X-LBG-E	3.5 ± 0.44	0.87 ± 0.052	7 ± 1.21	0.98
10:90 CF:RF-X-G-E	5 ± 0.88	0.78 ± 0.064	9 ± 1.64	0.97

The flow curves of dough samples containing different chestnut:rice flour ratio with/without gums and emulsifier can be seen in Figure 3.13. The flow curve of rice dough samples (without any gum or emulsifier) could not be measured properly because when rice flour was used alone, the mixture was not stable enough and flour particles quickly precipitated. Figure 3.13 shows that chestnut flour addition strongly influenced rheological properties of the dough.

Since chestnut flour has higher amount of fiber as compared to rice flour, the dough samples had higher yield stress values when their chestnut flour ratio increased (Table 3.3). In accordance to the yield stress values, the consistency index values also increased as the chestnut flour ratio increased. Fibrous structure of chestnut flour was the main reason for affecting rheological parameters. Entanglement of fibers creates additional resistance to flow and increases yield stress and apparent viscosity values. Furthermore, the hydroxyl groups available in fiber structures can bind more water through hydrogen binding mechanism which, in turn reduces the amount of available water for the plasticizing effects (Nelson, 2001).

Utilization of xanthan–guar and xanthan–LBG gum was also investigated in this study. Xanthan have ability to form high-viscosity pseudoplastic material and is commonly used in commercial gluten-free product industry. In addition, xanthan gum interacts with the smooth regions of the galactomannan molecules resulting in a synergistic interaction with galactomannans such as guar gum, locust bean gum, cassia gum and glucomannans such as konjac mannan (Wielinga and Maehall, 2000). Such a synergic effect is commonly preferred in food systems for the enhancement of texture. Further improvement of the texture was also reported with incorporation of emulsifier DATEM into gluten-free formulations. Therefore in this study, the effects of combination of different hydrocolloids (xanthan–guar and xanthan–LBG) and emulsifier DATEM on rheology of the samples having chestnut:rice flour ratio of 10:90, 20:80, 30:70 and 40:60 were investigated.

Addition of the gum blend (xanthan-guar and xanthan-LBG) and emulsifier increased consistency index and yield stress values of the dough samples (Figure 3.13 and Table 3.3). When the gum blends were compared, higher apparent viscosities were observed in xanthan-guar gum blend and emulsifier added samples. The flow curves of the xanthan-guar gum blend solution were shown to have higher apparent viscosity as compared to xanthan-LBG gum blend solution. Therefore, the higher apparent viscosity values can be obtained from the dough containing xanthan-guar gum blend and emulsifier DATEM mixture.

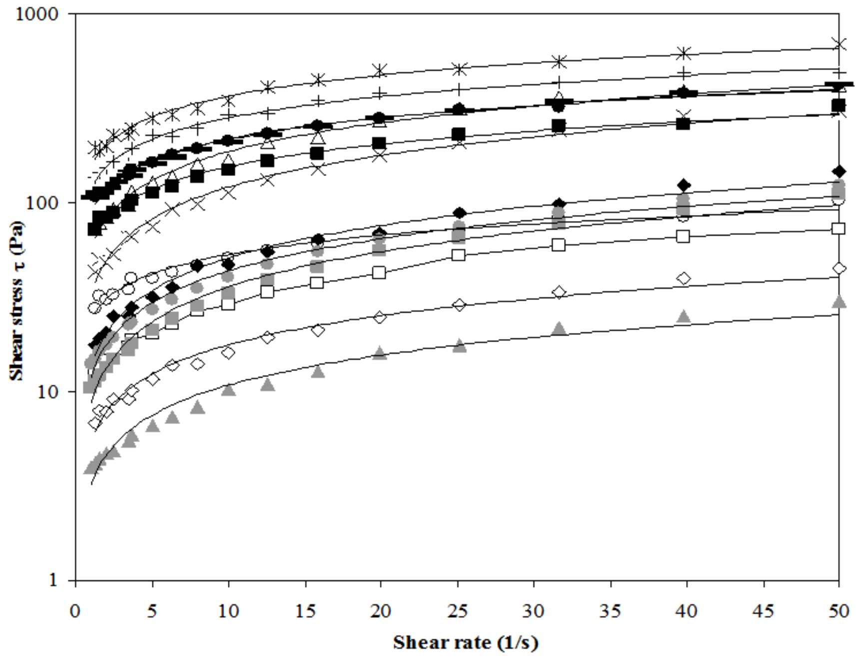

Figure 3.13. Flow curves obtained for dough samples containing different chestnut:rice flour ratio (CF:RF) with and without gum blend and emulsifier: (∗): 100:0 CF:RF dough, (+): 40:60 CF:RF+Xanthan+Guar+emulsifier, (●): 40:60 CF:RF+Xanthan+LBG+emulsifier, (−): 50:50 CF:RF, (△): 30:70 CF:RF+Xanthan+Guar+ emulsifier, (■): 30:70 CF:RF+Xanthan+LBG+emulsifier, (×): 20:80 CF:RF+Xanthan+Guar+emulsifier, (○): 40:60 CF:RF, (♦): 20:80 CF:RF+Xanthan+LBG+emulsifier, (●): 10:90 CF:RF+Xanthan+Guar+emulsifier, (■): 10:90 CF:RF+Xanthan+LBG+emulsifier, (□): 30:70 CF:RF, (◊): 20:80 CF:RF, (▲): 10:90 CF:RF, (—): model.

In the presence of xanthan-guar gum blend and emulsifier mixture, the dough samples containing chestnut:rice flour ratio of 40:60 had higher consistency index and yield stress values as compared to dough samples at chestnut:rice flour ratio of 50:50 without additive (Table 3.3). However, consistency index and yield stress values of these dough samples were still lower than that of dough samples containing higher amount of chestnut:rice flour ratio (100:0) without additives.

The linear viscoelastic modulus of dough samples containing chestnut and rice flour at different ratios with/without gums and emulsifier can be seen in Figure 3.14 and Figure 3.15. All dough samples had a higher elastic modulus (G') than viscous modulus (G") in the studied frequency range indicating a weak gel behavior or solid like structure. On the other hand, no meaningful results for rice dough could be obtained, since it did not keep its homogenous structure during measurement.

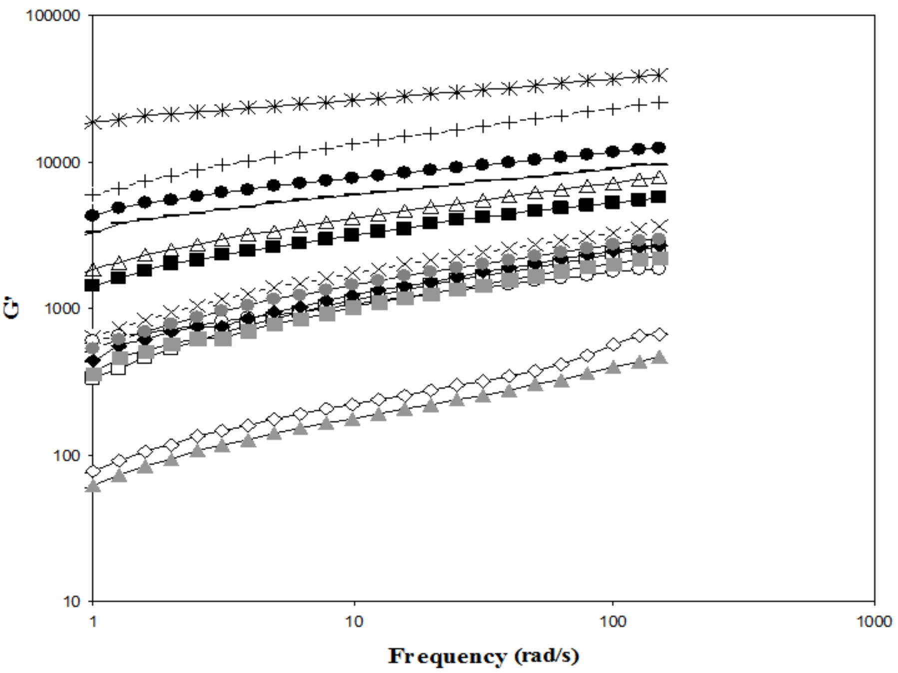

Figure 3.14. Linear viscoelastic modulus (storage modulus) of dough samples containing different chestnut:rice flour ratio (CF:RF) with and without gum blend and emulsifier: (∗): 100:0 CF:RF dough, (+): 40:60 CF:RF+Xanthan+Guar+emulsifier, (−): 50:50 CF:RF, (●): 40:60 CF:RF+Xanthan+LBG+emulsifier, (△): 30:70 CF:RF+Xanthan+Guar+emulsifier, (■): 30:70 CF:RF+Xanthan+LBG+emulsifier, (×): 20:80 CF:RF+Xanthan+Guar+emulsifier, (○): 40:60 CF:RF, (●): 10:90 CF:RF+Xanthan+Guar+emulsifier, (♦): 20:80 CF:RF+Xanthan+LBG+emulsifier, (■): 10:90 CF:RF+Xanthan+LBG+emulsifier, (□): 30:70 CF:RF, (◊): 20:80 CF:RF, (▲): 10:90 CF:RF.

As expected, the highest elastic modulus (G') and viscous modulus (G") values were obtained when only chestnut flour was used. It was found that the viscoelastic properties were directly proportional with the chestnut flour content. There was an increase in both elastic and viscous moduli values with increasing the chestnut flour content. Entanglement of fibers in chestnut flour appears to be responsible for the high elastic moduli values of the dough samples. In general, the addition of the gum blends (xanthan-guar and xanthan-LBG) with emulsifier increased the G' and G" moduli of the dough samples (Figure 3.14 and Figure 3.15). Similar to the flow properties; xanthan-guar blend containing dough had higher elastic and viscous moduli values than xanthan- LBG blend containing ones.

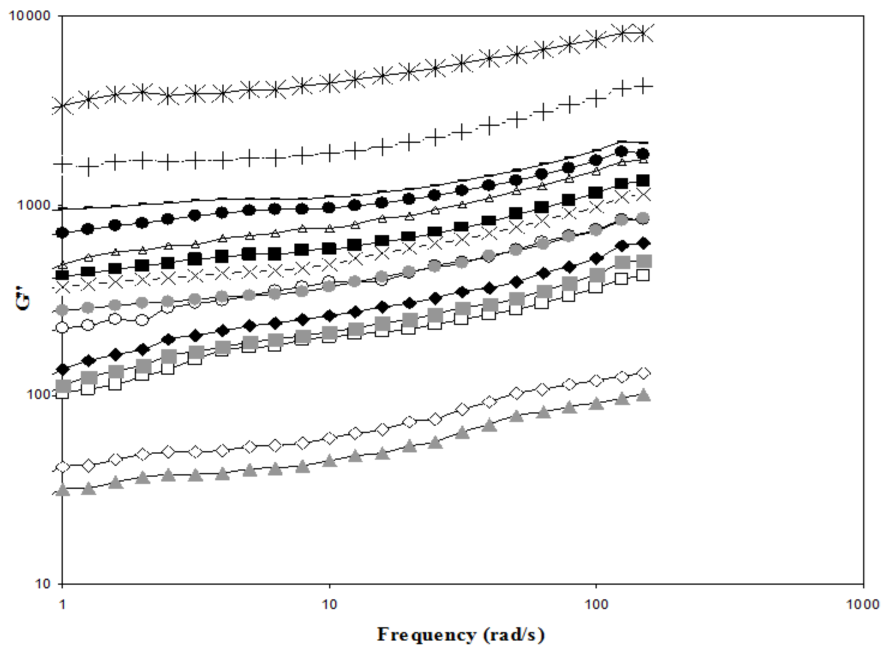

Figure 3.15. Linear viscoelastic modulus (loss modulus) of dough samples different chestnut:rice flour ratio (CF:RF) with and without gum blend and emulsifier: (✳): 100:0 CF:RF dough, (+): 40:60 CF:RF+Xanthan+Guar+emulsifier, (−): 50:50 CF:RF, (●): 40:60 CF:RF+Xanthan+LBG+emulsifier, (△): 30:70 CF:RF+Xanthan+Guar+emulsifier, (■): 30:70 CF:RF+Xanthan+LBG+emulsifier, (×): 20:80 CF:RF+Xanthan+Guar+emulsifier, (○): 40:60 CF:RF, (●): 10:90 CF:RF+Xanthan+Guar+emulsifier, (♦): 20:80 CF:RF+Xanthan+LBG+emulsifier, (■): 10:90 CF:RF+Xanthan+LBG+emulsifier, (□): 30:70 CF:RF, (◊): 20:80 CF:RF, (▲): 10:90 CF:RF.

3.2.2 Baking Tests

Bread samples were evaluated according to their firmness, specific volume and color. When the bread sample was prepared using only chestnut flour, the firmest structure with the lowest volume was observed because of the rigid and compact structure of the fibrous chestnut flour dough (Figure 3.16 and Figure 3.17).

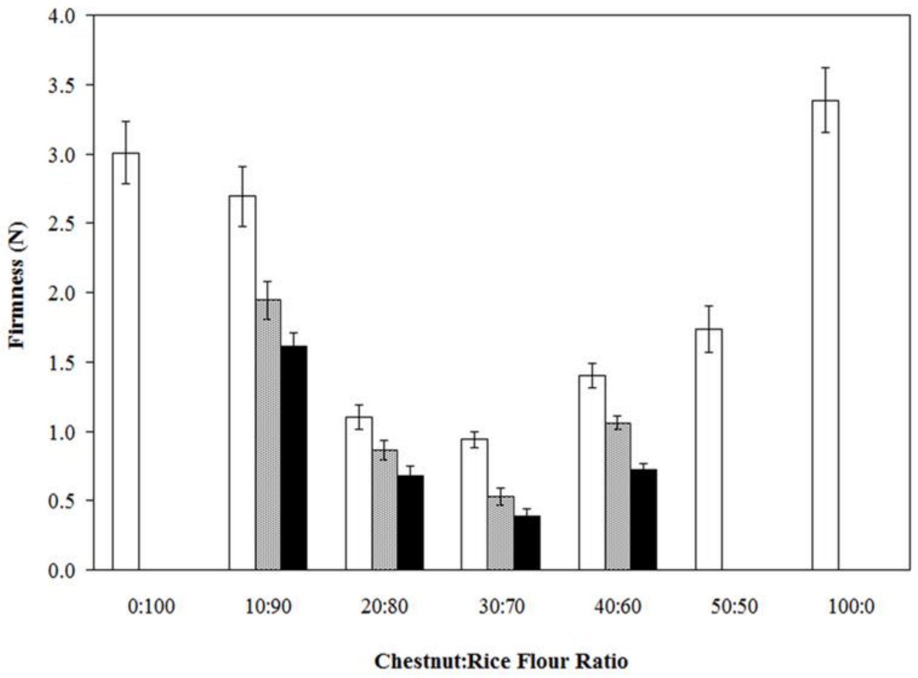

Figure 3.16. Firmness values of bread samples prepared using different chestnut:rice flour ratio with and without gum blend and emulsifier. (white bar): Breads without gum blend and emulsifier, (dotted gray bar): Breads containing Xanthan+LBG+emulsifier, and (black bar): Breads containing Xanthan+Guar+ emulsifier.

Fiber content is known to restrict expansion of the gas cells (Collar et al., 2007). As a result, the finished product has a compact texture as opposed to a cellular structure. This finding was in agreement with several previous studies (Pomeranz et al., 1977; Shogren et al., 1981; Sievert et al., 1990; Gómez et al., 2003; Gómez et al., 2008). The increase in the chestnut flour content decreased the loaf volume but increased the firmness of breads. Relatively high sugar content of the chestnut flour may also hinder or reduce the starch gelatinization during baking leading to low specific volume and firm texture of breads. Sugars are known to delay starch gelatinization by reducing the water activity of the system and the stabilizing the amorphous regions of the starch granule by interacting with starch chains (Sumnu et al., 2000). Thus, breads cannot entrap the gas bubbles leading to lower volume and firmer structure.

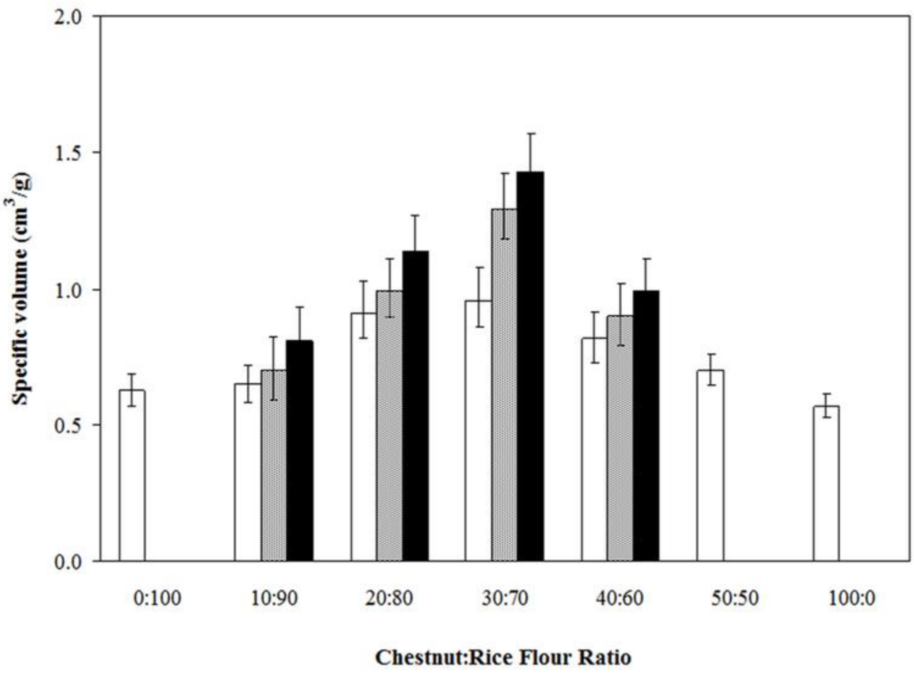

Figure 3.17. Specific volume of bread samples prepared using different chestnut:rice flour ratio with and without gum blend and emulsifier. (white bar): Breads without gum blend and emulsifier, (dotted gray bar): Breads containing Xanthan+LBG+emulsifier, and (black bar): Breads containing Xanthan+Guar+ emulsifier.

As can be seen from Figure 3.16 and Figure 3.17 an optimum flour ratio between chestnut and rice flour was needed to obtain desired quality parameters. As shown, the breads containing chestnut:rice flour ratio at 30:70 was the best in terms of measured quality parameters (Table A. 10-Table A. 13). The fiber content of the chestnut flour may have a critical role in this observation. Several previous studies reported that the presence of fiber may improve quality parameters of bread and other baked products as long as it is less than certain content (Brockmole and Zabik, 1976; Chaplin, 2003; Lebesi and Tzia, 2009). However, if a baked product contains too much fiber its volume and texture properties may be unacceptable. In other words, volume may decrease and texture may become undesirably firm.

Although rice breads had low amount of sugar as compared to chestnut flour, they had also undesirable quality parameters. The absence of fiber, hydrocolloid and emulsifier might prevent the entrapment of air bubbles and holding of water resulting in firm texture and insufficient specific volume (Gallagher et al., 2004; Anton and Artfield, 2008; Nunes et al., 2009).

Two-way ANOVA results showed that addition of gum blends (xanthan–guar and xanthan–LBG) with emulsifier caused a significant increase in the specific volume and decrease in the firmness values of the bread samples ($p \leq 0.05$). (Table A. 13). According to Tukey multiple comparison test, the highest specific volume and the lowest firmness values were obtained for the bread samples containing 30:70 chestnut:rice flour ratio, xanthan-guar and emulsifier (Table A. 10-Table A. 12). The effect of the chestnut:rice flour ratio on the bread color was summarized in Figure 3.18. L^* values of breads decreased but a* value increased as the chestnut flour content increased. There was almost no variation among b* values. The original color of the chestnut flour had darkening effect on the crust bread color. In addition, high sugar content of chestnut flour leads to browning of the crust through Maillard and caramelization reactions during the baking process (Sacchetti et al., 2004; Gómez et al., 2008). Therefore, the characteristic brown color as in the traditional wheat flour bread may be obtained for chestnut flour containing breads.

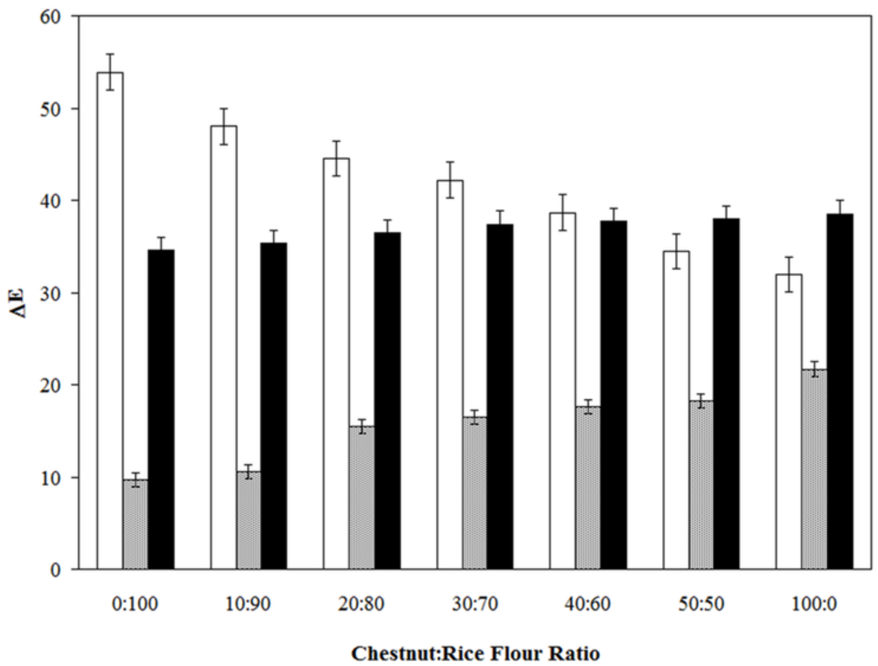

Figure 3.18. Color of breads containing different chestnut:rice flour ratio. (white bar): L*, (dotted gray bar): a* and (black bar): b* value.

The results of sensory analysis of the breads made using chestnut and rice flours are given in Table 3.4. According to the rheological, textural, and colour measurements, the best final product were obtained when the chestnut:rice flour ratio at 30:70 was used. Therefore, breads prepared at this flour ratio with/without additives were tested. The acceptability of breads declined mainly due to more compact texture of the crumb and crack formation occurred in the breads containing only chestnut flour. The highest scores for the texture were obtained when xanthan-guar gum blend and DATEM were used in breads prepared using 30:70 chestnut:rice flour ratio ($p \leq 0.05$) (Table A. 17).

The scores of the sensory evaluation for the flavor showed that the breads containing chestnut:rice flour ratio at 30:70 had higher scores as compared to 100% chestnut bread and 100% rice bread (Table A. 17). Breads prepared by using only chestnut flour had lower flavor score as compared to breads made with chestnut:rice flour ratio of 30:70. This may be due to the off-flavor formation as a result of Maillard reactions. Furthermore, low scores might have also caused by intense chestnut flavor in high chestnut flour containing breads. Sacchetti et al. (2004) found a similar result. Rice breads were not accepted due to the lack of unique taste of chestnut flour. On the other hand, addition of the blends of hydrocolloids and emulsifier did not cause any significant difference ($p \leq 0.05$) in the taste of breads.

Table 3.4. Effects of chestnut:rice flour ratio and addition of gum blend with DATEM on the texture, flavor and color of gluten-free breads. Formulations having different letters (a, b, c and d) are significantly different ($p \leq 0.05$).

Formulation	Texture	Flavor	Color
100:0 CF:RF	2.3 [d]	3.8 [b]	3.2 [b]
0:100 CF:RF	2.1 [d]	2.7 [c]	2.1 [c]
30:70 CF:RF	3.5 [c]	4.3 [a]	4.3 [a]
30:70 CF:RF-X-LBG-E	4.1 [b]	4.4 [a]	4.2 [a]
30:70 CF:RF-X-G-E	4.6 [a]	4.1 [a,b]	4.4 [a]

The crust color of breads was acceptable when they contain chestnut:rice flour ratio at 30:70 with/without additives. Above this ratio, increasing sugar content triggered Maillard and caramelization reactions resulting in undesirable dark the color of the breads. The color of the rice bread was also found to be unacceptable due to their white color as compared to breads containing chestnut flour. When very high chestnut:rice flour ratio was used, intense brown color was observed which was also unacceptable. In addition, the bread surface was cracked.

Considering the color, texture and flavor attributes, using chestnut:rice flour ratio at 30:70 with the addition of the blends of xanthan-guar and emulsifier DATEM in gluten-free bread formulations were found to be the most appropriate combination among the tested formulations (Table A. 10-Table A. 17).

3.3 Optimization of Formulations and Infrared-microwave Combination Baking Conditions of Chestnut-rice Breads

Response surface methodology (RSM) was used to optimize gluten-free bread formulations and processing conditions. Rice flour mixed with different proportions of chestnut flour and different emulsifier contents were used to prepare breads. The relationships between the responses of weight loss, firmness, specific volume and colour change of the breads and independent variables of chestnut:rice flour ratio, emulsifier content, upper halogen lamp powers, microwave powers and baking time were determined by using second order models obtained.

The response variables were fitted to a second-order polynomial model equation in order to correlate the response variables to the independent variables. The general form of the second order polynomial equation was as follows:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2 + b_5X_{55}^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{15}X_1X_5 + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{25}X_2X_5 + b_{34}X_3X_4 + b_{35}X_3X_5 + b_{45}X_4X_5 + \varepsilon \quad (3.3)$$

where Yi's (Y_1-Y_4) are the dependent variables (weight loss, firmness, specific volume, and total color change (ΔE)), X_i's (X_1-X_5) are the independent variables (chestnut:rice flour ratio, emulsifier content, upper halogen lamp power, microwave power and baking time), b_o is the constant coefficient, b_i's (b_1-b_5) are the linear, b_{ii}'s (b_{11}-b_{55}) are the quadratic and b_{ij}'s (b_{12}-b_{45}) are the interactions regression terms and ε is the error.

By applying diagnostic plots, the assumptions of normality, independence and randomness of the residual were fulfilled. Unless the model exhibits an adequate fit, proceeding with exploration and optimization of a fitted response surface may result in misleading (Myers and Montgomery, 2002). Therefore, verifying the model adequacy is essential. To check the normality, normal probability curves of standardized residuals were sketched. The figures obtained from this drawing appeared to be linear. Nevertheless, to obtain definite results, Anderson and Darling normality test was also conducted. The results of these tests showed that the residuals were normally distributed with constant variance.

To test the various correlations against a representative body of available data, predicted values were plotted against the experimental values, the 45° line representing good correlation (Figure 3.19). High regression coefficients were calculated between the experimental and predicted data.

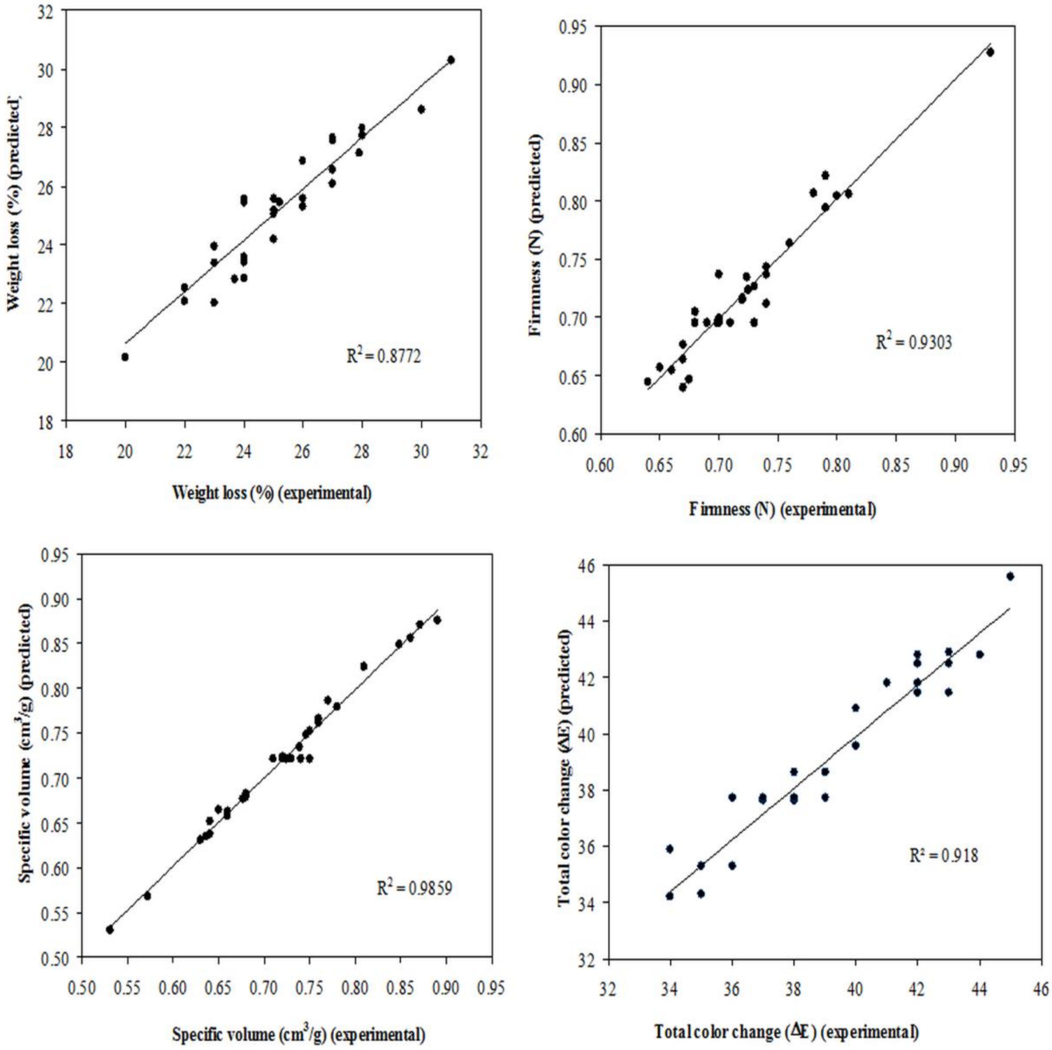

Figure 3.19. Comparison of predicted and experimental values of depemdent variables for gluten-free breads made of chestnut and rice flours a- Weight loss b- Firmness c- Specific volume d- Total color change (ΔE).

Table 3.5 shows the final model equations. The value of the coefficient of determination (R^2_{adj}) for the responses ranged between 0.794 and 0.998 which indicated high significance of the models.

Table 3.5. Regression equations for breads containing different formulations baked using different processing conditions in infrared-microwave combination oven.

Quality parameter	Equation	R^2 adj
Weight loss (%)	$Y_1 = 25.5792 - 0.8583X_1^{***} - 0.3583X_2 + 1.0831X_3^{***} + 1.5167X_4^{***} + 0.9917X_5^{***} - 0.4604X_1^{2**} - 0.4750X_1X_3 + 0.6250X_1X_4^{**} - 0.6X_2X_4^{*}$	0.835
Firmness (N)	$Y_2 = 0.6958 - 0.0041X_1^{*} - 0.0029X_2 + 0.0095X_3^{***} + 0.0204X_4^{***} + 0.0194X_5^{***} + 0.0098X_1^{2***} + 0.0260X_2^{2***} + 0.0062X_1X_2^{**} + 0.0087X_1X_4^{***} + 0.0343X_2X_3^{***} + 0.0268X_2X_4^{***} + 0.0187X_2X_5^{***} + 0.0319X_3X_4^{***} + 0.0150X_3X_5^{***} + 0.0112X_4X_5^{***}$	0.978
Specific vol. (cm^3/g)	$Y_3 = 0.7219 + 0.0771X_1^{***} + 0.0323X_2^{***} - 0.0198X_3^{***} - 0.0215X_4^{***} - 0.0288X_5^{***} - 0.0124X_4X_5^{***}$	0.983
Color change (ΔE^*)	$Y_4 = 37.7221 + 0.9167X_1^{***} + 2.8330X_3^{***} + 1.0417X_2^{2***}$	0.894
Cohesiveness	$Y_5 = 0.4719 + 0.0075X_1^{*} - 0.0322X_2^{**} + 0.0068X_3^{**} + 0.0035X_4 + 0.0136X_5^{***} + 0.0321X_2^{2***} - 0.0322X_1X_2^{**} + 0.0133X_1X_5^{**} - 0.0156X_2X_3^{*} - 0.0147X_2X_4^{*} - 0.0299X_2X_5^{***} - 0.0293X_3X_4^{***} - 0.0143X_3X_5^{*} - 0.0171X_4X_5^{*} - 0.0043X_5^{2*}$	0.794
Springiness (mm)	$Y_6 = 3.8107 + 0.0017X_1 - 0.1282X_2^{**} + 0.0345X_3 + 0.0149X_4 + 0.1449X_5^{***} + 0.0323X_1^{2*} + 0.2054X_2^{2***} - 0.1955X_1X_2^{***} - 0.0647X_1X_3^{*} + 0.1674X_1X_5^{***} - 0.0643X_2X_4^{*} - 0.2511X_2X_5^{***} - 0.2452X_3X_4^{***} - 0.0837X_3X_5^{**} - 0.0076X_4X_5^{**} - 0.0552X_5^{2***}$	0.936
Chewiness (N mm)	$Y_7 = 1.3469 + 0.0269X_1^{***} - 0.2835X_2^{***} + 0.0445X_3^{***} + 0.0256X_4^{***} + 0.0739X_5^{***} + 0.0419X_1^{2***} + 0.2722X_2^{2***} - 0.0065X_3^{2**} - 0.0166X_4^{2***} - 0.0309X_5^{2***} - 0.4384X_1X_2^{***} - 0.1670X_1X_3^{***} - 0.0125X_1X_4^{*} + 0.0848X_1X_5^{***} - 0.0604X_2X_3^{***} - 0.2127X_2X_4^{***} - 0.3093X_2X^{5***} - 0.2834X_3X_4^{***} - 0.1280X_3X_5^{***} - 0.2275X_4X_5^{***}$	0.998
Adhesiveness	$Y_8 = -0.0155 + 0.0009X_1 - 0.0012X_2^{**} + 0.0005X_3^{***} + 0.0001X_4 + 0.0002X_5^{*} + 0.0004X_1^{2***} + 0.0010X_2^{2***} - 0.0016X_1X_2^{***} - 0.0006X_2X_3^{*} - 0.0008X_2X_4^{**} - 0.0009X_2X_5^{**} - 0.0008X_3X_4^{**} - 0.0007X_3X_5^{**} - 0.0009X_4X_5^{***}$	0.848

*Significant at $p \leq 0.05$; **Significant at $p \leq 0.01$; ***Significant at $p \leq 0.001$

All the independent factors, except emulsifier content, significantly affected the weight loss of breads (Table 3.5). The effects of baking time and microwave power on the weight loss of breads are illustrated in Figure 3.20.

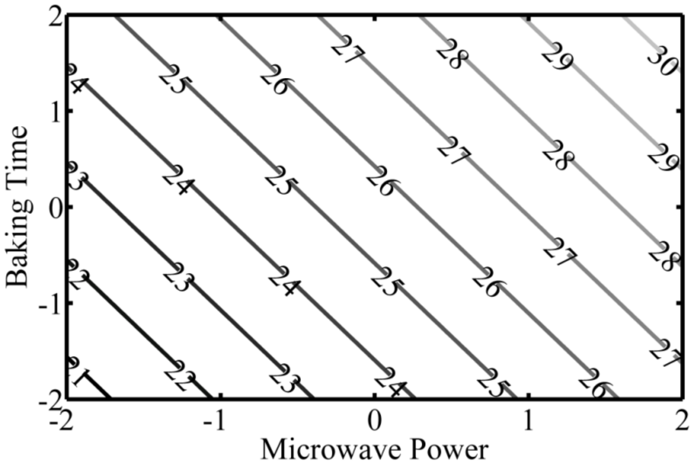

Figure 3.20. Variation of weight loss of the gluten-free breads with microwave power *(X_4)* and baking time *(X_5)* when X_1, $X_2$and $X_3 = 0$.

As the baking time and the microwave power increased, the weight loss of breads increased. Microwave power was more effective on weight loss of breads in comparison to the baking time. This finding is in agreement with a previous study in which the microwave power was found to be the dominant factor on the weight loss of wheat breads during the infrared-microwave combination baking (Keskin et al., 2004). As the microwave power increased, a greater interior pressure and concentration gradient occurred in the food which led to an increase in the drawing of liquid through the food boundary (Datta, 1990). Weight loss of breads increased also with increase in infrared powers (Table 3.5). With increasing infrared powers, breads were exposed to more radiative heat and the higher pressure gradient resulting in higher rate of removal of moisture from the bread samples.

As shown in Figure 3.21, weight loss of breads decreased as chestnut:rice flour ratio increased, but it increased with the baking time. The decrease in weight loss of breads with the increasing chestnut:rice flour ratio may be probably due to an increase in the fiber content of chestnut flour. Since fiber has water binding ability, the weight loss of breads decreased as more fiber was available in the formulations.

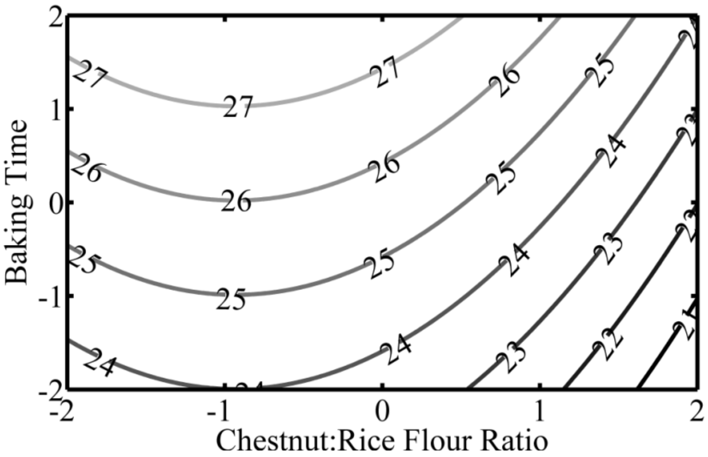

Figure 3.21. Variation of weight loss of the gluten-free breads with chestnut:rice flour ratio *(X_1)* and baking time *(X_5)* when X_2, $X_3$and X_4 = 0.

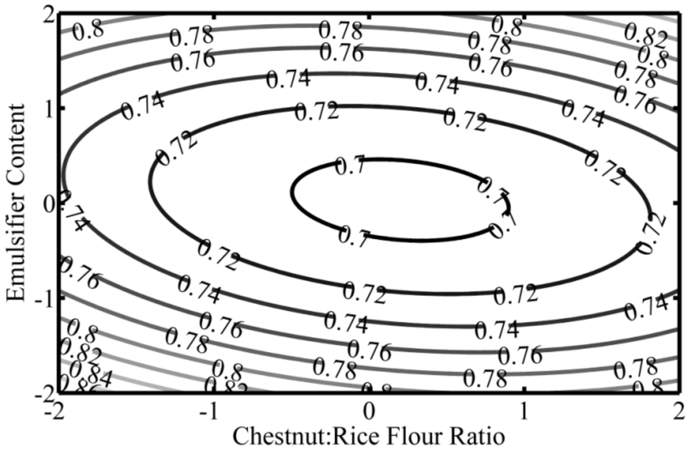

Figure 3.22. Variation of firmness of the gluten-free breads with chestnut:rice flour ratio *(X_1)* and emulsifier content *(X_2)* when X_3, X_4 and X_5= 0.

Because of the lack of fiber, rice breads (chestnut:rice flour ratio of 0:100, which corresponds to a coded value of -2) could not entrap the air bubbles and hold moisture resulting in a firmer texture (Figure 3.21 and Figure 3.22). Using chestnut and rice flour together in the formulation provided more viscous dough and in consequence a softer structure. Firmness values decreased with increasing chestnut: rice flour ratio up to a coded level of approximately 0, which corresponds to the 40:60 chestnut:rice flour ratio. However, the firmness values increased after this point which may be due to the high fiber content of chestnut flour. There is an optimum concentration for using chestnut flour in gluten-free breads. When chestnut flour content exceeded the optimum level, firmer texture was obtained. Similar to the chestnut:rice flour ratio, there was an optimum value for emulsifier content in terms of firmness of breads (Figure 3.22). High and low concentrations of DATEM resulted in firmer structure. This finding was in agreement with the previous attempts of determination of the optimum amount of DATEM in wheat based products (Swanson et al., 1999; Chin et al., 2007).

Microwave power, infrared power and baking time were the most significant factors for bread firmness (Table 3.5). The increase in bread firmness with respect to time may be explained by the increase in weight loss during the baking process. This finding is in agreement with the previous study of Demirekler et al. (2004).

The cohesiveness, springiness, chewiness and adhesiveness data of gluten-free breads were also modeled. For these quality parameters, second order models were fitted and high coefficient of determination values were observed (R^2 adj = 0.794-0.998) (Table 3.5).

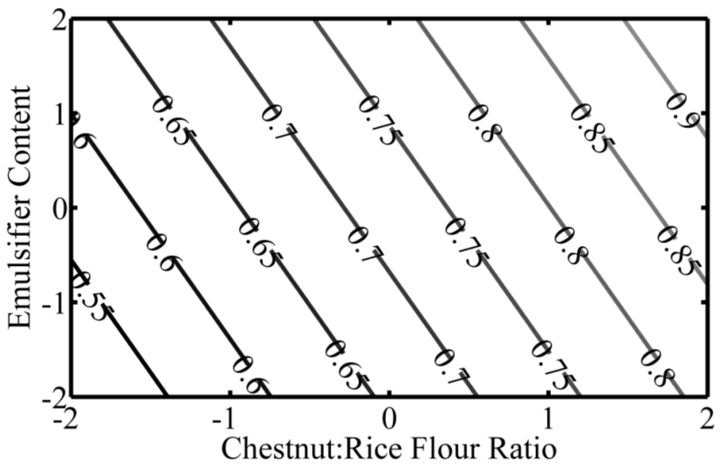

Figure 3.23. Variation of specific volume of the gluten-free breads with chestnut:rice flour ratio *(X_1)* and emulsifier content *(X_2)* when X_3, X_4 and $X_5 = 0$.

All of the independent factors were found to be significant on the affecting specific volume of breads (Table 3.5). As the chesnut:rice flour ratio and emulsifier content increased, specific volume of the breads increased (Figure 3.23). Such an increase in loaf volume may be explained by the gas retention capacity of the fiber. Rice breads (coded value of -2) had very low specific volume due to the absence of fiber. Emulsifiers are responsible from aeration of the aqueous phase and stabilization of expanding gas bubbles in the dough during baking. Therefore, higher specific volume values were promoted by the addition of emulsifiers.

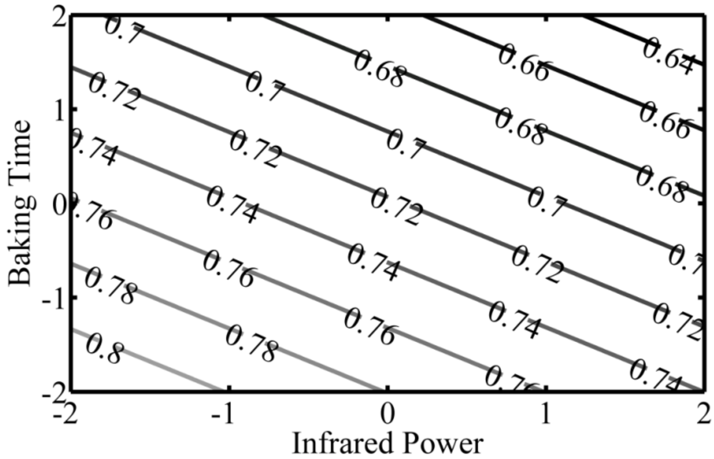

Figure 3.24. Variation of specific volume of the gluten-free breads with infrared power *(X_3)* and baking time *(X_5)* when X_1, X_2 and X_4= 0.

The specific volume of breads decreased, as baking time and infrared power increased Table 3.5 and Figure 3.24). It is well known that near infrared radiation provides low penetration depth and concentrates radiation at the surface of the product resulting in high surface temperature (Keskin et al., 2004). Such a high surface temperature leads to immediate crust formation and retardation of expansion of breads leading to low volume. Therefore, higher infrared power levels resulted in lower specific volume values of breads due to the sudden crust formation. The decrease in specific volume of breads with increasing baking time may be explained by the shrinkage of breads.

It can be seen from the model equation that ΔE* values of breads changed significantly with change in chestnut:rice flour ratio and infrared power (Table 3.5). On the other hand, microwave power, emulsifier content and time did not have significant effect on the ΔE* values of breads (Table 3.5). As microwave power did not have any effect on the ambient air temperature and accordingly on the surface temperature of breads, the increase in microwave power did not affect bread colors significantly.

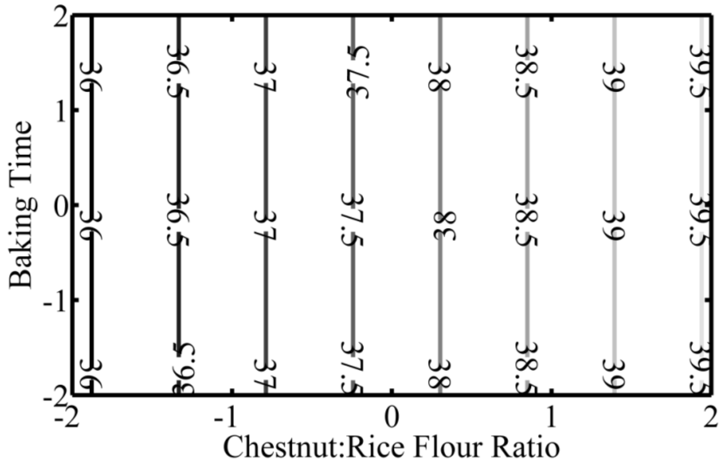

Figure 3.25. Variation of ΔE of the gluten-free breads with chestnut:rice flour ratio *(X_1)* and baking time *(X_5)* when X_2, X_3 and X_4= 0.

Figure 3.25 shows the significant effect of chestnut flour on the color of breads. The increase in ΔE* values of breads with the addition of chestnut flour may be explained mainly by browning reactions. Since more sugar was available in formulation that led to formation of brown pigments through Maillard and caramelization reactions. The natural dark color of chestnut flour might also be effective on the ΔE* values of breads. Time did not have any significant effect on ΔE* value of the breads (Figure 3.25).

The effect of time on browning might be suppressed by the significant effect of infrared power on the color of breads. Even in shorter times, browning reactions could occur in the presence of infrared powers. The increase in bread colour, as infrared power increased, can be seen in Figure 3.26. Bread darkening due to infrared power which causes higher surface temperature was also reported by other researchers (Demirekler et al., 2004; Keskin et al., 2004). It is also important to note that the browning of breads by either by infrared power or chestnut flour was desirable in gluten–free breads since most of the gluten-free products have a lighter color than traditional gluten containing products.

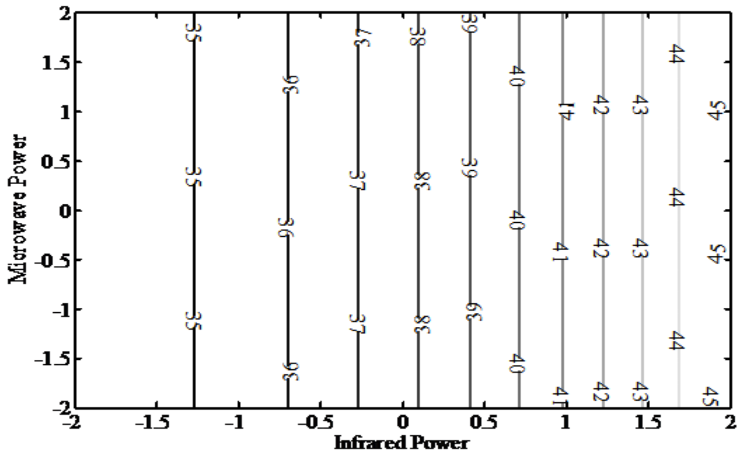

Figure 3.26. Variation of ΔE of the gluten-free breads with infrared power *(X_3)* and microwave power *(X_4)* when X_1, X_2 and X_5= 0.

To find the optimum point, a Matlab program was written by considering a maximum specific volume and a minimum weight loss and a constraint of firmness (0.25-0.75) and ΔE* values (31-39). Optimum values were shown in Table 3.6.

Table 3.6. The optimum coded and rounded uncoded values of the baking conditions and formulations in infrared-microwave combination oven for gluten-free breads.

Independent variables	Optimum coded value	Optimum rounded uncoded value
Chestnut:rice flour ratio	0.33	46.50
Emulsifier content (%)	0.46	0.62
Infrared power (%)	-2	40
Microwave power (%)	-2	30
Time (min)	-2	9

Response values for the gluten-free breads baked in the infrared-microwave combination oven was calculated and shown in Table 3.7. To make a comparison, breads formulated by 0.5% emulsifier and 30:70 chestnut to rice flour ratio and wheat bread prepared without any gum and emulsifier were also baked in the conventional oven.

Table 3.7. Response values for the gluten-free breads (containing chestnut flour, rice flour and xanthan-guar gum blend) baked in infrared-microwave combination oven and conventional oven and for wheat breads baked in conventional oven at the optimum conditions

Response variables	Infrared-microwave combination baking	Conventional baking	Conventional baking
	Gluten-free breads	Gluten-free breads	Wheat bread
Weight loss (%)	18.50	8.51	9.32
Firmness (N)	0.75	0.48	0.85
Specific volume (cm^3/g)	0.85	0.48	0.75
Total color change (ΔE)	35.00	37.30	31.06
Cohesiveness	0.29	0.39	0.56
Springiness (mm)	3.98	3.61	3.26
Chewiness (Nmm)	0.47	0.58	1.41
Adhesiveness	0.02	0.02	0.01

Gluten-free breads containing 46.5% chestnut flour and 0.62% emulsifier baked at 40% infrared and 30% microwave power for 9 min had comparable firmness, specific volume, and color values with conventionally baked ones. In addition, conventional baking time of gluten-free breads was reduced by 64% when infrared-microwave combination oven used. However, higher moisture loss was obtained in infrared-microwave combination oven. The firmness and color of optimized gluten-free breads were also not significantly different than those of conventionally baked wheat breads (Table 3.7). However, wheat breads lost less moisture. In addition, wheat breads had higher specific volume as compared to optimized gluten-free breads. This is an expected result since whatever ingredient is added to gluten-free formulations; it is not possible to reach the same volume of wheat breads due to the viscoelastic property of gluten. However, our aim was to design gluten-free chestnut-rice bread formulations to be baked in infrared-microwave combination oven having comparable quality with conventionally baked gluten-free breads not with wheat breads.

3.4 Bread Quality of Gluten-free Tigernut-rice Bread Formulations

The effects of different tigernut:rice flour ratios (0:100, 5:95, 10:90, 15:85, 20:80 and 25:75) on quality of gluten-free bread formulations baked in infrared-microwave combination and conventional ovens were determined.

The weight loss of breads baked in conventional and infrared-microwave combination ovens are shown in Figure 3.27. Significantly higher weight losses were obtained for breads baked in infrared-microwave combination oven (16.3±1.12%-28.7±1.73%) as compared to the ones baked conventionally (7.7±0.91%-13.8±1.60%) ($p \leq 0.05$) (Figure 3.27) (Table A. 18). This is similar to the results obtained in Table 3.7. When bread formulations were compared, the highest weight loss was obtained in %100 rice breads. The absence of fiber in rice breads resulted in high weight loss. However, partial replacement of rice flour by tigernut flour (from 0:100 to 20:80) significantly decreased the weight loss of breads baked in infrared-microwave combination oven ($p \leq 0.05$). This is similar to the results obtained by chestnut flour (Figure 3.21). Tigernut flour addition was effective up to 10% in conventionally baked breads ($p \leq 0.05$). The reduction in the weight loss of breads (from 13.8±1.60% to 7.7±0.91%) with increasing tigernut:rice flour ratios (from 0:100 to 10:90) may be probably due to the increase in fiber contents of the formulations since the hydroxyl groups of fiber molecules allow water interaction (Sabanis et al., 2009). Many studies investigated to determine the functionality of fiber on the quality of baked products and it was reported that the quality of products may be improved by addition of certain amount of fiber (Pomeranz et al., 1977; Sabanis et al., 2009). It was also found that substitution of a certain amount of flour such as tigernut flour (Ade-Omowaye et al., 2008; Chinma et al., 2010) may enhance the quality of wheat products due to their fiber content.

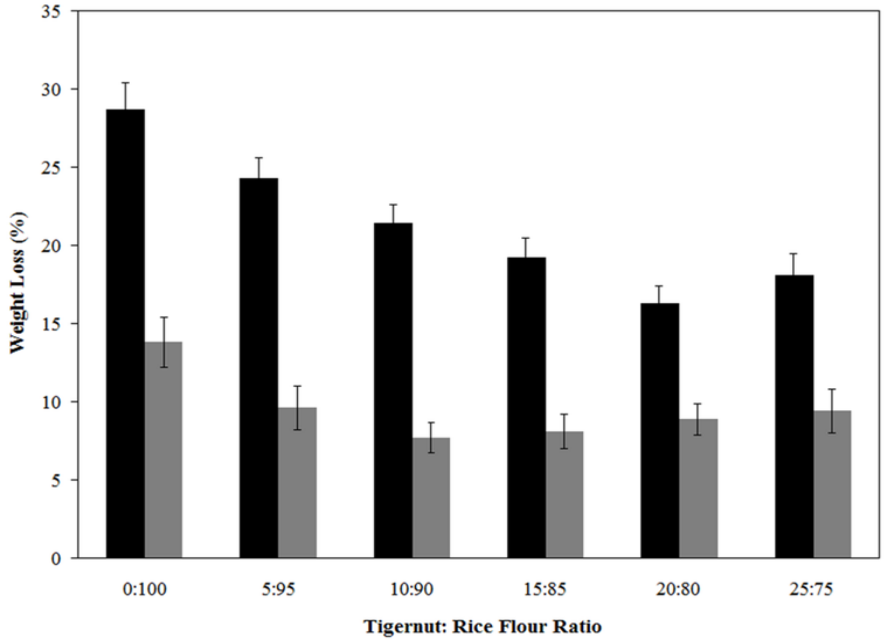

Figure 3.27. Weight loss of breads containing different tigernut:rice flour ratios and baked in conventional (gray bar) and infrared-microwave combination oven (black bar).

Change in firmness and specific volume of breads containing different tigernut:rice flour ratios and baked in conventional and infrared-microwave combination ovens are shown in Figure 3.28 and Figure 3.29, respectively.

As shown in Figure 3.28, breads baked in infrared-microwave combination oven had significantly higher firmness values than the ones baked in conventional oven ($p \leq 0.05$) (Table A. 19). Generally, firmer texture of breads baked in combination oven may be explained by the higher moisture loss of these products (Figure 3.27) which is in agreement with the previous study of Sumnu et al. (2005). Breads baked in both conventional (1.08 ± 0.06–1.32 ± 0.09 cm^3/g) and infrared– microwave combination (0.95±0.07–1.35±0.08 cm3/g) oven had similar specific volume values (Figure 3.29).

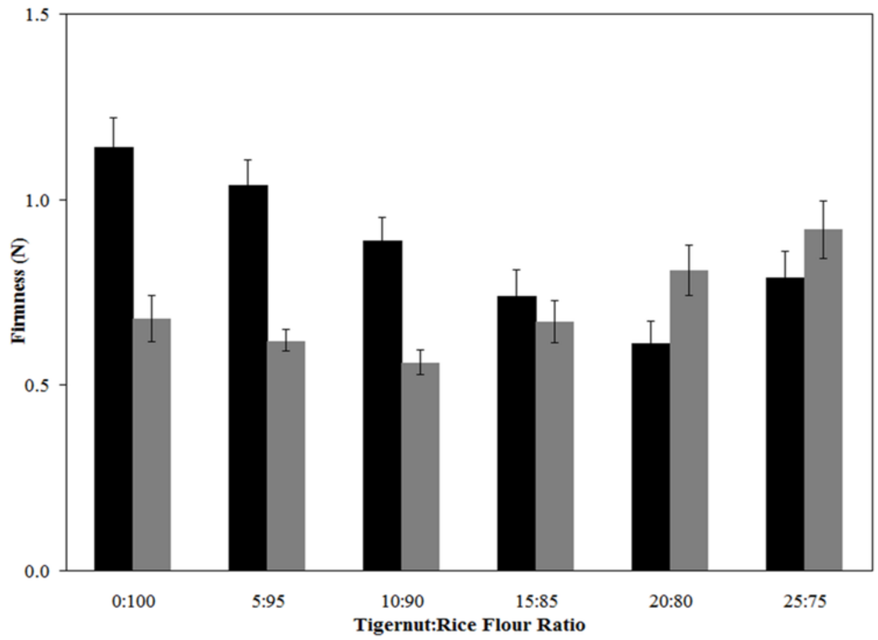

Figure 3.28. Firmness of breads containing different tigernut:rice flour ratios and baked in conventional (gray bar) and infrared-microwave combination oven (black bar).

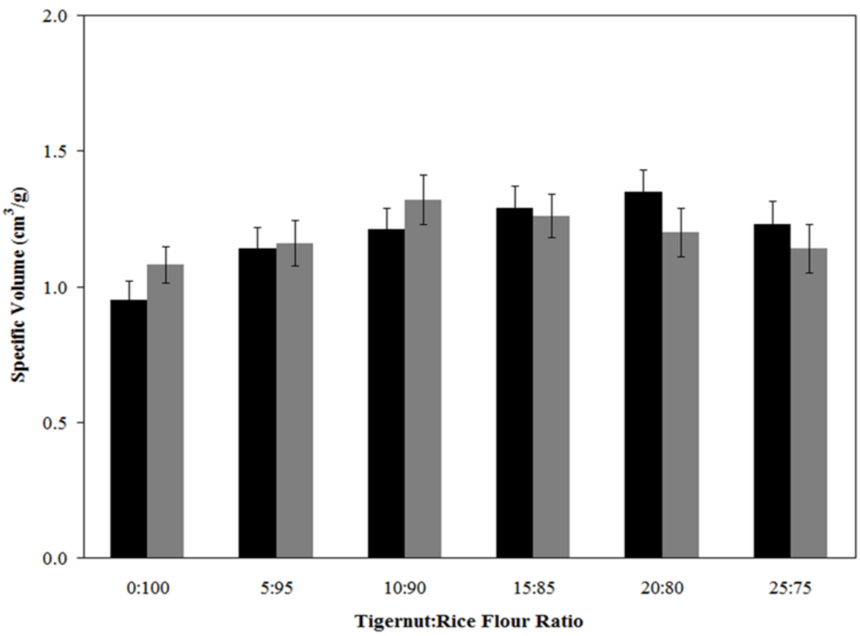

Figure 3.29. Specific volume of breads containing different tigernut:rice flour ratios and baked in conventional (gray bar) and infrared-microwave combination oven (black bar).

When different formulations were compared, rice breads had the firmest texture and lowest specific volume in both infrared-microwave combination and conventional ovens (Figure 3.28-Figure 3.29). This shows that rice dough structure can not retain CO_2 during mixing and proofing.

The lowest volume of rice breads can also be seen in Figure 3.30 a and b. However, partial replacement of rice flour with tigernut flour significantly improved the quality of gluten-free breads ($p \leq 0.05$) (Figure 3.30 c and d) (Table A. 20). In other words, the volume was increased and texture became softer by means of tigernut flour substitution because fiber content of tigernut flour improved gas retention and water holding abilities to dough. In addition to fiber, fat might have an important role in the enhancement of bread quality. Oil has a plasticizing effect on the viscoelastic properties of dough since it has an ability to reduce the concentration of entanglements tending to a temporary network structure (Fu et al., 1997). This plasticizing effect of fat has a strong ability on dough's development and rheological properties as well as bread quality. Tigernut flour contains higher amount of fat (20.5%) compared to rice flour (2.1%), so substitution of a certain amount of tigernut flour resulted in improvement of volume and texture of breads.

As can be seen in Figure 3.27-Figure 3.29, for conventionally baked breads tigernut:rice flour ratio of 10:90 (weight loss, firmness and specific volume values were 7.7±0.91%, 0.56± 0.03 N, 1.32±0.09 cm3/g, respectively) and for infrared-microwave combination baked breads tigernut:rice flour ratio of 20:80 (weight loss, firmness and specific volume values were 16.3±1.12%, 0.61± 0.06 N, 1.35±0.08 cm^3/g, respectively) were the most acceptable in terms of measured quality parameters. If higher concentration of tigernut flour was used, a greater increase of consistency of dough formulations restricted expansion of gas cells resulting in firmer texture and lower specific volume. This was also observed by other researchers when higher concentration of fiber was added to gluten-free formulations (Sabanis et al., 2009; Sciarini et al., 2010a).

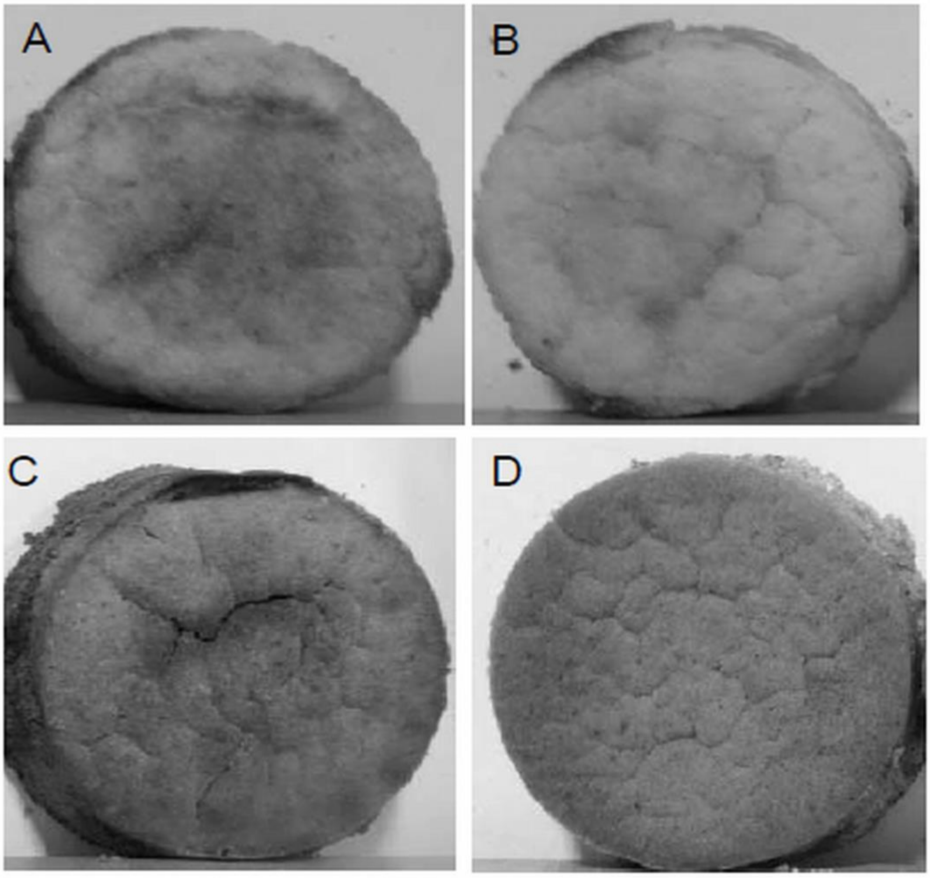

Figure 3.30. Bread samples, a- conventionally baked breads containing 0:100 tigernut:rice flour ratio, b- infrared-microwave combination baked breads containing 0:100 tigernut:rice flour ratio, c- conventionally baked breads containing 10:90 tigernut:rice flour ratio, d- infrared-microwave combination baked breads containing 20:80 tigernut:rice flour ratio.

Figure 3.31 shows the effects of different tigernut:rice flour ratios and baking methods on crust color of breads.

According to two-way ANOVA, both baking method and tigernut:rice flour ratio significantly affected ΔE^* values of bread crust (Table A. 21). Although crust of conventionally baked breads had significantly higher ΔE^* values compared to the infrared-microwave combination baked breads ($p \leq 0.05$), conventionally baked breads containing 10:90 tigernut:rice flour ratio ($\Delta E^*=43\pm1.17$) and infrared-microwave combination baked breads containing 20:80 tigernut:rice flour ratio (ΔE^*=42.3±1.67) had similar ΔE^* values.

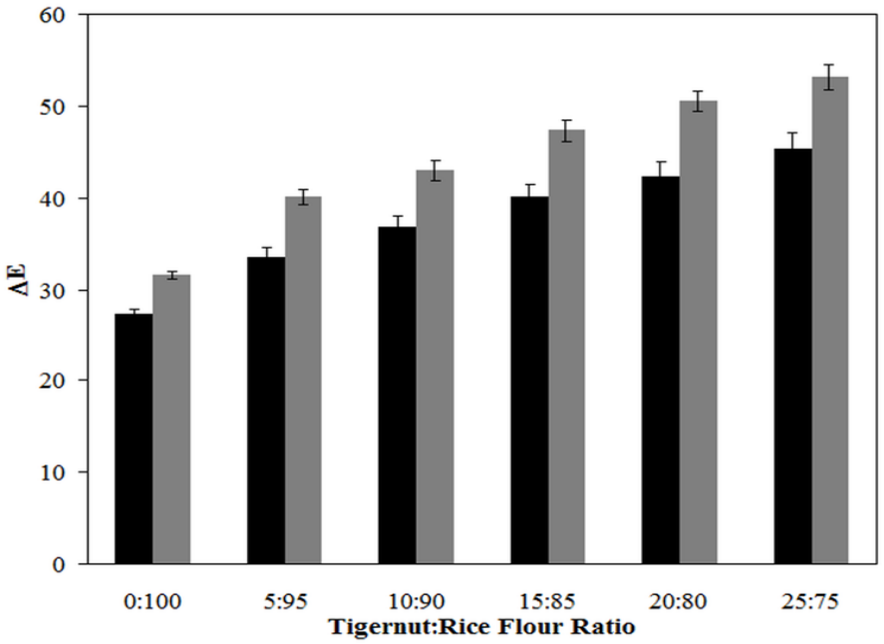

Figure 3.31. Crust color values of breads containing different tigernut:rice flour ratios and baked in conventional (gray bar) and infrared-microwave combination oven (black bar).

ΔE^* values of crust of breads increased with the addition of tigernut flour. This may be due to the fact that as the tigernut:rice flour ratio increased, more sugar was available in formulation that promoted the formation of brown pigments through Maillard and caramelization reactions. Another possible reason might be the natural dark color of tigernut flour. Thus, bread formulations prepared using relatively dark flours may be an alternative to eliminate generally encountered crust color problem of gluten-free breads since most of gluten-free breads have a lighter color compared to wheat based ones.

3.5 Effects of Different Gums, Gum Blends and DATEM mixture and Flour Types on Macro- and Micro-structure of Breads

The influences of different gums (xanthan, guar, locust bean (LBG), agar, methylcellulose (MC), carboxymethylcellulose (CMC) and hydroxypropyl methylcellulose (HPMC)) or gum blends (xanthan-guar and xanthan-LBG) addition on crumb structure of gluten-free rice breads baked in conventional oven were pointed out by using X-ray microtomography. Moreover, the effects of chestnut flour and xanthan–guar gum blend–emulsifier DATEM mixture addition on macro- and microstructure of rice breads baked in conventional and infrared–microwave combination ovens were investigated by using the images obtained by a scanner and scanning electron microscopy (SEM). Porosity, number of pores, average size of pores, aspect ratio of pores and roundness of pores were used as parameters to describe the internal structure.

3.5.1 Effects of Different types of Gums, Gum Blends and DATEM mixture on Microstructure of Rice Breads

2D and 3D X-ray μCT images of gluten-free bread samples prepared with the addition of different gum or different gum blends are presented in Figure 3.32 and Figure 3.33. The interaction between hydrocolloids and emulsifiers assists water absorption and CO_2 retention ability of dough during mixing and proofing and provides stability to the dough during baking. Thus, hydrocolloids and emulsifiers are able to modify both dough rheology and bread quality by providing higher viscosity and viscoelastic properties to dough and giving more homogenous crumb structure (Figure 3.32 and Figure 3.33).

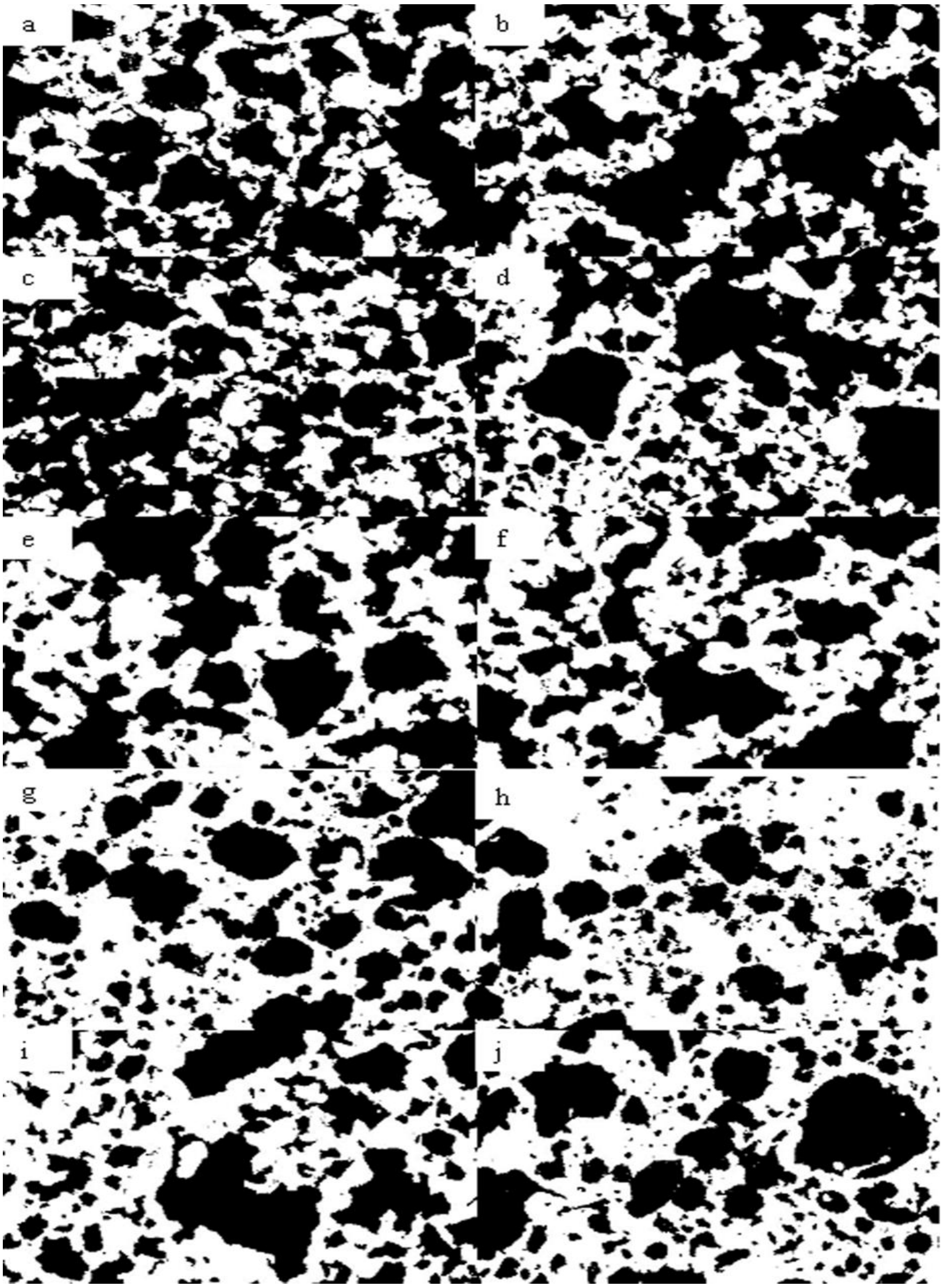

Figure 3.32. 2D X-ray μCT images of gluten-free rice bread slices prepared with different gums or gum blends. a-Control breads, b-Breads prepared with methylcellulose, c-Breads prepared with agar, d-Breads prepared with locust bean, e-Breads prepared with guar, f-Breads prepared with xanthan, g-Breads prepared with carboxymethylcellulose, h-Breads prepared with hydroxypropylmethylcellulose, i-Breads prepared with xanthan-locust bean gum blend, j-Breads prepared with xanthan-guar gum blend.

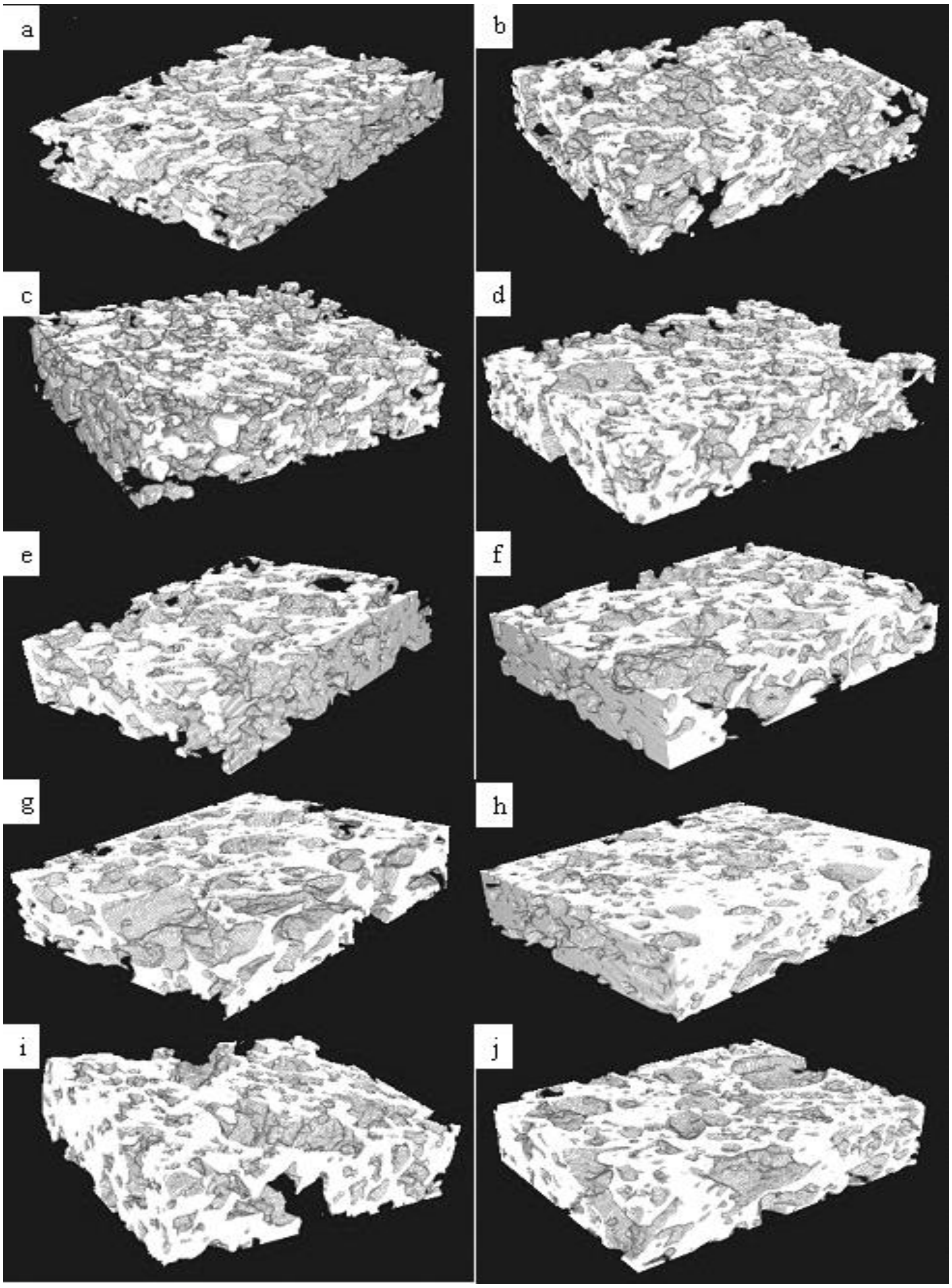

Figure 3.33. 3D X-ray μCT images of gluten-free rice bread samples prepared with different gums or gum blends. a-Control breads, b-Breads prepared with methylcellulose, c-Breads prepared with agar, d-Breads prepared with locust bean, e-Breads prepared with guar, f-Breads prepared with xanthan, g-Breads prepared with carboxymethylcellulose, h-Breads prepared with hydroxypropylmethylcellulose, i-Breads prepared with xanthan-locust bean gum blend, j-Breads prepared with xanthan-guar gum blend.

Crumb structure of breads prepared with MC and agar showed similarity with control bread crumb structure. Pores within the food materials can be classified as closed pores that are closed from all sides, blind pores that with one end closed, open pores where the flow characteristically takes places (Sahin and Sumnu, 2006; Datta et al, 2007). As depicted in Figure 3.32a-c and Figure 3.33a-c, control breads and breads prepared with MC and agar had a very open sponge-like structure. As compared to crumb structures of other breads, the higher amounts of pores in these breads were interconnected with other pores that indicated their heterogeneous structure with lots of void spaces (open pores). The types of pores and the distribution of pores greatly affected appearance of crumb structure, hence quality of breads (Datta et al., 2007). In a very recent study of Wang et al. (2011), the critical role of open and closed pores on the shape and texture of bakery products have been reported. It has been stated that non-uniform distribution of open pores as well as wide distribution of closed cells in breads might cause the total or partial collapse of breads when they are taken out of the oven. The role of the viscosity and viscoelastic properties on crumb structure cannot also be ignored. Our previous findings demonstrated that in the lack of additives, the viscoelastic properties of control rice dough was not high enough to provide sufficient bubble stability during fermentation and baking process (Figure 3.7 and Figure 3.11). Thus, control rice breads had undesirable appearance with non-uniform crumb structure and very large pores. It was visually observed that neither MC nor agar was capable of providing high viscosity and viscoelastic structure to dough during mixing. This might be the other reason for their undesirable, heterogeneous crumb appearance with non-uniformly distributed void spaces (Figure 3.32 a-c and Figure 3.33 a-c). In the presence of additives except MC and agar, gluten-free breads had relatively finer crumb structure with their smaller pores (Figure 3.32 a-c and Figure 3.33 a-c). The presence of relatively higher number of small pores might be provided by the capture of more gas bubbles and moisture in their closed pores (Figure 3.32 d-j and Figure 3.33 d-j). In addition, the presence of these additives might have provided sufficient viscosity and viscoelastic properties to dough samples that provided bubble capture and stability during baking (Mettler and Seibel, 1993; Guarda et al., 2004; Lazaridou et al., 2007; Sciarini et al., 2010b).

Porosity, number of pores, averages size of pores, aspect ratio and roundness values of pores were also studied with X-ray μCT (Table 3.8 and Table 3.9). One-way ANOVA results showed that porosity, number of pores and averages size of pores were significantly affected by the addition of different gums ($p \leq 0.05$), while the differences in aspect ratio and roundness values of pores for breads prepared with different formulations were found to be not statistically different (Table A. 22-Table A. 26). Recent studies have showed that porosity measurement is not a property that can be used to describe pore structure since it does not give any information about whether pores are distributed homogenously or heterogeneously (Falcone et al., 2004; Gonzales-Barron and Butler, 2008). However, appearance of bread crumb can be efficiently quantified and qualified by X-ray μCT since it gives more detailed inside information about homogeneity and fineness of crumb structure by providing 2-D or 3-D images.

Table 3.8. Porosity of the gluten-free rice bread samples prepared with different gum or gum blends of identical size (~ 0.688cm^3). Formulations having different letters (a, b and c) are significantly different ($p \leq 0.05$).

Gluten-free bread samples	Porosity
Control	0.568[a]
MC[d]	0.629[a]
A[e]	0.602[a]
LBG[f]	0.539[b]
G[g]	0.510[b]
X[h]	0.453[c]
CMC[i]	0.471[c]
HPMC[j]	0.382[c]
X-LBG	0.502[c]
X-G	0.423[c]

[d]Methylcellulose, [e]Agar, [f]Locust bean gum, [g]Guar gum , [h]Xanthan, [i]Carboxymethylcellulose, [j]Hydroxypropyl methylcellulose

Table 3.9. Quantification of the porous structure per slice thickness (0.036mm) of the gluten-free rice bread samples prepared with different gums or gum blends. Formulations having different letters (a, b and c) are significantly different ($p \leq 0.05$).

Gluten-free bread samples	Number of pores per 1.85cm^2 area	Aspect ratio of the pore	Roundness of the pore	Average size of the pore (cm^2)
Control	8.56[c]	1.810[a]	0.597[a]	0.165[a]
MC	5.10[c]	1.782[a]	0.609[a]	0.298[a]
A	3.99[c]	1.723[a]	0.637[a]	0.478[a]
LBG	11.0[b]	1.909[a]	0.583[a]	0.088[b]
G	11.4[b]	1.949[a]	0.559[a]	0.083[b]
X	13.9[a]	1.942[a]	0.577[a]	0.055[c]
CMC	15.5[a]	1.835[a]	0.597[a]	0.050[c]
HPMC	14.3[a]	1.814[a]	0.601[a]	0.040[c]
X-LBG	12.3[a]	1.890[a]	0.583[a]	0.071[b]
X-G	14.4[a]	1.855[a]	0.592[a]	0.047[c]

Analysis was done in duplicate. Pores > 0.01 cm^2 considered. Values are means of 100 slices.

As shown in Table 3.8 and Table 3.9, breads containing MC and agar and control breads had the highest porosity values with their lowest number of pores. This result also indicated their non-uniform crumb structure with very large pores. In the study of Wang et al. (2011), it has been reported that extremely interconnected and open pores of breads are responsible for 99% of bread's total porosity. Thus, the highest average areas of pores determined for these breads might be probably due to the interconnection between all gas cells (Table 3.9, Figure 3.32 and Figure 3.33a-c). A significant negative correlation between porosity and number of pores (r=-0.90) and a positive correlation between porosity and average size of pores (r=0.80) also exhibited the noticeable effect of void spaces on porosity of crumb structure. On the other hand, the lowest porosity, the lowest average area of pores and the highest number of pores were obtained for gluten-free breads prepared with the addition of xanthan, CMC, xanthan-guar, xanthan-LBG and HPMC. Another negative correlation was also observed between number of pores and average size of pores (r=-0.94). This result showed that breads prepared with the addition of xanthan, CMC, xanthan-LBG, xanthan-guar and HPMC had higher number of smaller pores attributing to their finer crumb structure.

The aspect ratio of all the bread samples which expresses the relationship between the width of the pore to its height was found to be under 2, indicating ellipsoidal nature of the pores (Ishida et al., 2001). The roundness of pores in gluten-free bread samples prepared with different additives was ranged between 0.559 and 0.637 indicating their non-circular shape.

3.5.2 Effects of Chestnut flour and Xanthan-guar gum blend-DATEM Mixture Addition on Macro-structure of Rice Breads

Figure 3.34 shows the scanned images of gluten-free bread samples prepared with different formulations and baked in different ovens. The scanned images of bread samples prepared without additives and baked in different ovens are shown in Figure 3.34a, c, e and g. Breads formulated with rice flour and containing no gum and DATEM had non-uniform and larger pores (Figure 3.34a). As explained before, this might be due to the fact that the viscosity and viscoelastic properties of rice dough was not sufficient to allow bubble capture during the fermentation and baking process. The puffing effect of infrared-microwave combination baking was not effective on the size and distribution of pores in rice bread crumb either (Figure 3.34e). Therefore, control rice breads had heterogeneous and coarser crumb with very large pores (Figure 3.34a and e). On the other hand, in the presence of chestnut flour, even in the absence of additives, large pores in bread crumb were prevented (Figure 3.34c and g). As mentioned in section of 3.2.1, the higher fiber content of chestnut flour enhanced the viscoelastic properties and resulted in entrapment of more air bubbles which might be other reason of more uniform crumb structure with small pores of chestnut flour containing breads. Moreover, using different baking ovens resulted in noticeable differences in the size and distribution of pores of chestnut-rice bread crumbs (Figure 3.34c and g). During infrared-microwave combination heating, higher internal pressure and faster vaporization occurred inside chestnut-rice breads that created a puffing effect. Therefore, among all gluten-free breads prepared without additives, the most uniform structure with small pores was obtained from breads prepared with using chestnut and rice flour and baked in infrared-microwave combination oven (Figure 3.34g).

It has been shown that the benefit of hydrocolloids as dough stabilizers can be promoted in the presence of surfactants (Bollain and Collar, 2004). This may be due to the fact that the interaction between hydrocolloids and emulsifiers assists the entrapment of air bubbles during mixing and fermentation process. While hydrocolloids improve bread quality by increasing water absorption and viscoelastic properties of dough (Kohajdova and Karovicova, 2009), emulsifiers lower the surface tension of dough leading to the subdivision of the entrapped air bubbles into more and smaller bubbles during mixing (Kokelaar et al., 1995; Ribotta et al., 2004b). Consequently, in the presence of xanthan-guar gum blend-DATEM mixture, the pores of gluten-free breads were smaller and more uniform in size (Figure 3.34b, d, f and h). Among all gluten-free breads, the most homogenous structure was obtained in the presence of chestnut flour, xanthan-guar gum blend-DATEM mixture addition and infrared-microwave combination baking (Figure 3.34).

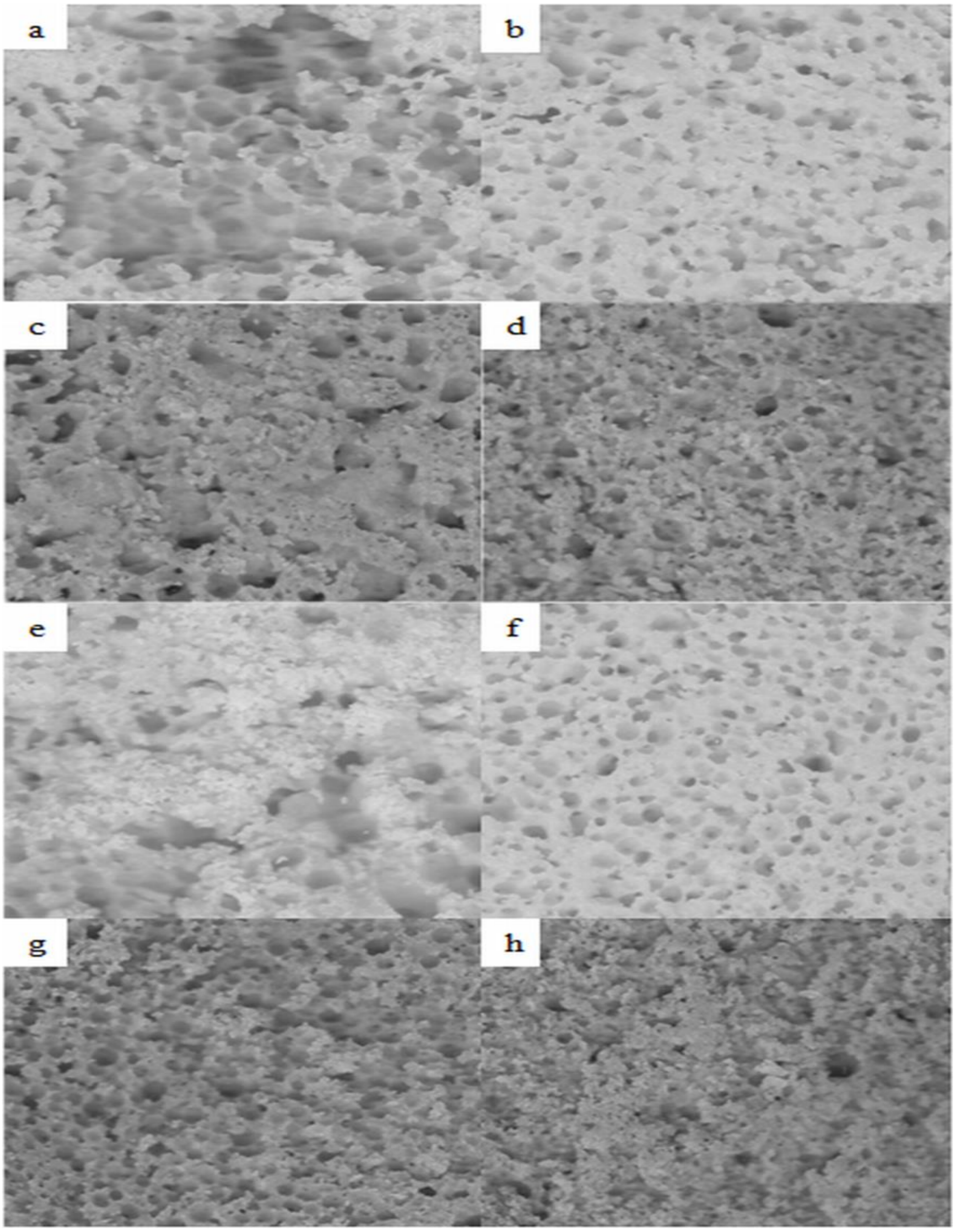

Figure 3.34. Scanned images of different gluten-free bread formulations baked in different ovens. a- Rice bread baked in conventional oven, b-Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven, c-Chestnut-rice breads baked in conventional oven, d-Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven. e- Rice bread baked in infrared-microwave combination oven, f-Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination oven, g-Chestnut-rice breads baked ininfrared-microwave combination, h-Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination.

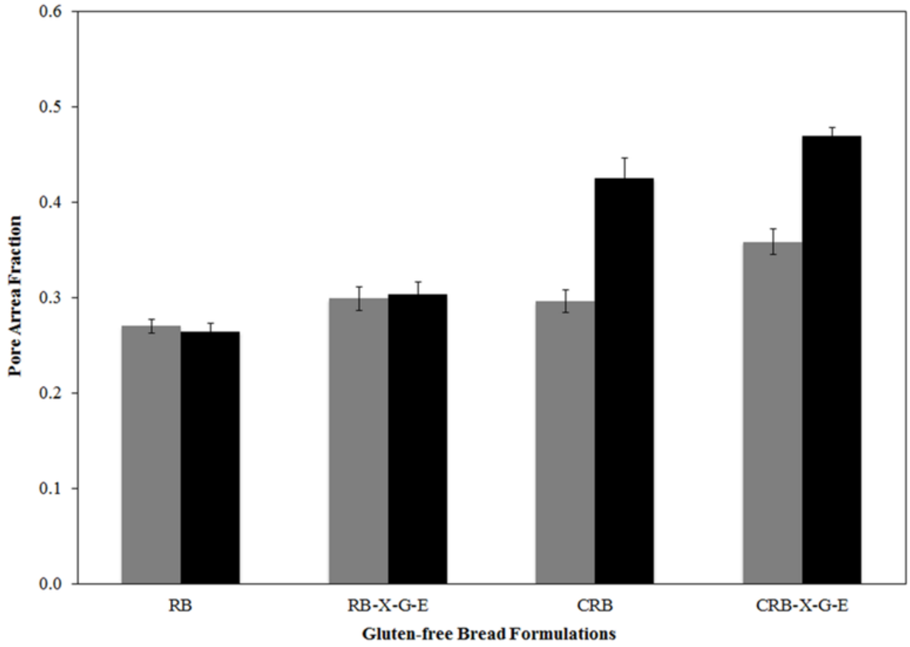

Figure 3.35. Based on scanned images, pore area fractions of different gluten-free bread formulations baked in conventional (gray bar) and infrared-microwave combination oven (black bar). (RB: Rice bread, RB-X-G-E: Rice bread containing xanthan-guar gum blend-DATEM mixture, CRB: Chestnut-rice bread, CRB-X-G-E:Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture).

Figure 3.35 shows the pore area fractions of gluten-free breads prepared with different formulations and baked in different ovens based on scanned images. According to two-way ANOVA, both gluten-free bread formulations and oven type were found to be significantly effective on the pore area fractions of crumb structure ($p \leq 0.05$) (Table A. 27). The lowest pore area fraction values were obtained from rice breads without any additives. In the absence of xanthan-guar gum blend-DATEM mixture, rice dough had very low viscosity and viscoelastic moduli values, which prevented entrapment of air bubbles resulting in low specific volume values (Figure 3.13 and Figure 3.14). However, fiber content of chestnut flour provided higher apparent viscosity and viscoelastic properties to dough. This property helped entrapment of more air bubbles into chestnut flour containing dough and caused higher specific volume values. Thus, chestnut flour containing breads had higher pore area fractions as compared to rice breads.

As mentioned before, gums and emulsifiers have the ability to improve volume and texture of breads by increasing water absorption and gas retention ability of dough during mixing and fermentation process and by providing stability to the dough during baking. Recently, it has also been demonstrated that addition of emulsifiers together with hydrocolloids into gluten-free formulations is critical since the complex formed by hydrocolloid; emulsifier and dough components have an important role in the enhancement of dough handling ability and bread quality (Nunes et al., 2009). Therefore, in the presence of xanthan-guar gum-DATEM mixture, higher pore area fraction values were obtained in rice and rice-chestnut breads.

As shown in Figure 3.35, there were significant differences in the pore area fraction values of gluten-free breads baked in different ovens ($p \leq 0.05$). Pore area fraction values of breads baked in infrared-microwave combination oven were significantly higher than that of conventionally baked ones ($p \leq 0.05$). The high internal heat generation in infrared-microwave combination baking produces higher internal pressure, which creates a puffing effect. This puffing effect might be the reason of looser and more porous structure in gluten-free breads baked in infrared-microwave combination oven. The increased effect of infrared-microwave combination oven on pore area fraction values has been also recognized for wheat breads (Ozkoc et al., 2009a).

Among all gluten-free breads, the highest pore area fraction values were obtained from breads prepared with chestnut flour with xanthan-guar gum blend-DATEM mixture addition and baked in infrared-microwave combination oven (Figure 3.35). This result is in a good agreement with our previous findings in which volume of breads containing chestnut flour and baked in infrared-microwave oven were found to be significantly higher than that of conventionally baked one ($p \leq 0.05$) (Figure 3.24).

Pore area distributions of different gluten-free bread formulations and baked in conventional and infrared-microwave combination ovens are presented in Table 3.10. According to two-way ANOVA both bread formulations and oven types affected pore area distributions of breads significantly ($p \leq 0.05$) (Table A. 27). Among all gluten-free breads, the lowest total number of pores was obtained from conventionally baked rice breads prepared without additives. As discussed before, the reason for this is the lack of incorporation of sufficient air bubbles. The addition of xanthan-guar gum blend-DATEM mixture caused entrapment of more air into dough resulting in an increase in total number of pores in conventionally baked rice breads (67%). However, addition of xanthan-guar gum blend-DATEM mixture did not cause such a noticeable increase in total number of pores of rice breads baked in infrared-microwave combination oven. This may be due to the fact that high pressure gradient occurring inside the breads during infrared-microwave combination was found to be more effective on total number of pores of these breads as compared to additives. In general, it can be said that baking type resulted in noticeable change in the total number of pores and distribution of pores of rice breads and when rice bread formulations were baked in infrared-microwave baking oven, approximately 23-28% increase in small size of pores (0-5 mm2) occurred (Table 3.10)

As opposed to rice dough, chestnut flour containing dough could incorporate sufficient amount of air bubbles during the mixing and fermentation process. Both the presence of additives and baking type did not result in noticeable change in the total number of pores of chestnut-rice breads. However, despite the slight differences in total number of pores of chestnut-rice breads, high pressure during infrared-microwave baking changed pore area distribution of chestnut-rice breads resulting in approximately a 71% increase in the number of large pores (>10 mm^2).

Pore roundness of the gluten-free bread samples were also determined by analyzing the scanned images of crumbs and no significant difference was obtained in roundness values of gluten-free breads ($p \leq 0.05$) (Table A. 30). The roundness values of pores were in between 0.61 and 0.67 showing that the pores in breads had not circular shape.

Table 3.10. Pore area distribution of gluten-free breads prepared with different formulations and baked in different ovens.

Number of Pores	Oven Type	RB-X-G-E	RB	CRB-X-G-E	CRB
Range of Pore Area (mm^2)	Conventional				
0-5		161	98	278	339
5-10		62	23	54	32
10-20		24	18	28	24
>20		3	11	1	5
Total number of pores	Infrared-microwave combination	250	150	361	400
0-5		259	271	291	292
5-10		54	25	27	26
10-20		16	23	26	25
>20		0	5	17	19
Total number of pores		329	324	361	362

RB: Rice bread, RB-X-G-E: Rice bread containing xanthan-guar gum blend-DATEM mixture, CRB: Chestnut-rice breads, CRB-X-G-E: Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture.

3.5.3 Effects of Chestnut Flour and Xanthan-guar Gum Blend-DATEM Mixture Addition on Microstructure of Rice Breads

The image analysis method was also used for obtaining quantitative information on bread samples examined with SEM at magnification of 20x. Like scanned images, pore area fraction values of breads showed that breads formulated with chestnut flour with xanthan-guar gum blend-DATEM mixture addition and baked in infrared-microwave combination oven were found to be the highest (Figure 3.36). Although fiber had a critical role in the enhancement of rheological properties of dough and bread quality, it was not sufficient to stabilize gas cell in gluten-free bread formulations. As mentioned above, addition of xanthan-guar gum blend-DATEM mixture and using of infrared-microwave combination baking were found to be necessary to obtain higher pore area fraction values from breads.

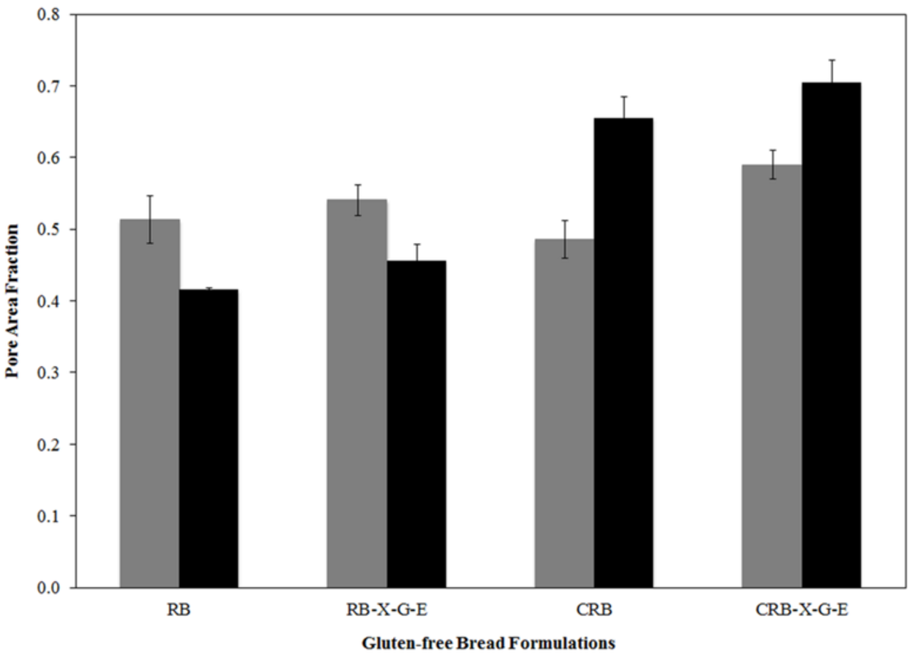

Figure 3.36. Based on SEM at a magnification of 20×, pore area fractions of different gluten-free bread formulations baked in conventional (gray bar) and infrared-microwave combination oven (black bar). (RB: Rice bread, RB-X-G-E: Rice bread containing xanthan-guar gum blend-DATEM mixture, CRB: Chestnut-rice bread, CRB-X-G-E: Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture).

SEM results of the outside and inside of bread crumbs prepared with different formulations and baked in different ovens can be seen in Figure 3.37 and Figure 3.38, respectively. In gluten-free breads, the viscosity of the dough is critical to prevent the settling of the flour particles and escaping of gas cells prior to starch gelatinization and hence, provide homogenous system during fermentation and baking until starch gelatinization (Alvarez-Jubete et al., 2010). In the absence of additives, rice breads especially conventionally baked ones had less developed pores since sufficient amount of air bubbles could not be entrapped into dough (Table 3.10 and Figure 3.37a and Figure 3.37e). Partial replacement of rice flour with chestnut flour resulted in higher amount pores (Table 3.10 and Figure 3.37c and Figure 3.37g) since fiber content of chestnut flour provided higher viscosity values to gluten-free dough. In addition, the complex formed by protein-fiber-starch may decrease starch-protein binding resulting in more homogenous structure as compared to rice breads (Figure 3.35and Figure 3.37a and Figure 3.37c) (Sabanis et al., 2009). The difference in the distribution of starch granule size may also have implications on appearance of crumb structures. SEM observation of dough samples prepared from only rice flour and by the replacement of rice flour with chestnut flour without any additive showed the considerable differences in the size and shape of the rice and chestnut starch granules. The rice starch granules appeared to have relatively smaller in size ranging between 3-7 μm in diameter, while chestnut starches had larger granules with a diameter of around 8-12 μm. In the study of Park et al. (2004), the significant relationship between starch granule size and gas retention was found to be responsible for final crumb appearance.

Flours that have larger starch granules tended to release more amylose during baking since they contained more amylose as compared to small granules. As a result, a film like structure was formed by the interaction between amylose and protein which might coalesce less during baking (Park et al., 2004, Alvarez-Jubete et al., 2010). This is in agreement with the increase in crumb fineness with the replacement of chestnut flour observed in our study. While the release of small starch granules of rice flour might weaken and rise of gas cells (Figure 3.37a), larger starch granules dispersed among the smaller starch granules in chestnut flour containing dough helped to stabilize gas bubbles during bread making resulting in better crumb grain (Figure 3.37c). However, the pores of conventionally baked chestnut-rice breads were not evenly distributed as much as that of baked in infrared-microwave combination oven. In addition, some swollen and evenly dispersed of starch granules created a continuous sheet on the some part of chestnut bread crumb (Figure 3.37c). Similar to scanned images of breads, SEM observation showed that among all breads prepared without any additives, the most homogenous structure was obviously obtained from breads formulated with chestnut flour and baked infrared-microwave combination oven (Figure 3.37g).

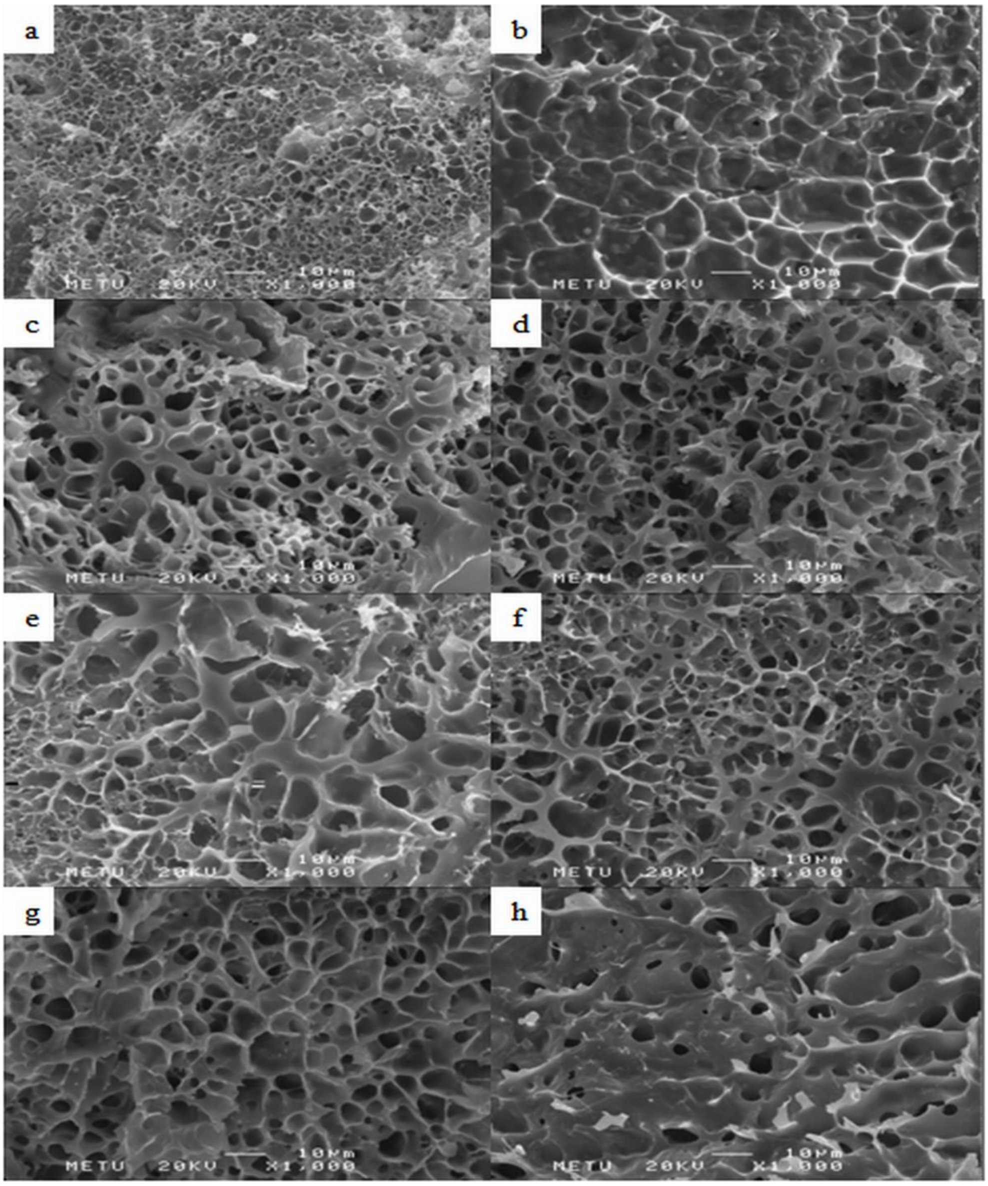

Figure 3.37. SEM micrographs (1000×) of outside of gluten-free bread crumb samples baked in different ovens. a-Rice bread baked in conventional oven, b-Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven, c-Chestnut-rice breads baked in conventional oven, d-Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven. e-Rice bread baked in infrared-microwave combination oven, f-Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination oven, g-Chestnut-rice breads baked ininfrared-microwave combination, h-Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination.

The addition of xanthan-guar gum blend-DATEM mixture improved bread structures since more homogenous pore distributions were obtained in gluten-free breads (Figure 3.37b, d, f and h). As can be seen in Figure 3.37h, in the presence of high internal pressure, fiber and additive, the surface of the starch granules were stretched and rolled up into fibrils and formed veil-like structure in gluten-free chestnut-rice breads.

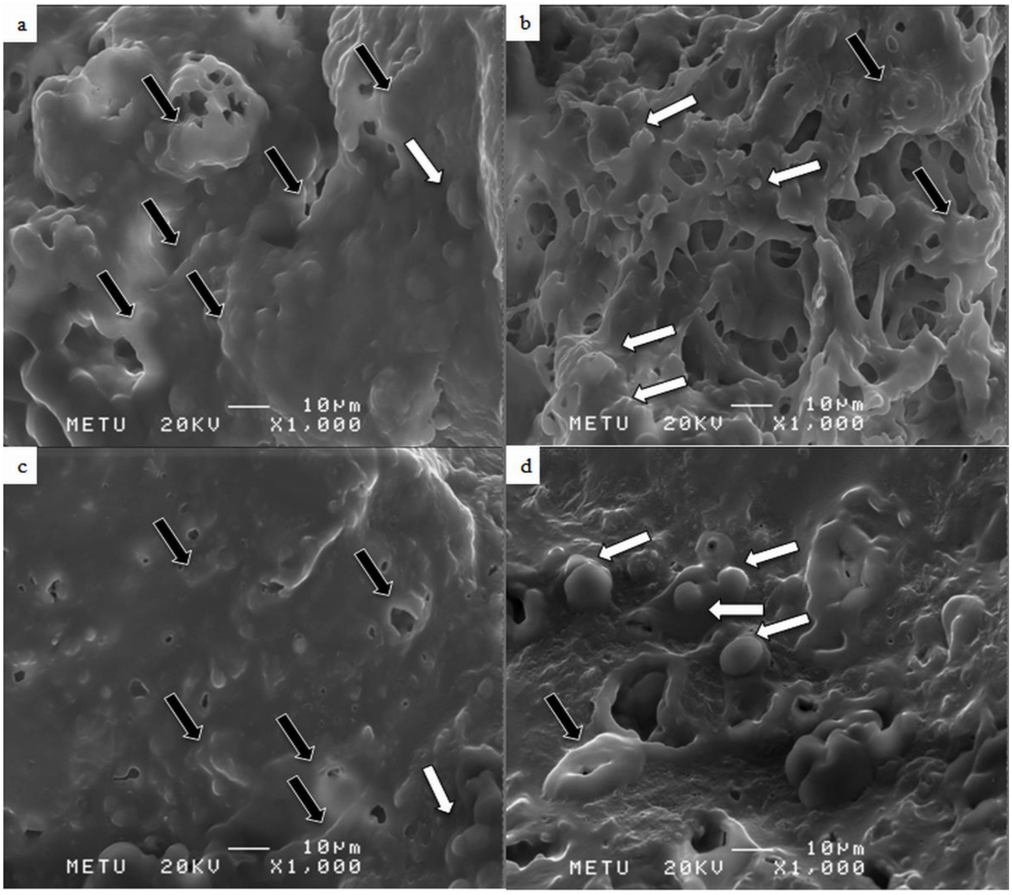

Figure 3.38. SEM micrographs (1000×) of inside of gluten-free bread crumb samples baked in different ovens a- Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven, b-Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination oven, c- Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven. d- Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination. (White arrows represent starch granules residues and black arrows represent deformed starch granules).

According to inside bread crumb images obtained at 1000× magnifications, breads baked in conventional and infrared-microwave combination ovens had granular and deformed starch together (Figure 3.38). However, breads prepared with both rice and chestnut flour and baked in infrared-microwave combination oven had more granular residues (Figure 3.38d). Furthermore, the starch granules in these breads did not lose their identity and did not disintegrate completely. Incomplete disintegration of starch granules may be due to the fact that shorter processing time that affects swelling and gelatinization. Sakıyan and coworkers (2011) found that gelatinization degrees in cakes baked infrared-microwave combination (85-93%) were found to be lower than that in conventionally baked cakes (70-90%). Higher fiber and sugar content of flour are also effective in incomplete disintegration of starch granules. Higher fiber content and sugar content in chestnut flour might increase gelatinization temperatures resulting in hindering of starch gelatinization during baking. Thus, in the presence of both chestnut flour and infrared-microwave combination baking, more granular residues were obtained.

3.6 Effect of Xanthan-guar Gum Blend-DATEM Mixture and Chestnut flour on Staling of Gluten-free Rice Breads

The effects of chestnut flour and a xanthan-guar gum blend-DATEM mixture on staling of gluten-free rice breads baked in conventional and infrared-microwave combination ovens were studied. Staling properties of the bread were assessed using moisture measurements, mechanical compression, differential scanning calorimetry (DSC), X-ray diffraction, and fourier transform infrared spectroscopy (FT-IR).

3.6.1 Moisture content

Moisture contents of bread samples were significantly affected by storage time, oven type, and formulations ($p \leq 0.05$) (Table 3.11). Significantly lower moisture content were obtained in breads stored at longer times, breads baked in infrared-microwave combination oven and breads prepared without chestnut flour and xanthan-guar gum blend-DATEM mixture ($p \leq 0.05$) (Table A. 31 and Table A. 32).

During storage, moisture is transferred from the crumb to the crust causing a reduction in crumb moisture due to the difference in vapor pressures (Sabanis et al., 2009). Thus, the lowest moisture losses were obtained in breads stored at shortest time. In Table 3.11, it can be noted that fresh bread samples lost moisture most rapidly during the first day of storage. After 24 h aging, moisture loss of bread crumb changed slowly.

In infrared-microwave combination baking, the dominant mechanism is microwave heating. During microwave heating, the greater interior pressure and the higher moisture concentration gradient result in an increase in the diffusion of water through the bread. Thus, significantly higher moisture losses were obtained from breads baked in infrared-microwave combination oven ($p \leq 0.05$), which is in agreements with Figure 3.27 and Table 3.7.

As illustrated in Table 3.11, significantly higher moisture contents were obtained in breads containing chestnut flour and xanthan-guar gum blend-DATEM mixture (CRB-X-G-E), at all storage time and for both oven types, signifying lower water loss. As discussed before, the water binding ability of fiber and gums prevents water loss during storage and with the possible hydrogen bonding between fiber and starch and gums and starch that delay the starch retrogradation (Sabanis et al., 2009).

Table 3.11. Moisture content of gluten-free bread formulations baked in conventional and infrared-microwave combination ovens at different storage times

Storage Time (h)	Oven Type	RB-X-G-E	RB	CRB-X-G-E	CRB
	Conventional				
1		49.5±0.13	47.5±0.12	54.7±0.13	52.3±0.14
24		47.8±0.19	45.7±0.14	51.3±0.09	48.0±0.12
48		46.6±0.16	44.1±0.17	49.9±0.11	47.4±0.10
72		46.1±0.10	43.6±0.14	49.2±0.14	46.7±0.13
96		45.9±0.08	43.4±0.12	48.9±0.12	46.5±0.17
	Infrared-microwave combination				
1		47.9±0.15	46.2±0.11	52.4±0.14	49.4±0.15
24		46.0±0.13	44.8±0.10	49.9±0.12	47.6±0.18
48		45.5±0.11	44.4±0.08	48.8±0.14	45.9±0.16
72		45.1±0.12	44.1±0.13	48.4±0.12	45.5±0.14
96		44.8±0.14	43.6±0.09	48.2±0.16	45.3±0.18

RB: Rice bread, RB-X-G-E: Rice bread containing xanthan-guar gum blend-DATEM mixture, CRB: Chestnut-rice bread, which was prepared by replacement of 30% or 46% of rice flour with chestnut flour, CRB-X-G-E: Chestnut-rice bread which was prepared by replacement of 30% or 46% of rice flour with chestnut flour and containing xanthan-guar gum blend-DATEM mixture.

3.6.2 Firmness

Effects of storage time, oven type and gluten-free bread formulations on firmness values of breads were found to be statistically significant ($p \leq 0.05$) (Figure 3.39 and Figure 3.40) (Table A. 33 and Table A. 34). The firmness values of all breads increased linearly during storage (r^2=0.93-0.98) following zero order kinetics. The rate constant was the highest for rice breads prepared without additives and baked in conventional and infrared-microwave combination oven (0.060 N/day). The rate constant for chestnut-rice breads prepared with additives and baked in both ovens were the lowest (0.041 N/day).

Fast staling (increase in firmness) is one of the quality problems associated with gluten-free breads. Obviously, starch is the main cause of staling in gluten-free breads. Researchers have tried to identify the roles of amylose and amylopectin in staling. Ghiasi et al. (1984) found that firming of breads was not only as a result of amylopectin retrogradation, but also due to leaching out of the amylose granules. Upon cooling, amylose retrogradation occurs very fast and helps to stabilize the crumb. Thus, the formation of ordered amylose structure in the center of the gelatinized granules might be attributed to initial firming of breads due to its rapid retrogradation. In contrast, amylopectin retrogradation is slower and seems to be the critical factor for the aspects of staling like crumb firming and loss of elasticity. In addition to starch, the role of water on either the firming of crust and/or the retrogradation process cannot be ignored. In bread, water behaves as a plasticizer for the amorphous regions, which makes its main components more flexible. During storage of bread, water is transferred between the bread components and cannot act as a plasticizer (Gray and BeMiller, 2003). Thus, migration of water from crumb to crust and amylopectin retrogradation, especially the formation of double helical structures and crystalline regions, are considered to be the main reasons for firming and/or staling of breads (Arendt et al. 2008).

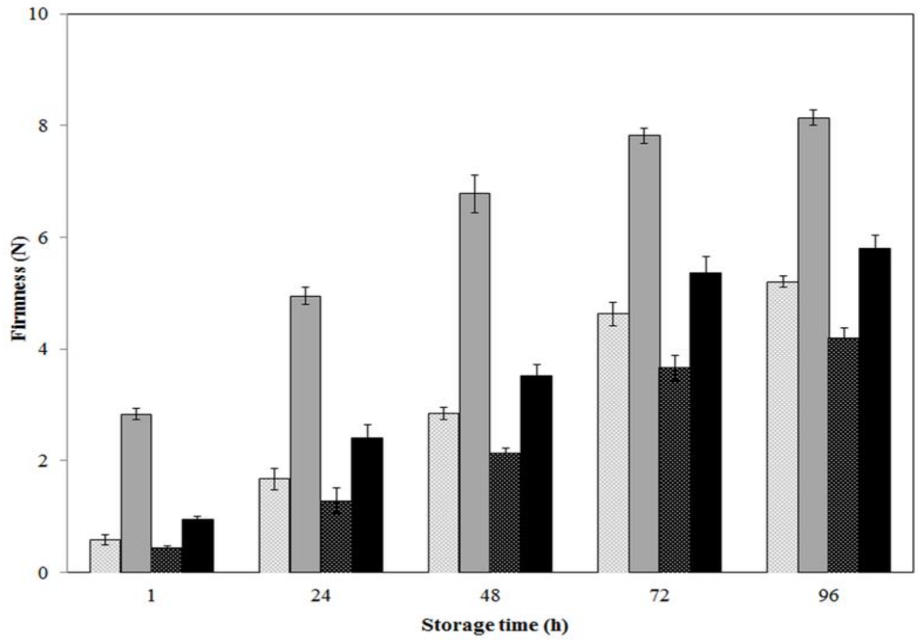

Figure 3.39. Firmness of different gluten-free bread formulations baked in conventional oven at different storage times. (dotted gary bar): Rice bread containing xanthan-guar gum blend-DATEM, (gray bar): Rice bread, (dotted black bar): Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture, (black bar): Chestnut-rice bread.

As indicated in Figure 3.39 and Figure 3.40, gluten-free breads baked in the infrared-microwave combination oven had significantly higher firmness values than the ones baked in the conventional oven ($p \leq 0.05$) (Table A. 33 and Table A. 34). During microwave baking, more amylose is leached out of starch granules and that increases the amount of amylose with the ability of forming a starch gel (Sumnu and Sahin, 2005b). Moreover, the distribution of amylose in microwave baked bread is more uneven and contains less bound water as compared to the amylose in bread baked in a conventional oven.

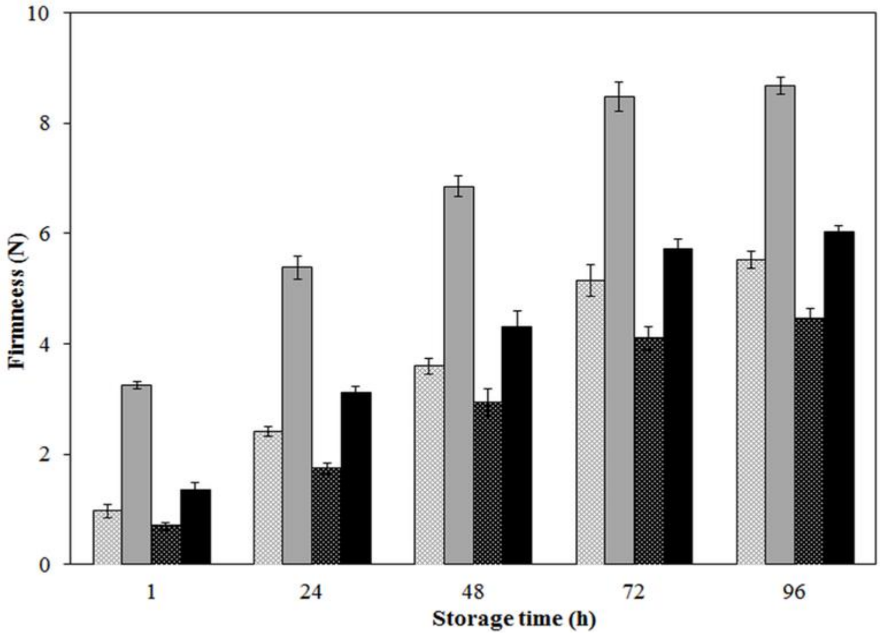

Figure 3.40. Firmness of different gluten-free bread formulations baked in infrared-microwave combination oven at different storage times. (dotted gary bar): Rice bread containing xanthan-guar gum blend-DATEM, (gray bar): Rice bread, (dotted black bar): Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture, (black bar): Chestnut-rice bread.

Upon cooling, the surrounding amylose molecules align and increase crumb firmness. Since the amylose fractions of microwave-baked breads have higher ability to realign into a more crystalline structure than the amylose molecules leaching in conventionally baked breads, the microwave-baked breads have firmer texture (Sumnu, 2001). Upon cooling period, the surrounding amylose molecules align and contributed to crumb firmness. In addition, entanglements between starch and protein might be triggered by higher moisture loss in breads (Hug-Iten et al., 2003; Ozkoc et al., 2009b; Patel et al., 2005).

As depicted in Figure 3.39 and Figure 3.40, among all fresh breads, the highest firmness values (2.83and 3.25 N) were obtained from rice breads prepared without any additives. As discussed previously, in the absence of chestnut flour and additives, rice dough had low viscosity and viscoelastic moduli, which prevented entrapment of gas during mixing and proofing, and resulted in breads with low volume and firm texture. Staling of breads was significantly retarded with the replacement of rice flour with chestnut flour and even more with further addition of xanthan-guar gum blend-DATEM mixture ($p \leq 0.05$). The presence of highly water-binding macromolecules such as fibers, hydrocolloids and emulsifiers noticeably enhanced the mixing properties and handling ability of dough that helped the entrapment of more air bubbles. Thus, lower firmness values (0.43 and 0.69 N) were obtained from breads in the presence of chestnut flour and xanthan-guar gum blend-DATEM mixture. Such a reduction in crumb firmness values of breads with fibers, hydrocolloids and emulsifiers were also reported (Guarda et al., 2004; Santos et al., 2008; Ozkoc et al., 2009b; Sumnu et al., 2010).

3.6.3 DSC (Differential Scanning Calorimeter)

Amylopectin retrogradation can be monitored and quantified by DSC. Retrogradation enthalpies (ΔH_r) of bread samples were significantly affected by storage time, oven type and gluten-free formulations according to three-way ANOVA ($p \leq 0.05$) (Table A. 35 and Table A. 36). During amylopectin retrogradation, crystal structures are formed and these crystal structures require an extra amount of energy for their melting (Santos et al., 2008). As a result of the crystal growth and the reorganization of amylopectin in crystal structures, retrogradation enthalpies of breads increase over the storage time. DSC curves with retrogradation endotherms are presented in Fig. B. 1 and B. 2.

As illustrated in Figure 3.41 and Figure 3.42, amylopectin retrogradation enthalpies of different breads baked in different ovens increased linearly with storage time. Breads prepared with a mixture of rice and chestnut flour and in the presence of xanthan gum and DATEM exhibited lower retrogradation enthalpies than the bread prepared with rice flour alone. At 24 hours storage time breads prepared with either chestnut or in the presence of xanthan gum and emulsifiers exhibited similar retrogradation enthalpies. However, at longer storages times, amylopectin retrogradation of breads was significantly reduced in the presence of both chestnut flour and xanthan-guar gum blend-DATEM mixture ($p \leq 0.05$) (Table A. 35 and Table A. 36). The same behavior was observed in breads baked with the two different ovens (Figure 3.41 - Figure 3.42). In other words, the synergic interaction between chestnut flour and xanthan-guar gum blend-DATEM mixture found to be more effective on staling of gluten-free breads stored at longer times.

The differences in retrogradation enthalpies for breads baked in infrared-microwave combination and conventional ovens were not statistically significant. This is in agreement with a previous study conducted on staling properties of wheat breads baked in these different ovens (Ozkoc et al., 2009b). In the study, it was suggested that the infrared-microwave combination heating partially solved the rapid staling problem observed with microwave heating since the retrogradation enthalpies of breads baked in infrared-microwave combination oven (ΔHr= 0.65-0.73 J/g) were found to be between the values obtained for conventionally (ΔHr= 0.35-0.75 J/g) and microwave-baked breads (ΔHr= 0.72-0.87 J/g) (Ozkoc et al., 2009b).

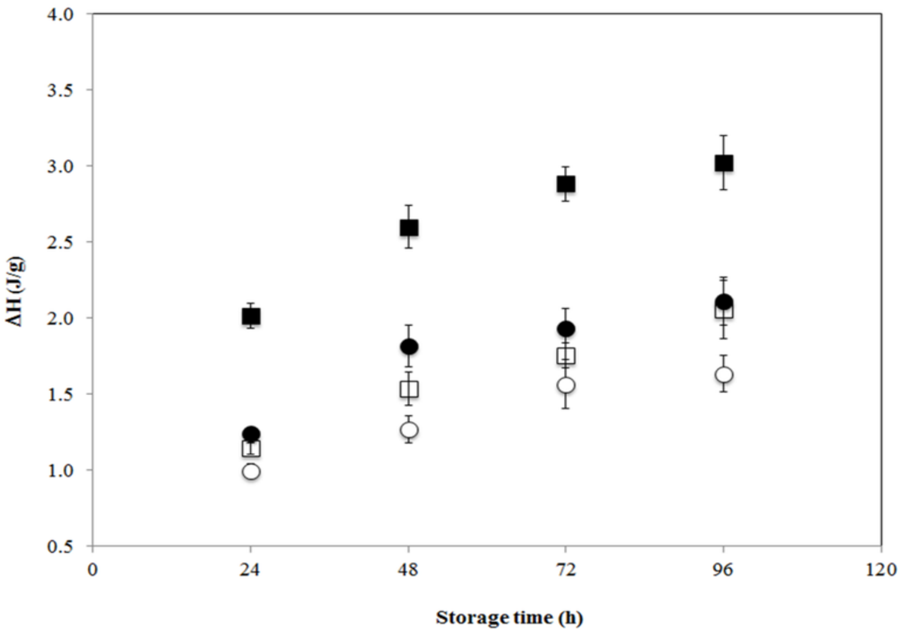

Figure 3.41. Retrogradation enthalpy of different gluten-free bread formulations baked in conventional oven at different storage times. (black square): Rice bread, (black circle): Chestnut-rice bread, (white square): Rice bread containing xanthan-guar gum blend-DATEM, (white circle): Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture.

The slightly higher retrogradation enthalpies observed in breads baked in infrared-microwave combination oven was probably as a result of the higher moisture loss occurring during combination baking. The high retrogradation observed in breads prepared without chestnut flour and additives agreed with those of Kadan et al. (2001) and Gujral et al. (2003b), who reported fast amylopectin retrogradation of rice bread crumbs. Fiber and hydrophilic additives bind available water for gelatinizing starch granules, forcing them to melt at higher temperatures and requiring less energy to disorganize its structure (lower ΔH for gelatinization). Such a diluting effect of gelatinization of starch may also decrease availability of starch for crystallization and modify the structure of the formed crystals (Santos et al., 2008). The replacement of rice flour with chestnut flour decreased total starch content and probably the amylopectin content of breads since the starch content of rice flour (79.9% in flour basis) was higher than that of chestnut flour (47.8% in flour basis).Thus, replacement of rice flour with chestnut flour and addition of xanthan-guar gum blend-DATEM mixture clearly reduced the retrogradation enthalpies of the amylopectin during storage.

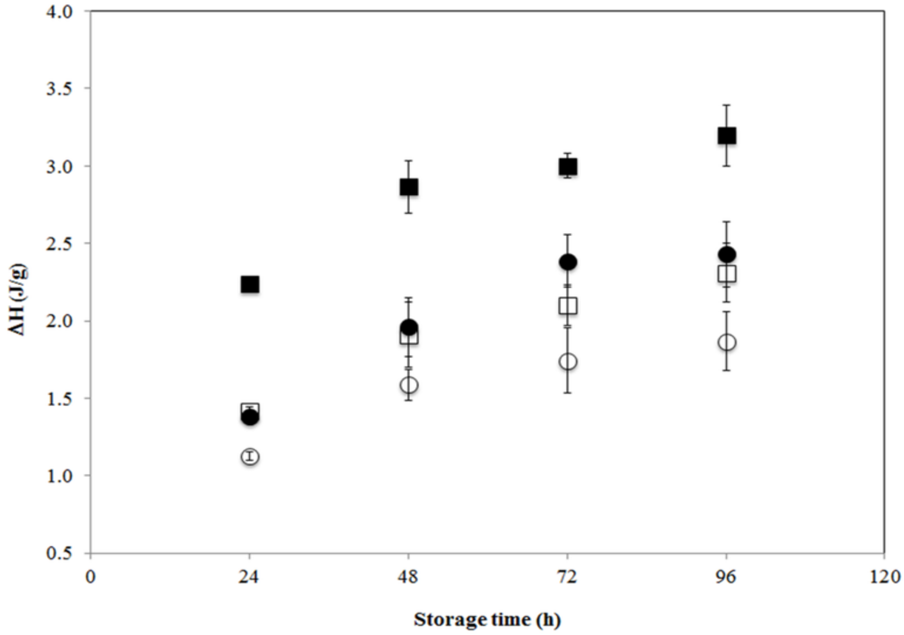

Figure 3.42. Retrogradation enthalpy of different gluten-free bread formulations baked in infrared-microwave combination oven at different storage times. (black square): Rice bread, (black circle): Chestnut-rice bread, (white square): Rice bread containing xanthan-guar gum blend-DATEM, (white circle): Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture.

3.6.4 X-ray Diffraction

X-ray diffraction has been used to examine bread staling, in particular the formed crystalline structure of starch. X-ray diffraction diagrams of fresh and aged breads are depicted in Figure 3.43a-h. Starch retrogradation involves both changes in the amylopectin and amylose fraction. Amylose recrystallization occurs about 1 h after baking, while amylopectin recrystallization during cooling is slower. Thus, fresh breads (stored for only 1h) had peaks at around 2θ of 20° corresponding to the V-type structure formed by the helical inclusion complex between amylose and fatty acids in bread samples. Results have shown that starch content of fresh breads was gelatinized, but not yet recrystallized (Hug-Iten et al., 2003). During staling, the peaks observed in fresh breads (at around 2θ of 20°) remained unchanged. The X-ray diffractograms for all aged breads showed peaks at 17, 19.5 and 22°. Moreover, an additional peak at 24° was observed in breads at longer storage periods (Figure 3.43a-h.). In studies by Kadan et al. (2001) and Ji et al. (2010), it was reported that the appearance of 2θ peak at 17° in rice breads and rice cakes might be due to starch retrogradation. Osella et al. (2005) observed another peak at around 22° in gluten-free breads samples prepared with rice flour, corn and cassava starch. Ribotta et al. (2004c) analyzed B-type structure of breads with peaks at diffraction angles of 15, 17, 22.2 and 24°.These peaks which are characteristics of B-type structure are due to the crystallization of the amorphous starch melt, mostly of the amylopectin fraction and increased during storage. It has been indicated in the literature that native starches may have A, B or C-type structures based on their origins (Wang et al., 1998).These crystals contains different amount of water molecules and they affect the distribution of water within the crumb differently. During storage, B-type crystalline regions are formed which contain higher number of water molecules as compared to A and C-type starch as more water migrates into the crystalline region due to the recrystallization of amylopectin (Ozkoc et al. 2009b). As can be seen in Figure 3.43a-h, the increase in starch crystallinity with storage time also caused increase in the peak intensities. Generally, the replacement of rice flour with chestnut flour and addition of xanthan-guar gum blend-DATEM mixture resulted in decrease in these peak intensities (Figure 3.43c,d,g and h).When oven types are compared, it can be said that similar peak intensities were obtained from breads baked in conventional and infrared-microwave combination ovens (Figure 3.43a-h).

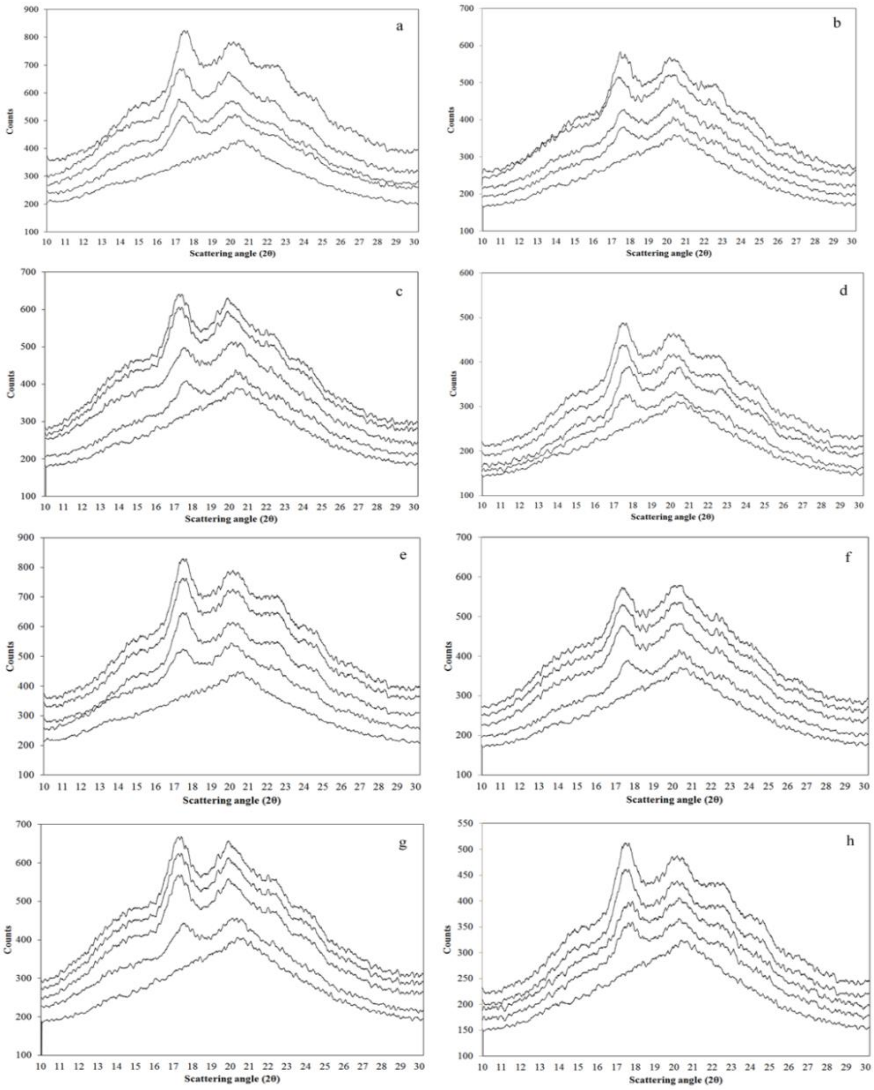

Figure 3.43. X-ray diffraction diagrams of different gluten-free bread formulations baked in conventional and infrared-microwave combination ovens and stored at different storage times (from bottom to top curves represent 1, 24, 48, 72 and 96 h, respectively) a- Rice bread baked in conventional oven, b- Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven, c- Chestnut-rice breads baked in conventional oven, d- Chestnut-rice bread containing xanthan-guar gum blend- DATEM mixture and baked in conventional oven, e- Rice bread baked in infrared-microwave combination oven, f- Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination oven, g- Chestnut-rice breads baked in infrared-microwave combination, h- Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination.

The total mass crystallinity grades of bread samples were significantly affected by storage time and bread formulations ($p \leq 0.05$) (Table A. 37 and Table A. 38). The formation of a gel structure due to starch retrogradation has been related to the development of crystallites by the interchain association of the amylose and amylopectin fractions. As illustrated in Figure 3.44 and Figure 3.45, increase in crystallinity values of bread samples with storage time was found to be statistically significant ($p \leq 0.05$) and higher crystallinity values were observed in breads stored for longer periods. Gluten-free breads baked in both conventional and infrared-microwave combination ovens exhibited statistically similar crystallinity values.

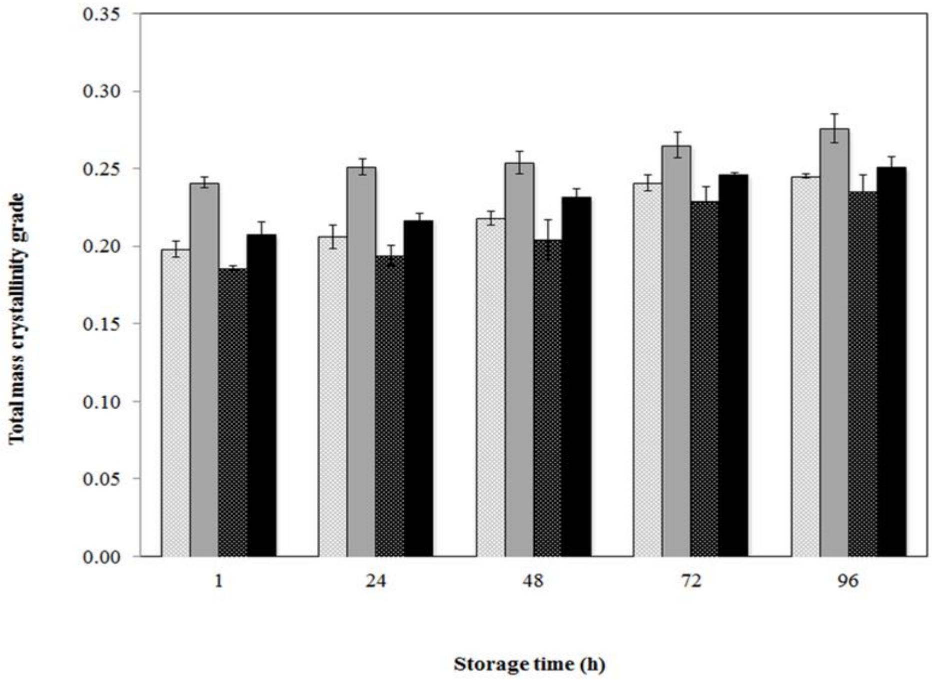

Figure 3.44. Total mass crystallinity grades of different gluten-free bread formulations baked in conventional oven at different storage times. (dotted gray bar): Rice bread containing xanthan-guar gum blend-DATEM, (gray bar): Rice bread, (dotted black bar): Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture, (black bar): Chestnut-rice bread.

As illustrated in Figure 3.44 and Figure 3.45, the lowest crystallinity values were obtained in gluten-free breads prepared with the chestnut flour and xanthan-guar gum blend-DATEM mixture. As discussed before, due to their hydrophilic nature, gums like xanthan and guar gum have the ability to bind water that prevent water loss during storage and decrease the effective water content associated to starch, which is needed for amylopectin recrystallization. DATEM surfactants were reported to have anti-staling effect on breads (Gray and BeMiller, 2003). The retarding mechanism of DATEM might be related to their anti-firming ability due to their effect on cell wall thickness and elasticity of breads.

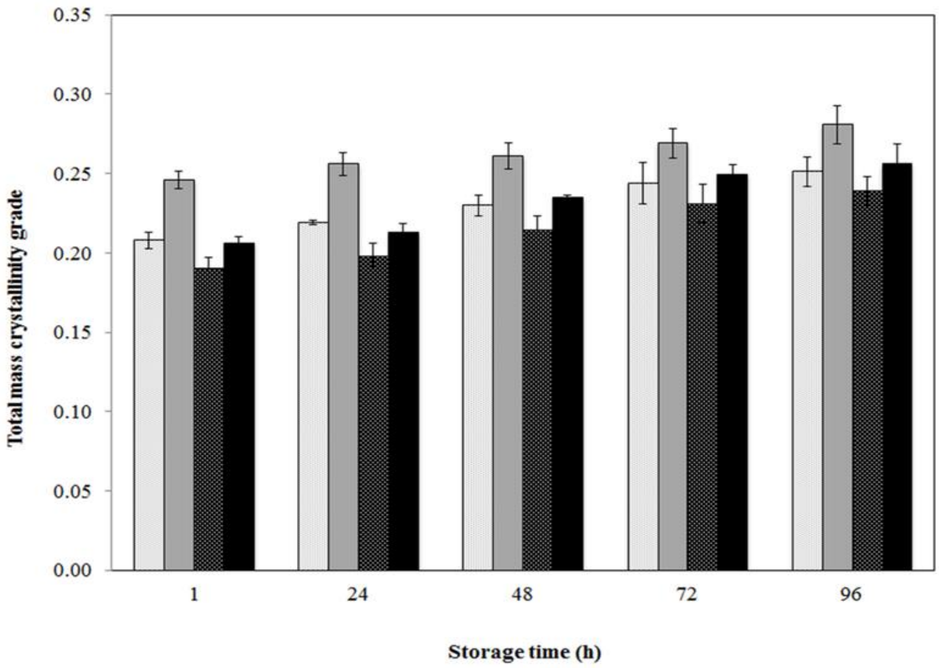

Figure 3.45. Total mass crystallinity grades of different gluten-free bread formulations baked in infrared-microwave combination oven at different storage times. (dotted gray bar): Rice bread containing xanthan-guar gum blend-DATEM, (gray bar): Rice bread, (dotted black bar): Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture, (black bar): Chestnut-rice bread.

In addition, the formation of a complex between amylose-DATEM may interfere with crystallization of the amylopectin and/or may retard water distribution, hence retrogradation (Gudmundsson, 1994). Therefore, the observed decreases in total mass crystallinity values of bread samples with the addition of xanthan-guar gum blend-DATEM mixture may be related to the decrease in the interaction of starch fractions. Crystallinity values of bread samples also decreased with the replacement of rice flour with chestnut flour ($p \leq 0.05$). In presence of chestnut flour, starch retrogradation might be delayed as result of the possible hydrogen binding between fiber and starch, which prevent starch–starch interactions, thereby decreasing availability of organized starch for crystallization. Furthermore, the starch content of rice flour (79.9% in flour basis) was higher than that of chestnut flour (47.8% in flour basis), therefore the replacement of rice flour with chestnut flour decreased the total starch content in the sample, hence probably the amylose content of breads. In high-amylose starches, the amylose fraction has been indicated to have synergetic effects on the amylopectin retrogradation (Fredriksson et al., 1998). In the literature, it was also indicated that the incorporation of even small amounts of flour, which had no amylose content, decreased starch retrogradation of rice breads (Kadan et al., 2001; Varavinit et al., 2003). The highly significant correlations were observed between retrogradation enthalpies and total mass crystallinity of gluten-free breads baked in conventional (r=0.85-0.90) and infrared-microwave combination (r=0.84-0.92) ovens. Consequently, it can be said that breads prepared with chestnut flour had lower retrogradation and staling tendency due to their higher content of fiber and lower starch content.

3.6.5 FT-IR (Fourier Transform Infrared Spectroscopy)

The retrogradation behavior of gluten-free breads samples prepared with chestnut and rice flour with/without additives were also investigated using FT-IR spectroscopy. Since carbohydrate polymers such as starch are extensively hydrogen bonded, conformational changes due to starch retrogradation can be monitored in the FT-IR spectra by analyzing band-narrowing and changes in band intensities (Wilson et al., 1991). While band narrowing is caused by a reduction in the range of conformations and a smaller distribution of bond energies (Wilson et al., 1991; Karim et al., 2000), changes of intensities bands are caused by variations in specific starch conformations such as long-range ordering and crystallinity (Gray and BeMiller, 2003). The spectra of gluten-free bread samples in the region of 750–1352 cm^{-1} are depicted in Figure 3.46a to h. The spectra of gluten-free bread samples showed major peaks at around 1074, 1041, 1022, and 925 cm^{-1}which might be assigned to the C-O-H bending and CH_2 related modes and at 1150 cm^{-1} which may be attributed to C-O and C-C stretching with COH contributions (Van Soest et al., 1995). During ageing of bread, the most obvious spectral change was the increase in band intensities. As shown in Figs. Figure 3.46a-h, retrogradation of gluten-free breads resulted in increases in the heights of bands giving a maximum intensity at 1022 cm^{-1}. Of particular interest, peaks at ∼1041 cm^{-1} are associated to crystalline regions of starch, while peaks at 1020 cm^{-1} are characteristic of amorphous regions of starch and the peak at 925 cm^{-1} is sensitive to water (Karim et al., 2000). In addition, the band at 1150 cm^{-1} is often used as an ‘‘internal correction standard peak’’, to make the measurements independent of uncontrollable factors (Ozkoc et al., 2009b). Thus, the ratio of the peak intensities at 1041 and 1150 cm^{-1} and 1041and 1022 cm^{-1}, which have been assigned to starch retrogradation in the literature, were used to monitor retrogradation (Van Soest et al., 1994, 1995; Smits et al., 1998).

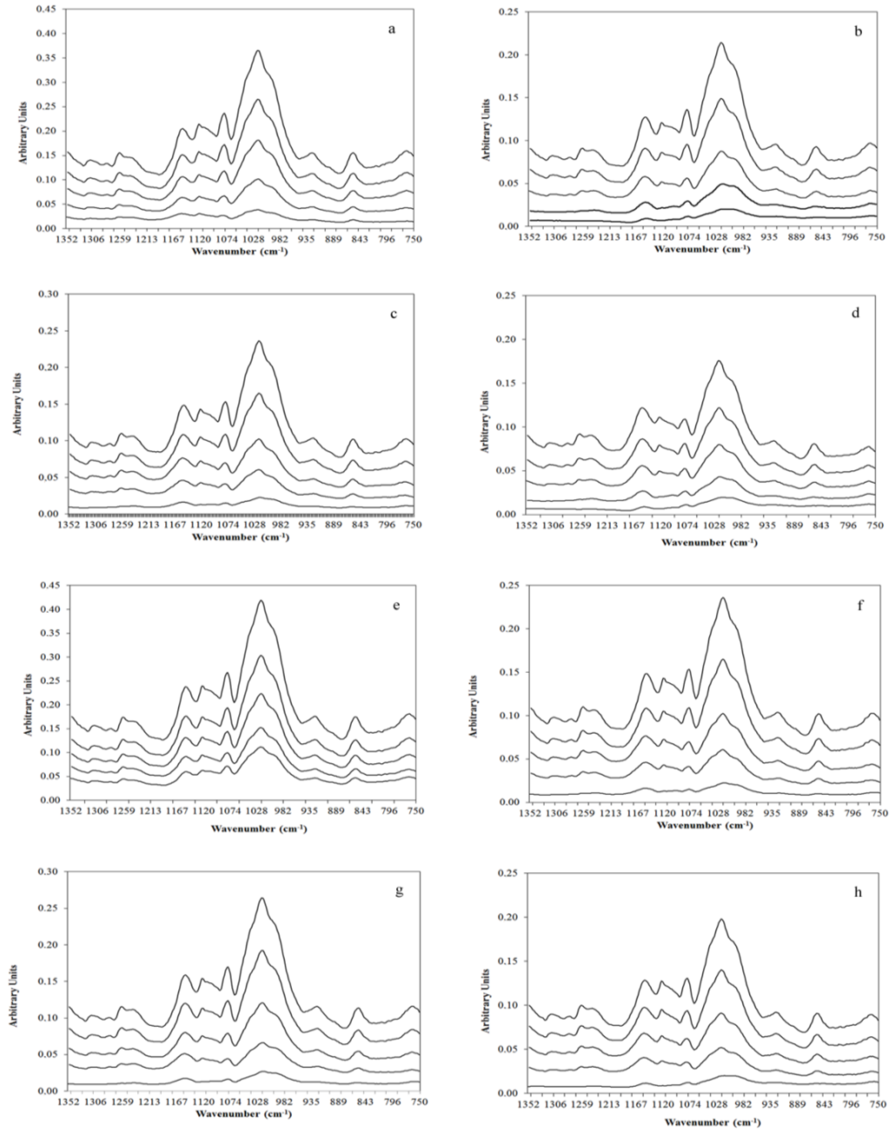

Figure 3.46. FTIR spectra of different gluten-free bread formulations baked in conventional and infrared-microwave combination ovens and stored at different storage times (from bottom to top curves represent 1, 24, 48, 72 and 96 h, respectively) a- Rice bread baked in conventional oven, b- Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven, c- Chestnut-rice breads baked in conventional oven, d- Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in conventional oven, e- Rice bread baked in infrared-microwave combination oven, f- Rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination oven, g- Chestnut-rice breads baked in infrared-microwave combination, h- Chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture and baked in infrared-microwave combination.

The integral area ratios of peaks around 1041 cm^{-1} and 1,151 cm^{-1} has been observed by other researchers (Ozkoc et al., 2009b), relating it to the progressive ordering of the amylopectin polymer present in bread, hence used to monitor starch retrogradation. The integral area ratios of peaks around 1041 cm^{-1} (A_1) and 1150 cm^{-1} (A_2) are reported in Table 3.12. According to three-way ANOVA, A_1/A_2 was significantly affected by storage time, oven type and gluten-free formulations ($p \leq 0.05$). A1/A2 increased with storage time while decreased with the replacement of rice flour by chestnut flour and addition of xanthan-guar gum blend-DATEM mixture. This result also revealed that starch retrogradation of breads was delayed by replacement of rice flour with chestnut flour and addition of xanthan-guar gum blend-DATEM mixture. In addition, higher A_1/A_2 values of breads baked in an infrared-microwave combination oven might be related to their higher water loss.

Table 3.12. The integral peak area ratios of peaks appearing around 1041 cm^{-1} (A_1)and around 1150 cm^{-1} (A_2) of gluten-free bread formulations baked in conventional and infrared-microwave combination ovens at different storage times.

A_1/A_2					
Storage Time (h)	Oven Type	RB-X-G-E	RB	CRB-X-G-E	CRB
	Conventional				
1		1.8±0.12	3.4±0.52	1.7±0.62	2.2±0.2
24		2.9±0.41	4.3±0.61	2.2±0.33	3.2±0.27
48		3.4±0.32	5.2±0.30	3.1±0.17	3.7±0.54
72		4.3±0.53	5.7±0.74	3.9±0.25	4.7±0.62
96		4.5±0.32	6.3±0.55	4.1±0.53	4.9±0.71
	Infrared-microwave combination				
1		2.2±0.25	3.8±0.35	1.9±0.10	2.6±0.28
24		3.2±0.57	4.7±0.37	2.4±0.21	3.5±0.21
48		3.9±0.44	5.3±0.51	3.4±0.28	4.1±0.46
72		4.4±0.82	6.4±0.40	3.9±0.41	4.9±0.51
96		4.7±0.67	7.1±0.71	4.2±0.38	5.2±0.34

RB: Rice bread, RB-X-G-E: Rice bread containing xanthan-guar gum blend-DATEM mixture, CRB: Chestnut-rice bread, which was prepared by replacement of 30% or 46% of rice flour with chestnut flour, CRB-X-G-E: Chestnut-rice bread which was prepared by replacement of 30% or 46% of rice flour with chestnut flour and containing xanthan-guar gum blend-DATEM mixture

Table 3.13. The ratios of peak intensities bands (R) at 1041 and 1022 cm^{-1} of gluten-free bread formulations baked in conventional and infrared-microwave combination ovens at different storage times.

R					
Storage Time (h)	Oven Type	RB-X-G-E	RB	CRB-X-G-E	CRB
	Conventional				
1		0.79±0.07	0.79±0.10	0.80±0.03	0.78±0.03
24		0.82±0.05	0.81±0.03	0.83±0.04	0.81±0.06
48		0.83±0.07	0.83±0.12	0.86±0.02	0.85±0.03
72		0.85±0.03	0.85±0.05	0.89±0.04	0.87±0.08
96		0.89±0.08	0.94±0.09	0.91±0.08	0.89±0.10
	Infrared-microwave combination				
1		0.81±0.07	0.82±0.07	0.78±0.04	0.78±0.04
24		0.83±0.09	0.84±0.09	0.85±0.08	0.83±0.05
48		0.85±0.06	0.85±0.05	0.86±0.03	0.84±0.06
72		0.88±0.05	0.87±0.08	0.91±0.09	0.86±0.04
96		0.92±0.11	0.89±0.06	0.92±0.05	0.91±0.07

RB: Rice bread, RB-X-G-E: Rice bread containing xanthan-guar gum blend-DATEM mixture, CRB: Chestnut-rice bread, which was prepared by replacement of 30% or 46% of rice flour with chestnut flour, CRB-X-G-E: Chestnut-rice bread which was prepared by replacement of 30% or 46% of rice flour with chestnut flour and containing xanthan-guar gum blend-DATEM mixture.

Retrogradation behavior of breads has also been observed by an increase in the ratio of the peak intensities at 1041 and 1022 cm^{-1}, which suggests a reduction in the amorphous nature or an increase in organization of the structure (Smits et al., 1998; Ji et al., 2010) (Figure 3.46 and Table 3.13).The ratios of peak intensities at 1041 cm^{-1} and 1022 cm^{-1} increased from 0.79 to 0.89, 0.79 to 0.94, 0.80 to 0.91, 0.78 to 0.89 for breads baked in conventional oven and from 0.81 to 0.92, 0.82 to 0.89, 0.78 to 0.92, 0.78 to 0.91 for infrared-microwave combination oven after 5 days storage time (Table 3.13). This result indicated a reduced amount of amorphous material and a more organized starch due to retrogradation.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

All rice and rice–chestnut dough formulations had shear thinning behavior with different power law constants and they obeyed power law and Herschel–Bulkley models, respectively. Xanthan, xanthan–LBG and xanthan–guar gum mixture were observed to be the most effective gums in improving dough structure. It was possible to obtain high quality breads by using chestnut and rice flours at a ratio of 30:70.

Response surface methodology was successfully applied to the optimize formulation and the baking conditions of the gluten-free chestnut and rice breads to be baked in infrared–microwave combination oven. The chestnut:rice flour ratio and infrared power were found to be the significant factors in affecting all the quality parameters of gluten-free breads. The microwave power and baking time significantly affected the firmness, weight loss and specific volume of breads. On the other hand, emulsifier content was found to be insignificant in affecting all the quality parameters, except specific volume of breads. Partial replacement of rice flour by chestnut flour improved the quality of gluten-free breads, significantly. Gluten-free breads baked in infrared–microwave combination oven at the optimum conditions had statistically similar quality with conventionally baked ones in terms of colour, specific volume and firmness. In addition, conventional baking time of gluten-free breads was significantly reduced.

Tigernut flour also improved the quality parameters of gluten-free breads. Conventionally baked breads containing 10:90 tigernut:rice flour ratio and the infrared–microwave combination-baked breads prepared using 20:80 tigernut:rice flour ratio had best quality parameters in terms of firmness, specific volume, and color values.

X-ray microtomography was successfully used for characterization of gluten-free bread structures. X-ray microtomography results indicated that addition of different gums or gum blends were found to be effective on crumb porous structure of gluten-free breads. The lowest porosity, the lowest average area of pores and the highest number of pores was obtained from gluten-free breads prepared with the addition of xanthan, CMC, xanthan-guar, xanthan-LBG and HPMC indicating their finer crumbs. Different formulations and oven types were found to be effective on pore area fractions and pore area distributions of bread crumbs. Breads prepared with chestnut flour and xanthan–guar gum blend–DATEM mixture had a more porous structure. In addition, pore area fraction values of breads increased when the infrared–microwave combination baking method was used. Based on scanned and SEM images, the highest pore area fractions were obtained from gluten-free breads containing chestnut flour and xanthan–guar gum blend–DATEM mixture and baked in infrared–microwave combination oven. Generally, the usage of infrared–microwave combination baking increased the number of small pores in rice breads and large pores in chestnut–rice breads. The replacement of rice flour with chestnut flour partially resulted in a more uniform structure. The presence of additives and infrared–microwave combination oven increased the uniformity of microstructure of rice and rice–chestnut breads. SEM observation showed that breads prepared with chestnut flour and baked in an infrared– microwave combination oven had more starch granules, which did not lose their identity and did not disintegrate completely.

Firmness, moisture loss, retrogradation enthalpies, total crystallinity values, and FTIR results showed that starch retrogradation in bread samples increased during storage of breads. Partial replacement of rice flour with chestnut flour and addition of xanthan-guar gum blend-DATEM mixture significantly decreased moisture loss, firmness, retrogradation enthalpy, and total mass crystallinity of gluten-free bread samples. The use of infrared-microwave combination oven did not result in excessive firmness after storage. In addition, retrogradation enthalpy values and total mass crystallinity of gluten-free breads baked in conventional and combination ovens showed that it should be possible to produce breads by combination heating with similar staling degrees as conventionally baked ones. The partial replacement of rice flour with chestnut flour and addition of xanthan-guar gum blend-DATEM mixture retarded staling of gluten-free bread formulations baked in different ovens. In addition, addition of chestnut flour improved the quality of gluten-free rice breads. Therefore, chestnut flour may be recommended to be used in gluten-free bread formulations to be baked both conventional and infrared-microwave combination oven.

In the future study, the effects of frozen storage on quality and staling of gluten-free chestnut-rice doughs may be investigated. In addition, as a further research partial-baking of gluten-free breads in different ovens (infrared-microwave combination and conventional) can be studied.

REFERENCES

(http://www.webmd.com/digestive-disorders/celiac-disease/celiac-disease-diagnosis-tests. Last visited: May, 2013).

http://www.xn--lyak-zoa4g.com/haber/45-2colyak-hastaligi-bilimsel-toplantisi-bursa39da-ya.html. Last visited: May, 2013).

AACC, 2000. Approved Methods of the American Association of Cereal Chemists (10th ed.) Methods 10-05, 44-15 (formerly 72-10) and 74–09. The Association, St. Paul, Minnesota.

Acs, E., Kovacs, Z., Matuz, J., 1997. Possibilities of producing low-protein, gluten-free bread. 1. Structure formation. Novenytermeles, 46, 227-234.

Ade-Omowaye, B. I. O., Akinwande, B. A., Bolarinwa, I. F., Adebiyi, A. O., 2008. Evaluation of tigernut (Cyperusesculentus) –wheat composite flour and bread. African Journal of Food Science, 2, 087-091.

Aguilera, J. M., 2005. Why food microstructure? Journal of Food Engineering, 67, 3–11.

Ahlborn, G. J., Pike, O. A., Hendrix, S. B., Hess, W. M., Huber, C. S., 2005. Sensory, mechanical, and microscopic evaluation of staling in low-protein and gluten-free breads. Cereal Chemistry, 82, 328-335.

Alvarez-Jubete, L., Auty, M., Arendt, E. K., Gallagher, E., 2010. Baking properties and microstructure of pseudocereal flours in gluten-free bread formulations. European Food Research and Technology, 230, 437–445.

Anderson, V. L. and Mc Lean, R. A. 1974. Design of experiments: A realistic approach. Markel Dekker, Inc., New York.

Anton, A. A. and Artfield, S. D. 2008. Hydrocolloids in gluten-free breads: A review. International Journal of Food Sciences and Nutrition, 59(1), 11-23.

AOAC, 1990. Association of Official Analytical Chemists, Official methods of analysis. Methods 923.03; 925.10; 963.15; 978.17; 982.14 and 991.43, 15th ed. Washington, DC.

AOAC, 1995. Association of Offcial Analytical Chemists, Official methods of analysis. Method 991.19, 15th ed. Washington, DC.

Arendt, E. K. and Moore, M. M., 2006. Gluten-free cereal based products. In: Bakery Products: Science and Technology, (Eds.) Hui, Y.H., Rosell, C.M., Gómez, M., Blackwell Publishing, NY, USA, pp. 471–497.

Arendt, E. K., Morrissey A., Moore M. M., Dal Bello, F., 2008. Gluten-free Breads. In: Gluten-free Cereral products and Beverages (Eds.) Arendt, E. K and Dal Bello, F, (1st ed.), Academic Press, Oxford, UK, pp. 289-321.

Babin, P., Della Valle, G., Chiron, H., Cloetens, P., Hoszowska, J., Pernot, P., Réguerre, A.L., Salvo, L., Dendievel, R., 2006. Fast X-ray tomography analysis of bubble growth and foam setting during breadmaking. Journal of Cereal Science, 43, 393–397.

Barcenas, M. E., and Rosell, C. M., 2005. Effect of HPMC addition on the microstructure, quality and aging of wheat bread. Food Hydrocolloids, 19, 1037–1043.

Bardella, M. T., Fredella, C., Prampolini, L., Molteni, N., Giunta, A. M., Bianchi, P. A., 2000. Body composition and dietary intakes in adult celiac disease patients consuming a strict gluten-free diet. American Journal of Clinical Nutrition, 72(4), 937-939.

BeMiller, J. N., 2008. Gluten-free Breads. In: Gluten-free Cereral products and Beverages. Academic Press, (Eds) Arendt, E. K and Dal Bello, F, (1st ed.), Oxford, UK, pp. 203-217.

BeMiller, J. N. and Whistler, R.L., 1996. Carbohydrates. In: Food Chemistry. (Eds.) O.R., Fennema and Marcel Dekker, New York, pp. 158-220

Berk, Z., 1976. Introduction to the biochemistry of foods. Elsevier, New York, pp. 116-117.

Bezerra, M. A., Santelli, R. E., Oliveira, E. P., 2008. Response Surface Methodology (RSM) as a tool for optimization in analytical chemistry. Talanta, 76, 965–977.

Blaiotta, G., Di Capua, M., Coppola, R., Aponte, M., 2012. Production of fermented chestnut purees by lactic acid bacteria. International Journal of Food Microbiology, 158, 195-202.

Bloksma, A. H. and Bushuk, W., 1988. Rheologhy and chemistry of dough. In: Wheat chemistry and technology. (Eds) Pomeranz, Y. American Association of Cereal Chemists, Inc., Minnesota, USA, pp. 131-219.

Bollaín, C. and Collar, C., 2004. Dough viscoelastic response ofhydrocolloid/enzyme/surfactant blends assessed by uni- and bi- axial extension measurements. Food Hydrocolloids, 18, 499–507.

Bonaduce, I., Brecoulaki, H., Colombini, M. P., Lluveras, A., Restivoo, V., Ribechini, E., 2007. Gas chromatographicmass spectrometric characterisation of plant gums in samples from painted works of art. Journal of Chromatography A, 1144, 275–282.

Box, G. E. P. and Wilson, K. B., 1951. On the experimental attainment of optimum conditions. Journal of the Royal Statistical Society (Series B), 13, 1–45.

Bower, S. L., 2006. What is Celiac Disease. In Celiac disease: a guide to living with gluten intolerance. (Eds.) S. L. Bower, M. K., Sharrett, and S., Plogste, (1st ed.). Demos Medical Publishing, New York, pp. 1-9.

Brites, C., Trigo, M. J., Santos, C., Collar, C., Rosell, C. M., 2010. Maize based Gluten-free bread: Influence of processing parameters on sensory and instrumental quality. Food and Bioprocess Technology, 3, 707-715.

Brockmole, C. L., Zabik, M. E., 1976.Wheat bran and middlings in white layer cakes. Journal of Food Science 41, 357–360.

Buffler., C. R., 1993. Microwave cooking and processing: Engineering fundamentals for the food scientist.Pp.6, 39, 54. New York, USA: Avi Book.

Campanella, O. H., Peleg, M., 1987. Squeezing flow viscosimetry of peanut butter. Journal of Food Science, 52, 180–184.

Catassi, C., Fornaroli, F., Fasano, A., 2002. Celiac disease: From basic immunology to bedside practice. Clinical and Applied Immunology Reviews, 3(1-2), 61-71.

Cato, L., Gan, J. J., Rafael, L. G. B., Small, D. M., 2004. Gluten free breads using rice flour and hydrocolloid gums. Food Australia, 56, 75–78.

Chaplin, M. F., 2003. Fibre and water binding. Proceeding of the Nutrition Society, 62, 223–227.

Chenlo, F., Moreira, R., Pereira, G., Silva, C. C., 2007. Evaluation of the rheological behaviour of chestnut (castanea sativa mill) flour pastes as function of water content and temperature. Electronic Journal of Environmental Agriculture and Food Chemistry, 6(2), 1794-1802.

Chin, N. L., Goh, S. K., Rahman, R. A., Hashim, D. M., 2007.Functional effect of fully hydrogenated palm oil-based emulsifiers on baking performance of white bread. International Journal of Food Engineering, 3, 1–15.

Chinma, C. E., Abu, J. O. Abubakar, Y. A., 2010. Effect of tigernut (Cyperusesculentus) flour addition on the quality of wheat-based cake. International Journal of Food Science and Technology, 45(8), 1746–1752.

Chinma, C.E., Abu, J.O., Akoma, S.N., 2012. Effect of Germinated Tigernut and MoringaFlour Blends on the Quality of Wheat-Based Bread. Journal of Food Processing and Preservation. ISSN 1745-4549, 1-7.

Ciclitira, P. J. and Moodie, S. J., 2003.Coeliac disease. Best Practice and Research Clinical Gastroenterology, 17(2), 181-195.

Codex standard for foods for special dietary use for persons intolerant to gluten, 1979. Codex Standard, 118, 1-3.

Collar, C., Santos, E., Rosell, C. M., 2007. Assessment of the rheological profile of fibre-enriched bread doughs by response surface methodology. Journal of Food Engineering, 78, 820–826.

Correia, P., Leitão, A., Beirão-da-Costa M. L., 2009. The effect of drying temperatures on morphological and chemical properties of dried chestnuts flours. Journal of Food Engineering, 90, 325–332.

Coskuner, Y., Ercan, R., Karababa, E., Nazlıcan, A. N., 2002. Physical and chemical properties of chufa (Cyperusesculentus L) tubers grown in the Çukurova region of Turkey.Journal of the Science of Food and Agriculture, 82(6), 625–631.

Crockett R., 2009. The Physicochemical Properties of Gluten-Free Dough with the Addition of Hydrocolloids and Proteins, MS Thesis, The Ohio State University, USA.

D'Appolonia, B. L., and Morad, M. M., 1981. Bread staling. Cereal Chemistry, 58, 186-190.

Datta, A. K. (1990). Heat and mass transfer in the microwave processing of food. Chemical Engineering Progress, 86, 47–53.

Datta, A.K., Greedipalli, S.S.R., Almeida, M.F., 2005. Microwave combination heating. Food Technology, 59, 36-40.

Datta, A. K. and Ni, H., 2002. Infrared and hot air-assisted microwave heating of foods for control of surface moisture. Journal of Food Engineering, 51, 355-364.

Datta A. K., Sahin S., Sumnu G., Keskin O., 2007. Porous media characterization of breads baked using novel heating modes. Journal of Food Engineering, 79, 106–116.

Decareau, R.V., 1992. Microwave Foods: New Product Development. Connecticut: Food Nutrition Press Inc., pp 117.

Demirekler, P., Sumnu, G., Sahin, S., 2004. Optimization of bread baking in halogenlamp-microwave combination oven by response surface methodology. European Food Research and Technology, 219, 341-347.

Demirkol, O. S., 2007. Investigation of physical properties of different cakes formulations during baking with microwave and infrared-microwave combination, PhD thesis, METU, Ankara.

Dobraszczyk, B. J., Grant, M., Campbell, Gan, Z., 2001. Bread: A unique food. In: Cereals and cereal products: chemistry and technology. (Eds) D.A.V. Dendy and B. J. Dobraszczyk. Gaithersburg, ML: Aspen Publications, pp. 182-232.

Edwards, W. P., 2007. Gums and Gelling Agents or Hydrocoollids. In: The Science of Bakery Products. The Royal Science of Chemistry. pp.125-127.

Ellis, H. J., Deward, D., Pollock, E. L., Gonzales-Cinca, N., Engel, W., Wieser, H., 2006. The toxicity recombinant HMW glutenin sub-units of wheat patients with celiac disease. In: M. Stern (Ed.), Proceedings of the 20 th Meeting of the Working Group on Prolamin Analysis and Toxicity. Verlag Wissenschaftiliche Scripten, Zwickau, pp. 35-40.

Falcone, P. M., Baiano, A., Conte, A., Mancini, L., Tromba, G., Zanini, F., Del Nobile, M. A., 2006.Imaging techniques for the study of food microstructure: a review. Advances in Food and Nutrition Research, 51, 205–263.

Falcone, P. M., Baiano, A., Zanini, F., Mancini., L., Tromba., G., Dresossi., D., Montanari, F., Scuor, N., Del Nobile, M. A., 2005. Three- dimensional quantitative analysis of bread crumb by x-ray microtomography. Food Engineering and Physical Properties, 70, 265–272.

Falcone, P. M, Baiano, A., Zanini, F., Mancini, L., Tromba., G., Montanari, F., Del Nobile, M. A., 2004. A novel approach to the study of bread porous structure: Phase-contrast X-ray Microtomography. Food Engineering and Physical Properties, 69, 38−43.

FAO STAT, 1999. Food and Agriculture Organization of the United States.Available:http://faostat.fao.org/site/339/default.aspx

Farrera-Rebollo, R. R., Salgado-Cruz., M. P., Chanona-Pérez, J., Gutiérrez-López, G. F., Alamilla-Beltrán, L., Calderón-Domínguez, G., 2012. Evaluation of Image Analysis Tools for Characterization of Sweet Bread Crumb Structure. Food Bioprocess and Technology, 5 (2), 474-484.

Fasano, A., Berti, I., Gerarduzzi, T., Not, T., Colletti, R. B., Drago, S., 2003. Prevalence of celiac disease in at-risk and not-at-risk groups in the United States. Archives of Internal Medicine, 163, 286-292.

Fredriksson, H., Silverio, J., Andersson, R., Eliasson., A. C., Aman., P., 1998. The influence of amylose and amylopectin characteristics on gelatinization and retrogradation properties of different starches. Carbohydrate Polymers, 35, 119-134.

Fu, J., Mulvaney, S. J., Cohen, J., 1997. Effect of added fat on the rheological properties of wheat flour doughs. Cereal Chemistry, 74, 304–311.

Gallagher, E., Gormley, T.R., Arendt, E.K., 2004. Recent advances in the formulation of gluten-free cereal-based products. Trends in Food Science and Technology, 15, 143-152.

Gambus, H., Nowotna, A., Ziobro, R., Gumul, D., Sikora, M., 2001. The effect of use of guar gum with pectin mixture in gluten-free bread. Electronic Journal Polish Agricultural University, 4, 1-13.

Gan, J., Rafael, L. G. B., Cato, L., Small, D. M., 2001. Evaluation of the potential of different rice flours in bakery formulations. In: Wooton, M., Batey, I.L., Wrigley, C.W. (Eds.), Cereals. Proceedings of the 51st Australian Cereal Chemistry Conference, 9, 13 September, 2001, Royal Australian Chemical Institute, Coogee, New South Wales, Australia, Werribee, Australia, pp. 309–312.

Ghiasi, K., Hoseney, R. C., Zeleznak, K., Rogers, D. E., 1984. Effects of waxy barley starch and reheating on firmness of bread crumb. Cereal Chemistry, 61, 281-285.

Giese, J., 1992. Advances in microwave food processing. Food Technology, 46 (9), 118-123.

Goesaert, H., Brijs, K., Veraverbeke, W. S., Courtin, C. M., Gebruers, K., Delcour, J. A., 2005. Wheat flour constituents: how they impact bread quality, and how to impact their functionality. Trends in Food Science and Technology 16, 12–30.

Gómez, M., Oliete, B., Caballero, P. A., Ronda, F., Blanco, C. A., 2008. Effect of nut paste enrichment on wheat dough rheology and bread volume. Food Science Technology International, 14, 57–65.

Gómez, M., Ronda, F., Blanco, C. A., Caballero, P. A., Apestequia, A., 2003. Effects of dietary fiber on dough rheology and bread quality. European Food Research Technology, 216, 51–56.

Gonzales-Barron, U. and Butler, F., 2008. Fractal texture analysis of bread crumb digital images. European Food Research and Technology, 226, 721–729.

Gray, J. A. and BeMiller, J. N., 2003. Bread staling: molecular basis and control. Comprehensive Review in Food Science and Food Safety, 2, 1–21.

Guarda, A., Rosell, C. M., Beneditode Barber, C., Galotto, M. J., 2004. Different hydrocolloids as bread improvers and antistaling agents. Food Hydrocolloids, 18,241–247.

Gudmundsson, M., 1994. Retrogradation of starch and the role of its components. Thermochimica Acta, 246, 329-341.

Gujral, H. S., Guardiola, I., Carbonell, J. V., Rosell, C. M., 2003a. Effect of cyclodextrinase on dough rheology and bread quality from rice flour. Journal of Agriculture and Food Chemistry, 51, 3814-3818.

Gujral, H. S., Haros, M., Rosell, C. M., 2003b. Starch Hydrolyzing Enzymes for Retarding the Staling of Rice Bread.Cereal Chemistry, 80, 750–754.

Gujral, S. G. and Rosell, C. M., 2004. Improvement of the breadmaking quality of rice flour by glucose oxidase. Food Research International 37, 75–81.

Hamer, R. J., 2005. Coeliac Disease: Background and biochemical aspects. Biotechnology Advances, 23(6), 401-408.

Hegenbert, S., 1992. Microwave quality: Coming of age. Food Product Design, 17, 29-52.

Hoseney, R. C., 1986. Principles of cereal science and technology, (2nd eds.), American Association of Cereal Chemists, Inc., St. Paul, Minnesota, USA, pp. 205–206.

Hug-Iten, S., Escher, F., Conde-Petit, B., 2003. Staling of bread: Role of amylose and amylopectin and influence of starch-degrading enzymes. Cereal Chemistry, 80, 654–661.

Impoco, G., Carrato, S., Caccamo, M., Tuminello, L., Licitra, G., 2007. Quantitative analysis of cheese microstructure using SEM imagery. Communications to SIMAI Congress, 2, 1-10.

Ishida, N., Takano, H., Naito, S., Isobe, S., Uemura, K., Haishi, T., Kose, K., Koizumi, M., Kano, H., 2001. Architecture of baked breads depicted by a magnetic resonance imaging, Magnetic Resonance Imaging, 19, 867–874.

Ji, Y., Zhu K., Zhou, H., Qian, H., 2010. Study of the retrogradation behavior of rice cakes using rapid visco analyzer, Fourier transform infrared spectroscopy and X-ray analysis. International food science and technology, 45, 871-876.

Kadan, R. S., Robinsonm, M. G., Thibodeux, D. P., Pepperman, A. B., 2001. Texture and other physiochemical properties of whole rice bread.Journal of Food Science, 66,940-944.

Kang, M.Y., Choi, Y.H., Choi, H. C., 1997. Effects of gums, fats and glutens adding on processing and quality of milled rice bread. Korean Society for Food Science and Technology 29, 700–704.

Karim, A.A., Norziah, M. H., Seow, C. C., 2000. Methods for the study of starch retrogradation.Food Chemistry, 71, 9-36.

Kassama, L. S. and Ngadi, M. O., 2005. Pore development and moisture transfer in chicken meat during deep-fat frying. Drying Technology, 23, 907–923

Kelkar, S., Stella, S., Boushey, C., Okos, M., 2011. Developing novel 3D measurement techniques and prediction method for food density determination, Procedia Food Science, 1, 483–491.

Keskin, S. O., Ozturk, S., Sahin, S., Koksel, H., Sumnu, G., 2005. Halogen lamp-microwave combination baking of cookies. European Food Research and Technology, 220, 546-551.

Keskin, S. O., Sumnu, S., Sahin, S., 2004. Bread baking in halogen lamp-microwave combination oven. Food Research International, 37, 489-495.

Keskin, S. O., Sumnu, S., Sahin, S., 2007. A study on the effects of different gums ondielectric properties and quality of breads baked in infrared-microwave combination oven. European Food Research and Technology, 224(3), 329-334.

Kohajdova, Z. and Karovicova, J., 2009. Application of hydrolloids as baking improvers. Chemical Papers, 63, 26–38.

Kohajdová, Z., Karovičová, J., Schmidt, S., 2009. Significance of Emulsifiers and Hydrocolloids in Bakery Industry. Acta Chimica Slovaca, 2, 46 – 61.

Kokelaar, J. J., Garritsen, J. A., Prins, A., 1995. Surface rheological properties of sodium stearoyl-2-lactylate (SSL) and diacetyl tar- taric esters of mono (and di) glyceride (DATEM) surfactants after a mechanical surface treatment in relation to their bread improv- ing abilities. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 95, 69–77.

Kök, M. S., Hill, S. E., Mitchell, R., 1999. A Comparison of the rheological behaviour of crude and refined locust bean gum preparations during thermal processing. Carbohydrate Polymers, 38, 261–265.

Köksel, F., 2009. Effects of xanthan and guar gums on quality and staling of gluten-free cakes baked in microwave infrared combination oven, MS Thesis, METU, Ankara.

Krog, N., 1981. Theoretical aspects of surfactants in relation to their use in breadmaking.Cereal Chemistry, 58(3), 158-164.

Langton, M., Aström, A., Hermansson, A., 1996. Texture as a reflection of microstructure. Food Quality and Preference, 7(3-4), 185-191.

Lazaridou, A., Duta, D., Papageorgiou, M., Belc, N., Biliaderis, C.G., 2007. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. Journal of Food Engineering, 79, 1033–1047.

Lebesi, D. M. and Tzia, C., 2009. Effect of the addition of different dietary fiber and edible cereal bran sources on the baking and sensory characteristics of cupcakes. Food Bioprocess Technology.

Lee, M. and Lee, Y., 2006. Properties of gluten-free rice breads using different rice flours prepared by dry, wet and semi-wet milling. Food Engineering Progress 10, 180– 185.

Leray, G., Oliete, B., Mezaize, S., Chevallier, S., De Lamballerie, M., 2010. Effects of freezing and frozen storage conditions on the rheological properties of different formulations of non-yeasted wheat and gluten-free bread dough. Journal of Food Engineering,100 (1), 70-76.

Lopez, A. C. B., Pereira, A. J. G., Junqueira, R. G., 2004. Flour mixture of rice flour, corn and cassava starch in the production of gluten free white bread. Brazilian Archives of Biology and Technology 47 (1), 63–70.

Malkin, A. Y. and Isayev, A. I., 2006. Pressure corrections. In: Rheology: concepts, methods, and applications (1st ed.). ChemTac Publishing, Toronto, pp. 253-320.

Mandala, I. G., Savvas, T. P., Kostaropoulos, A. E., 2004. Xanthan and locust bean gum influence on the rheology and structure of a white model-sauce. Journal of Food Engineering, 64, 335-342.

Martin, M. L. and Hoseney, R. C., 1991. A mechanism of bread firming. 2. Role of starch hydrolyzing enzymes. Cereal Chemistry, 68, 503-507.

McCarthy, D. F., Gallagher, E., Gormley, T. R. Schober, T. J., Arendt, E. K., 2005. Application of response surface methodology in the development of gluten-free bread. Cereal Chemistry, 82 (5), 609-615.

McLoughlin, R., Sebastian, S. S, Qasim, A., McNamara, D., O’Connor, H. J., Buckley, M., O’Morain, C., 2003. Coeliac disease in Europe, Aliment Pharmacology Therapeutics, 18, 45–48.

Meda, V., Orsat, V., Ragvahan, V., 2005. Microwave heating and the dielectric properties of foods In: The microwave processing of foods, (Eds.) Helmar Schubert and Mark Regier, CRC Press, Washington DC, USA, pp. 61-73.

Mendoza, N., 2005. Coeliac disease: and overview of the diagnosis, treatment and management. British Nutrition Bulletin. 30, 231-236.

Metaxas, A. C., and Meredith, R. J., 1983. Industrial microwave heating. London: Peter Peregrimus, pp. 6, 80.

Mettler, E. and Seibel, W., 1993. Effects of emulsifiers and hydrocolloids on whole wheat bread quality: a response surface methodology study. Cereal Chemistry, 70(4), 373-7.

Mezaize, S., Chevallier, S., Le Bail, A., De Lamballerie, M., 2009. Optimization of gluten-free formulations for French-style breads. Journal of Food Science, 74 (3), 140-146.

Moore, M. M., Heinbockel, M., Dockery, P., Ulmer, H. M., Arendt, E. K., 2006. Network formation in gluten-free bread with application of transglutaminase. Cereal Chemistry, 83, 28-36.

Moore, M. M., Juga, B., Schober, T. J., Arendt, E. K., 2007. Effect of lactic acid bacteria onproperties of gluten-free sourdoughs, batters, and quality and ultrastructure ofgluten-free bread. Cereal Chemistry 84, 357–364.

Moore, M. M, Schober, T. J., Peter, D., Arendt, E. K., 2004. Textural Comparisons of Gluten-Free and Wheat-Based Doughs, Batters, and Breads. Cereal Chemisty, 81(5), 567-575.

Moreira, R., Chenlo, F., Torres, M. D., Prieto, D. M., 2010. Influence of particle size on the rheological behavior of chestnut flour doughs. Journal of Food Engineering, 100(2), 270-277.

Moreira, R., Chenlo, F., Torres, M. D., 2011a. Rheology of commercial chestnut flour doughs incorporated with gelling agents. Food Hydrocolloids, 25(5), 1361-1371.

Moreira, R., Chenlo, F., Torres, M. D., 2011b. Rheological properties of commercial chestnut flour doughs with different gums. International Journal of Food Science and Technology, 46(10), 2085-2095.

Morgan, K. R., Hutt, L., Gerrard, J., Every, D., Ross, M., Gilpin, M., 1997.Staling in Starch Breads: The Effect of Antistaling α-Amylase. Starch, 49(2), 54-59.

Mudgett, R. E., 1982. Electrical properties of foods in microwave processing. Food Technology, 36: 109-115.

Mujumdar, A. S., 2007. Handbook of industrial drying, Chapter 18, Infrared drying, Cristina Ratti, Arun S. Mujumdar 423-438.

Myers, R. H. and Montgomery, D. C., 2002. Response Surface Methodology (RSM): Process and Product Optimization Using Designed Experiments. Wiley Interscience Publication, New York, USA. pp. 1–3.

Nelson, A. L., 2001. High Fiber Ingredients. (1st eds.) Eagen Press Handbook Series, AACC, Minnesota. pp. 44–61.

Niewinski, M. M. and MS, R. D., 2008. Advances in Celiac Disease and Gluten-Free Diet, Journal of the American Dietetic Association, 661-672.

Nishita, K. D., Roberts, R. L., Bean, M. M., Kennedy, B. M., 1976. Development of a yeast-leavened rice-bread formula. Cereal Chemistry, 53, 626-635.

Nunes, M. H. B., Moore, M. M., Ryan, L. A. M., Arendt, E. K., 2009. Impact of emulsifiers on the quality and rheological properties of gluten-free breads and batters. European Food Research and Technology, 228, 633–642.

Oladele, A. K. and Aina, J. O., 2007. Chemical composition and functional properties of flour produced from two varieties of tigernut (Cyperusesculentus), African Journal of Biotechnology, 6(21), 2473-2476.

Olsson, E. E. M., Trägårdh, A. C., Ahrné, L. M., 2005. Effect of Near-infrared Radiation and Jet Impingement Heat Transfer on Crust Formation of Bread, Journal of Food Science, 70 (8), 484-491.

Onyango, C., Unbehend, G., Lindhuaer, M. G., 2009. Effect of cellulose-derivatives and emulsifiers on creep-recovery and crumb properties of gluten-free bread prepared from sorghum and gelatinised starch. Food Research International, 42, 949–955.

Orthoefer, F., 2008. Applications of emulsifiers in baked foods. In: Food Emulsifiers and Their Applications, (Eds.) Gerard, L. H. and Hartel, R. W., (2nd ed.), Springer, New York, NY, USA, pp. 211-233.

Osella, C.A., Sanchez, H.D., Carrara, C. R., Torre, M. A. D. L., Buera, M. P., 2005. Water Redistribution and Structural Changes of Starch During Storage of a Gluten-free Bread. Starch/Stärke, 57, 208-216.

Osorio, F., Gahona, E., Alvarez, F., 2003. Water absorption effects on biaxial extensional viscosity of wheat flour dough. Journal of Texture Studies 34, 147– 157.

Otsu, N., 1979. A threshold selection method from gray-level histograms. IEEE Transactions on Systems Man Cybernet, SMC-9, 62–66.

Ozkoc, S. O., Sumnu, G., Sahin, S., 2009a. The effects of gums on macro and micro-structure of breads baked in different ovens. Food Hydrocolloids, 23, 2182–2189.

Ozkoc, S. E., Sumnu, G., Sahin, S., Turabi, E., 2009b. Investigation of physicochemical of breads baked in microwave and infrared-microwave combination ovens during storage. European Food Research and Technology, 217, 8-19.

Ozmutlu, O., Sumnu, G., Sahin, S., 2001. Assessment of proofing of bread dough in the microwave oven. European Food Research Technology, 212, 487–490.

Park, S. H., Wilson, J. D., Chung, O. K., Seib, P. A., 2004. Size distribution and properties of wheat starch granules in relation to crumb score of pup-loaf bread. Cereal Chemistry, 81, 699–704.

Patel, B. K., Waniska, R. D., Seetharaman, K., 2005. Impact of different baking processes on bread firmness and starch properties in breadcrumb. Journal of Cereal Science, 42,173–184.

Pateras, I.M.C., 2007. Bread spoilage and staling. In: Technology of Breadmaking, Cauvain, S.P., Young, L.S. (Eds.), Springer, UK, pp. 275- 298,

Peressini, D., Pin, M., Sensidoni, A., 2011. Rheology and breadmaking performance of rice-buckwheat batters supplemented with hydrocolloids. Food Hydrocolloids, 25 (3), 340-349.

Phimolsiripol, Y., Mukprasirt, A., Schoenlechner, R., 2012. Quality improvement of rice-based gluten-free bread using different dietary fibre fractions of rice bran. Journal of Cereal Science, 56 (2), 389–395.

Polaki, A., Xasapis, P., Fasseas, C., Yanniotis, S., Mandala, I., 2010. Fiber and hydrocolloid content affect the microstructural and sensory characteristics of fresh and frozen stored bread. Journal of Food Engineering, 97, 1–7.

Pomeranz, Y., Shogren, M. D., Finney, K. F., Bechtel, D. B., 1977. Fibre in breadmaking–effects on functional properties. Cereal Chemistry, 54, 25-41.

Primo-Martín, C., van Dalen, G., Meinders, M. B. J., Don, A. Hamer, R. H., Van Vliet, T., 2010. Bread crispness and morphology can be controlled by proving conditions. Food Research International, 43, 207–217.

Ptaszek, P., Lukasiewicz, M., Achremowicz, B., Grzesik, M., 2007. Interaction of hydrocolloid networks with mono- and oligosaccharides. Polymer Bulletin, 58, 295-303.

Purhagen J. K., Sjöö, M. E., Eliasson A., 2012. The anti-staling effect of pre-gelatinized flour and emulsifier in gluten-free bread. European Food Research Technology, 235, 265–276.

Ranjan, R., Irudayaraj, J., Jun, S. 2002. Simulation of infrared drying process. Drying Technology, 20(2), 363-379.

Renzetti, S., Dal Bello, F., Arendt, E. K., 2004. Microstructure, fundamental rheology and baking characteristics of batters and breads from different gluten-free flours treated with a microbial transglutaminase, Journal of Cereal Science, 48(1), 33-45.

Renzetti, S. and Arendt, E. K., 2009. Effect of protease treatment on the baking quality of brown rice bread: From textural and rheological properties to biochemistry and microstructure, Journal of Cereal Science, 50 (1), 22-28.

Resurreccion, A. V. A., 2008. Consumer sensory testing for food product development. In: Developing New Food Products for a Changing Marketplace, (Eds.), Brody, Aaron L., Lord, John B. (2nd ed.), CRC Press Taylor and Francis Group, FL, USA, pp. 5–25.

Ribotta, P. D., Ausar, S. F., Morcillo, M. H., Perez, G. T., Beltramo, D. M., Leon, A. E., 2004a. Production of gluten-free bread using soybean flour. Journal of the Science of Food and Agriculture, 84, 1969–1974.

Ribotta, P. D., Perez, G. T., Leon, A. E., Anon, M. C., 2004b. Effects of emulsifier and guar gum on micro structural, rheological and baking performance of frozen bread dough. Food Hydrocolloids, 18, 305-313.

Ribotta, P. D., Cuffini, S., Leon, A. E., 2004c. The staling of bread: X-ray diffraction study. European Food and Research Technology, 218, 219-223.

Roccia P., Ribotta P. D., Ferrero C., Perez G.T., Leon A. E., 2012. Enzymes action on wheat-soy dough properties and bread quality. Food Bioprocess and Technology, 5, 1255-1264.

Rosell, C. M. and Collor, C., 2007. Rise based products. In: Handbook of Food Products Manufacturing (Ed) H.Y. Hui. Hoboken, NJ: Wiley-Interscience, pp. 523–523.

Rosell, C. M. and Marco, C., 2008. Rice. In: Gluten-free Cereal Products and Beverages, Arendt, E. K and Dal Bello, F, (1st ed.), Academic Press, Oxford, UK, pp. 81-101.

Rosell C. M., Rojas, J. A., Benedito de Barber, C., 2001. Influence of hydrocolloids on dough rheology and bread quality. Food Hydrocolloids, 15, 75–81.

Rosell, C. M. and Santos, E., 2010. Impact of fibers on physical characteristics of fresh and staled bake off bread. Journal of Food Engineering, 98, 273–281.

Rouille, J., Valle, G. D., Devaux, M. F., Marion, D., Dubreil, L., 2005. French bread loaf volume variations and digital imageanalysis of crumb grain changes induced by the minor components of wheat flour. Cereal Chemistry, 82, 20–27.

Russ, J. C., 2004. Image analysis of food microstructure. Boca Raton, London.

Sabanis, D., Lebesi, D., Tzia, C., 2009. Effect of dietary fibre enrichment on selected properties of gluten-free bread. Food Science and Technology, 42, 1380–1389.

Sacchetti, G., Pinnavaia, G. G., Guidolin E., Dalla-Rosa M., 2004. Effects of extrusion temperature and feed composition on the functional, physical and sensory properties of chestnut and rice flour-based snack-like products. Food Research International, 37, 527-534.

Sahin S. and Sumnu S. G., 2006. Physical Properties of Foods. New York. Springer, USA, pp.27, 241-242.

Sakiyan, O., Sumnu, G., Sahin, S., Meda, V., Koksel, H., Chang, P., 2011. A study on degree of starch gelatinization in cakes baked in three different ovens. Food Bioprocess Technology, 4, 1237-1244.

Sanchez, H. D., Osella, C. A., De La Torre, M. A., 2002. Optimization of gluten-free bread prepared from cornstarch, rice flour, cassava starch. Journal of Food Science. 67, 416-419.

Sanchez, H. D., Osella, C. A., De La Torre, M. A., 2004. Use of response surface methodology to optimize gluten-free bread fortified with soy flour and dry milk. Food Science and Technology International, 10, 5-9.

Sanchez-Pardo, M. E., Ortiz-Moreno, A., Mora-Escobedo, R., Chanona-Perez, J. J., Necoechea-Mondragon, H., 2008. Comparison of crumb microstructure from pound cakes baked in a microwave or conventional oven. LWT- Food Science and Technology, 41, 620–627.

Sánchez-Zapata, E., Munoz, C. M., Fuentes, E., Fernández-López, J., Sendra, E., Sayas, E., 2010. Effect of tigernut fibre quality characteristics of pork burger. Meat Science, 85, 70–76.

Santos, E., Collar, C., Rosell, M. C., 2008. Gelatinisation and retrogradation kinetics of high fibre-wheat flour blends: a calorimetric approach. Cereal Chemistry, 85, 455–463.

Sapirstein, H. D., Roller, R., Bushuk, W., 1994. Instrumental measurement of bread crumb grain by digital image analysis. Cereal Chemistry, 71(4), 383–391.

Sarkar, N. and Walker, L.C., 1995. Hydration-dehydration properties of.methylcellulose and hydroxyprophylmethylcellulose. Carbohydrate Polymers, 27, 177–185.

Schober, T. J., Messerschmidt, M., Bean, S. R., Park, S., Arendt, E. K., 2005. Gluten-Free Bread from Sorghum: Quality Differences Among Hybrids. Cereal Chemistry, 82 (4), 394-404.

Schober, T. J., Bean, S. R., Boyle, D. L., 2007. Gluten-free sorghum bread improved by sourdough fermentation: biochemical, rheological, and microstructural background. Journal of Agricultural and Food Chemistry 55, 5137–5146.

Sciarini, L. S., Ribotta, P. D., Leon, A. E., Perez, G. T., 2010a. Influence of gluten-free flours and their mixtures on batter properties and bread qualities. Food Bioprocess Technology, 3, 577–585.

Sciarini, L. S., Ribotta, P. D., León, A. E., Pérez, G. T., 2010b. Effect of hydrocolloids on gluten-free batter properties and bread quality. International Journal of Food Science and Technology, 45, 2306-2312.

Sciarini, L. S. Ribotta, P. D. León, A. E., Pérez G. T., 2012. Incorporation of several additives into gluten free breads: Effect on dough properties and bread quality. Journal of Food Engineering, 111(4), 590-597.

Selomulyo, V. O. and Zhou, W., 2007. Frozen bread dough: Effects of freezing storage and dough improvers. Journal of Cereal Science, 45, 1-17.

Sepulveda, D. R. and Barbosa-Canovas, G. V., 2003. Heat transfer in food products. In: Transport phenomena in food processing. J.W. (Eds.) Chanes, J.F. Velez-Ruiz, G.V. Barbosa-Canovas. Food Preservation Technology Series.

Seyhun, N., 2002. Retardation of staling of microwave baked cakes, MS Thesis, METU, Ankara.

Shyu, Y. S., Sung, W. C., Chang, M. H., Hwang, J. Y., 2008. Effect of Far Infrared Oven on the Qualities of Bakery Products, 6 (2-3), 105-118.

Shogren, M. D., Pomeranz, Y., Finney, K. F., 1981. Counteracting the deleterious effects of fibre in breadmaking. Cereal Chemisry 58, 142–144.

Sievert, D., Pomeranz, Y., Abdelrahman, A., 1990. Functional properties of soy polysaccharides and wheat bran in soft wheat products. Cereal Chemistry 67, 10–13.

Sivaramakrishnan, H. P., Senge, B., Chattopadhyay, P. K., 2004. Rheological properties of rice dough for making rice bread.Journal of Food Engineering, 62(9), 37–45.

Smits, A. L. M., Ruhnau, F. C., Vliagenthart, J. F. G., Van Soest, J. J. G., 1998. Ageing of starch based systems as observed with FT-IR and solid state NMR spectroscopy. Starch/Stärke, 50, 478-483.

Stampfli, L. And Nersten, B., 1995. Emulsifiers in bread making. Food Chemistry, 52, 353-360.

Stauffer, C. E., 1990. Leaving Agent. In: Functional Additives for Bakery Foods. AVI book, New York, USA, pp.183.

Steffe, J.F., 1996. Rheological methods in food process engineering. MI. Freeman Press.

Sumnu, G., 1997. Optimization of microwave baking of cakes, PhD Thesis, METU, Ankara.

Sumnu, G., 2001. A review on microwave baking of foods. International Journal of Food Science and Technology, 36**,** 117-127.

Sumnu, G., Koksel, F., Sahin, S., Basman, A., Meda, V., 2010. The effects ofxanthan and guar gums on staling of gluten-free rice cakes baked in different ovens. International Journal of Food Science and Technology, 45 (1), 87-93.

Sumnu, G. S., Ndife, M. K., Bayındırlı, L., 2000. Effects of sugar, protein and water content on wheat starch gelatinization due to microwave heating. European Food Research Technology 211, 169–174.

Sumnu G. and Sahin S., 2005a. Recent Developments in Microwave Processing. In: Emerging Technologies for Food Processing. D. Sun, (Ed). (pp. 419-444), Elsevier, UK.

Sumnu, G. and Sahin, S., 2005b. Baking using microwave processing. In: The Microwave Processing of Foods. H. Schubert and M. Regier (Eds), Woodhead Publishing Limited. Cambridge, pp.119-141.

Sumnu, G., Sahin, S., Sevimli, K. M., 2005. Microwave, infrared and infrared-microwave combination baking of cakes. Journal of Food Engineering, 71, 150–155.

Sweeny, R. A., Rexford, P. R., 1987. Comparison of LECO FP-228 ‘‘Nitrogen Determinator” with AOAC Copper Catalyst Kjeldahl Method for Crude Protein. Journal of the Association of Official Analytical Chemists, 70, 1028– 1030.

Sworn, G., 2000. Xanthan gum. In: Philips and Williams, (1st ed.), Handbook of hydrocolloids, Woodhead, Cambridge, England, pp. 103-115.

Tamstorf, S., 1983. Emulsifiers for bakery and starch products. Grindsted Technical Paper, TP 9-le, pp. l-27.

Tandoruk, O., 2005. Çölyak dosyası. Dünya gıda dergisi, pp. 15–25.

Tang, J., 2005. Dielectric properties of foods, Chapter 2. The microwave processing of foods, Edited by Helmar Schubert and Mark Regier, CRC Press, Washington DC, USA, 22-38.

Thomson, D., 1982. Response Surface Experimentation. Journal of Food Processing and Preservation, 6, 155-188.

Tlapale-Valdivia, A. D., Chanona-Pérez, J. J., Mora-Escobedo, R., Farrera-Rebollo, R. R., Gutiérrez-López, G. F., Calderón- Domínguez, G., 2010. Dough and crumb grain changes during mixing and fermentation and their relation with extension properties and bread quality of yeasted sweet dough. International Journal of Food Science and Technology, 45(3), 530–539.

Toufeili, I., Dagher, S., Shadarevian, S., Noureddine, A., Sarakbi, M., Farran, M. T., 1994. Formulation of gluten-free pocket type flat breads: optimization of methylcellulose, gum arabic, and egg albumen levels by response surface methodology. Cereal Chemistry, 71(6), 594-601.

Tronsmo, K. M., Faergestad, E. M., Longva, A., Schofield, J. D., Magnus, E. M., 2002. A Study of how Size Distribution of Gluten Proteins, Surface Properties of Gluten and Dough Mixing Properties Relate to Baking Properties of Wheat Flours. Journal of Cereal Science, 35(2), 201-214.

Turabi, 2010. Design of gluten-free rice cake formulations for baking in infrared-microwave combination oven. PhD Thesis, METU, Ankara.

Turabi, E., Sumnu, G., Sahin, S., 2008a. Rheological properties and quality of rice cakes formulated with different gums and an emulsifier blend. Food Hydrocolloids, 22, 305–312.

Turabi, E., Sumnu, G., Sahin, S., 2008b. Optimization of baking of rice cakes in infrared microwave combination oven by response surface methodology. Food and Bioprocess Technology, 1: 64–73.

Turabi, E., Sumnu, G., Sahin, S., 2010. Quantitative analysis of macro and microstructure of gluten-free rice cakes containing different types of gums baked in different ovens. Food Hydrocolloids, 24 (8), 755-762.

Turkey Standards Institution (TSE) standard for gluten reduced and gluten-free foods, 2005. (TS 13143).

Urlacher, B. and Noble, O., 1997. Xanthan. In: Thickening and gelling agents for food. In: A. Imeson (Ed.), Chapman and Hall, London. pp. 84.

Van Der Borght, A., Goesaert, H., Veraverbeke, W. S., Delcour, J., 2005. Fractionation of wheat and wheat flour into starch and gluten: overview of the main processes and the factors involved. Journal of Cereal Science, 41(3), 221-237.

Van Riemsdijk, L. E., Van der Goot, A. J., Hamer, R. J., Boom, R. M., 2011. Preparation of gluten-free bread using a meso-structured whey protein particle system. Journal of Cereal Science, 53, 355-361.

Van Soest, J. J. G., de Wit, D., Tournois, H., Vliegenthart, J. F. G., 1994. Retrogradation of potato starch as studied by Fourier transform infrared-spectroscopy. Starch/Stärke, 46, 453-457.

Van Soest, J. J. G., Tournois, H., de Wit, D., Vliegenthart, J. F. G., 1995. Short-range structure in (partically) crystalline potato starch determined with attenuated total reflectance Fourier-transform IR spectroscopy. Carbohydrate research, 279,201-214.

Varavinit, S., Shobsngob, S., Varanyanondc, W., Chinachotid, P., Naivikule, O., 2003. Effect of Amylose Content on Gelatinization, Retrogradation and Pasting Properties of Flours from Different Cultivars of Thai Rice.Starch/Stärke, 55,410–415.

Wang, S, Austin, P, Bell, S., 2011. It's a maze: The pore structure of bread crumbs. Journal of Cereal Science, 54, 203-210.

Wang, T.L., Bogracheva, T. Ya., Hedley, C. L., 1998. Starch: as simple as A, B, C?. Journal of experimental botany, 49, 481-502.

Wielinga, W.C., and Maehall, A. G., 2000. Galactomannans. In: Philips and Williams, (1st ed.), Handbook of hydrocolloids (pp. 137-155). Woodhead, Cambridge, England.

Wilson, R. H., Goodfellow, B. J., Belton, P.S., 1991. Comparison of Fourier Transform Mid Infrared Spectroscopy and Near Infrared Reflectance Spectroscopy with Differential Scanning Calorimetry for the Study of the Staling of Bread. Journal of the Science of Food and Agriculture, 54, 471-483.

Zayas, I. Y., 1993. Digital image texture analysis for bread crumb grain evaluation. Cereal Foods World, 38(10), 760–766.

Zghal, M. C., Scanlon, M. G., Sapirstein, H. D., 1999. Prediction of bread crumb density by digital image analysis. Cereal Chemistry, 76, 734–742.

Zghal, M. C., Scanlon, M. G., Sapirstein, H. D., 2002. Cellular structure of bread crumb and its influence on mechanical properties. Journal of Cereal Science, 36, 167−176.

APPENDIX A

STATISTICAL ANALYSIS

Table A. 1. Two-way ANOVA for viscosity values of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Emulsifier addition	2	Yes, no
Gum types	7	Xanthan, guar, xanthan-guar, LBG, LBG-guar, HPMC, pectin

Source	DS	SS	MS	F	P
Emulsifier Purawave	1	1005.8	1005.84	9.24	0.009
Gum types	6	13780	2296.66	21.09	0.000
Interaction	6	1425.6	237.59	2.18	0.107
Error	14	1524.5	108.89		
Total	27	17735.8			

Source	DS	SS	MS	F	P
Emulsifier DATEM	1	31222	31222.3	3955.77	0.000
Gum types	6	52645	8774.2	1111.67	0.000
Interaction	6	23026	3837.7	486.22	0.000
Error	14	111	7.9		
Total	27	107004			

Table A. 2. Two-way ANOVA for consistency index (K) values of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Emulsifier addition	2	Yes, no
Gum types	7	Xanthan, guar, xanthan-guar, LBG, LBG-guar, HPMC, pectin

Source	DF	SS	MS	F	P
Emulsifier Purawave	1	0.29	0.288	0.06	0.814
Gum types	6	2250.37	375.062	74.74	0.000
Interaction	6	59.93	9.988	1.99	0.135
Error	14	70.26	5.018		
Total	27	2380.85			

Source	DF	SS	MS	F	P
Emulsifier DATEM	1	3709.9	3709.9	93.87	0.000
Gum types	6	7450.5	1241.75	31.42	0.000
Interaction	6	2010.1	335.02	8.48	0.001
Error	14	553.3	39.52		
Total	27	13723.8			

Table A. 3. One-way ANOVA for consistency index (K) values of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor Levels	Values
Gluten-free bread formulations 24	Control 2 (wheat), DATEM, Purawave, xanthan, xanthan-DATEM, Xanthan-Purawave, guar, guar-Purawave, guar-DATEM, HPMC, HPMC-DATEM, HPMC-Purawave, LBG, LBG-DATEM, LBG-Purawave, pectin, pectin-Purawave, pectin-DATEM, xanthan-guar, xanthan-guar-Purawave, xanthan-guar-DATEM, xanthan-LBG, xanthan-LBG-Purawave, xanthan-LBG-DATEM

Source	DF	SS	MS	F	P
Gluten-free bread formulations	23	16990.5	738.7	29.27	0.000
Error	24	605.7	25.2		
Total	47	17596.2			

Level	N	Mean	StDev
Control 2 (wheat)	2	5.85	0.071
DATEM	2	1.05	0.071
Guar	2	10.35	2.051
Guar-DATEM	2	50.8	5.94
Guar-Purawave	2	10.2	0.424
HPMC	2	3.5	1.697
HPMC-DATEM	2	4.8	2.404

HPMC-Purawave	2	5.05	0.071
LBG	2	4.6	0.141
LBG-DATEM	2	14.1	1.414
LBG-Purawave	2	2.72	0.82
LBG-xanthan	2	15.9	0.99
LBG-xanthan-DATEM	2	46.1	20.365
LBG-xanthan-Purawave	2	13.9	2.687
Pectin	2	0.7	0.141
Pectin-DATEM	2	3.4	0.424
Pectin-Purawave	2	2.2	0.354
Purawave	2	0.25	0.212
Xanthan	2	30.05	3.041
Xanthan-DATEM	2	61.2	5.233
Xanthan-guar	2	15.85	0.778
Xanthan-guar-DATEM	2	61.7	7.071
Xanthan-guar-Purawave	2	21.8	5.94
Xanthan-Purawave	2	26.5	2.97

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Gluten-free bread formulations= control 2 (wheat) subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
DATEM	-25.26	-4.8	15.66
Guar	-15.96	4.5	24.96
Guar-DATEM	24.49	44.95	65.41

Guar-Purawave	-16.11	4.35	24.81
HPMC	-22.81	-2.35	18.11
HPMC-DATEM	-21.51	-1.05	19.41
HPMC-Purawave	-21.26	-0.8	19.66
LBG	-21.71	-1.25	19.21
LBG-DATEM	-12.21	8.25	28.71
LBG-Purawave	-23.59	-3.13	17.33
LBG-xanthan	-10.41	10.05	30.51
LBG-xanthan-DATEM	19.79	40.25	60.71
LBG-xanthan-Purawave	-12.41	8.05	28.51
Pectin	-25.61	-5.15	15.31
Pectin-DATEM	-22.91	-2.45	18.01
Pectin-Purawave	-24.11	-3.65	16.81
Purawave	-26.06	-5.6	14.86
Xanthan	3.74	24.2	44.66
Xanthan-DATEM	34.89	55.35	75.81
Xanthan-guar	-10.46	10	30.46
Xanthan-guar-DATEM	35.39	55.85	76.31
Xanthan-guar-Purawave	-4.51	15.95	36.41
Xanthan-Purawave	0.19	20.65	41.11

Gluten-free bread formulations = DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Guar	-11.16	9.3	29.76
Guar-DATEM	29.29	49.75	70.21

Guar-Purawave	-11.31	9.15	29.61
HPMC	-18.01	2.45	22.91
HPMC-DATEM	-16.71	3.75	24.21
HPMC-Purawave	-16.46	4	24.46
LBG	-16.91	3.55	24.01
LBG-DATEM	-7.41	13.05	33.51
LBG-Purawave	-18.79	1.67	22.13
LBG-xanthan	-5.61	14.85	35.31
LBG-xanthan-DATEM	24.59	45.05	65.51
LBG-xanthan-Purawave	-7.61	12.85	33.31
Pectin	-20.81	-0.35	20.11
Pectin-DATEM	-18.11	2.35	22.81
Pectin-Purawave	-19.31	1.15	21.61
Purawave	-21.26	-0.8	19.66
Xanthan	8.54	29	49.46
Xanthan-DATEM	39.69	60.15	80.61
Xanthan-guar	-5.66	14.8	35.26
Xanthan-guar-DATEM	40.19	60.65	81.11
Xanthan-guar-Purawave	0.29	20.75	41.21
Xanthan-Purawave	4.99	25.45	45.91

Gluten-free bread formulations= Guar subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Guar-DATEM	19.99	40.45	60.91
Guar-Purawave	-20.61	-0.15	20.31

HPMC	-27.31	-6.85	13.61
HPMC-DATEM	-26.01	-5.55	14.91
HPMC-Purawave	-25.76	-5.3	15.16
LBG	-26.21	-5.75	14.71
LBG-DATEM	-16.71	3.75	24.21
LBG-Purawave	-28.09	-7.63	12.83
LBG-xanthan	-14.91	5.55	26.01
LBG-xanthan-DATEM	15.29	35.75	56.21
LBG-xanthan-Purawave	-16.91	3.55	24.01
Pectin	-30.11	-9.65	10.81
Pectin-DATEM	-27.41	-6.95	13.51
Pectin-Purawave	-28.61	-8.15	12.31
Purawave	-30.56	-10.1	10.36
Xanthan	-0.76	19.7	40.16
Xanthan-DATEM	30.39	50.85	71.31
Xanthan-guar	-14.96	5.5	25.96
Xanthan-guar-DATEM	30.89	51.35	71.81
Xanthan-guar-Purawave	-9.01	11.45	31.91
Xanthan-Purawave	-4.31	16.15	36.61

Gluten-free bread formulations= Guar-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Guar-Purawave	-61.06	-40.6	-20.14
HPMC	-67.76	-47.3	-26.84
HPMC-DATEM	-66.46	-46	-25.54

HPMC-Purawave	-66.21	-45.75	-25.29
LBG	-66.66	-46.2	-25.74
LBG-DATEM	-57.16	-36.7	-16.24
LBG-Purawave	-68.54	-48.08	-27.62
LBG-xanthan	-55.36	-34.9	-14.44
LBG-xanthan-DATEM	-25.16	-4.7	15.76
LBG-xanthan-Purawave	-57.36	-36.9	-16.44
Pectin	-70.56	-50.1	-29.64
Pectin-DATEM	-67.86	-47.4	-26.94
Pectin-Purawave	-69.06	-48.6	-28.14
Purawave	-71.01	-50.55	-30.09
Xanthan	-41.21	-20.75	-0.29
Xanthan-DATEM	-10.06	10.4	30.86
Xanthan-guar	-55.41	-34.95	-14.49
Xanthan-guar-DATEM	-9.56	10.9	31.36
Xanthan-guar-Purawave	-49.46	-29	-8.54
Xanthan-Purawave	-44.76	-24.3	-3.84

Gluten-free bread formulations =Guar-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
HPMC	-27.16	-6.7	13.76
HPMC-DATEM	-25.86	-5.4	15.06
HPMC-Purawave	-25.61	-5.15	15.31
LBG	-26.06	-5.6	14.86
LBG-DATEM	-16.56	3.9	24.36

LBG-Purawave	-27.94	-7.48	12.98
LBG-xanthan	-14.76	5.7	26.16
LBG-xanthan-DATEM	15.44	35.9	56.36
LBG-xanthan-Purawave	-16.76	3.7	24.16
Pectin	-29.96	-9.5	10.96
Pectin-DATEM	-27.26	-6.8	13.66
Pectin-Purawave	-28.46	-8	12.46
Purawave	-30.41	-9.95	10.51
Xanthan	-0.61	19.85	40.31
Xanthan-DATEM	30.54	51	71.46
Xanthan-guar	-14.81	5.65	26.11
Xanthan-guar-DATEM	31.04	51.5	71.96
Xanthan-guar-Purawave	-8.86	11.6	32.06
Xanthan-Purawave	-4.16	16.3	36.76

Gluten-free bread formulations = HPMC subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
HPMC-DATEM	-19.16	1.3	21.76
HPMC-Purawave	-18.91	1.55	22.01
LBG	-19.36	1.1	21.56
LBG-DATEM	-9.86	10.6	31.06
LBG-Purawave	-21.24	-0.78	19.68
LBG-xanthan	-8.06	12.4	32.86
LBG-xanthan-DATEM	22.14	42.6	63.06
LBG-xanthan-Purawave	-10.06	10.4	30.86

Pectin	-23.26	-2.8	17.66
Pectin-DATEM	-20.56	-0.1	20.36
Pectin-Purawave	-21.76	-1.3	19.16
Purawave	-23.71	-3.25	17.21
Xanthan	6.09	26.55	47.01
Xanthan-DATEM	37.24	57.7	78.16
Xanthan-guar	-8.11	12.35	32.81
Xanthan-guar-DATEM	37.74	58.2	78.66
Xanthan-guar-Purawave	-2.16	18.3	38.76
Xanthan-Purawave	2.54	23	43.46

Gluten-free bread formulations= HPMC-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
HPMC-Purawave	-20.21	0.25	20.71
LBG	-20.66	-0.2	20.26
LBG-DATEM	-11.16	9.3	29.76
LBG-Purawave	-22.54	-2.08	18.38
LBG-xanthan	-9.36	11.1	31.56
LBG-xanthan-DATEM	20.84	41.3	61.76
LBG-xanthan-Purawave	-11.36	9.1	29.56
Pectin	-24.56	-4.1	16.36
Pectin-DATEM	-21.86	-1.4	19.06
Pectin-Purawave	-23.06	-2.6	17.86
Purawave	-25.01	-4.55	15.91
Xanthan	4.79	25.25	45.71

Xanthan-DATEM	35.94	56.4	76.86
Xanthan-guar	-9.41	11.05	31.51
Xanthan-guar-DATEM	36.44	56.9	77.36
Xanthan-guar-Purawave	-3.46	17	37.46
Xanthan-Purawave	1.24	21.7	42.16

Gluten-free bread formulations = HPMC-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG	-20.91	-0.45	20.01
LBG-DATEM	-11.41	9.05	29.51
LBG-Purawave	-22.79	-2.33	18.13
LBG-xanthan	-9.61	10.85	31.31
LBG-xanthan-DATEM	20.59	41.05	61.51
LBG-xanthan-Purawave	-11.61	8.85	29.31
Pectin	-24.81	-4.35	16.11
Pectin-DATEM	-22.11	-1.65	18.81
Pectin-Purawave	-23.31	-2.85	17.61
Purawave	-25.26	-4.8	15.66
Xanthan	4.54	25	45.46
Xanthan-DATEM	35.69	56.15	76.61
Xanthan-guar	-9.66	10.8	31.26
Xanthan-guar-DATEM	36.19	56.65	77.11
Xanthan-guar-Purawave	-3.71	16.75	37.21
Xanthan-Purawave	0.99	21.45	41.91

Gluten-free bread formulations = LBG subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-DATEM	-10.96	9.5	29.96
LBG-Purawave	-22.34	-1.88	18.58
LBG-xanthan	-9.16	11.3	31.76
LBG-xanthan-DATEM	21.04	41.5	61.96
LBG-xanthan-Purawave	-11.16	9.3	29.76
Pectin	-24.36	-3.9	16.56
Pectin-DATEM	-21.66	-1.2	19.26
Pectin-Purawave	-22.86	-2.4	18.06
Purawave	-24.81	-4.35	16.11
Xanthan	4.99	25.45	45.91
Xanthan-DATEM	36.14	56.6	77.06
Xanthan-guar	-9.21	11.25	31.71
Xanthan-guar-DATEM	36.64	57.1	77.56
Xanthan-guar-Purawave	-3.26	17.2	37.66
Xanthan-Purawave	1.44	21.9	42.36

Gluten-free bread formulations =LBG-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-Purawave	-31.84	-11.38	9.08
LBG-xanthan	-18.66	1.8	22.26
LBG-xanthan-DATEM	11.54	32	52.46
LBG-xanthan-Purawave	-20.66	-0.2	20.26
Pectin	-33.86	-13.4	7.06

Pectin-DATEM	-31.16	-10.7	9.76
Pectin-Purawave	-32.36	-11.9	8.56
Purawave	-34.31	-13.85	6.61
Xanthan	-4.51	15.95	36.41
Xanthan-DATEM	26.64	47.1	67.56
Xanthan-guar	-18.71	1.75	22.21
Xanthan-guar-DATEM	27.14	47.6	68.06
Xanthan-guar-Purawave	-12.76	7.7	28.16
Xanthan-Purawave	-8.06	12.4	32.86

Gluten-free bread formulations = LBG-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-xanthan	-7.28	13.18	33.64
LBG-xanthan-DATEM	22.92	43.38	63.84
LBG-xanthan-Purawave	-9.28	11.18	31.64
Pectin	-22.48	-2.02	18.44
Pectin-DATEM	-19.78	0.68	21.14
Pectin-Purawave	-20.98	-0.52	19.94
Purawave	-22.93	-2.47	17.99
Xanthan	6.87	27.33	47.79
Xanthan-DATEM	38.02	58.48	78.94
Xanthan-guar	-7.33	13.13	33.59
Xanthan-guar-DATEM	38.52	58.98	79.44
Xanthan-guar-Purawave	-1.38	19.08	39.54
Xanthan-Purawave	3.32	23.78	44.24

Gluten-free bread formulations = LBG-xanthan subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-xanthan-DATEM	9.74	30.2	50.66
LBG-xanthan-Purawave	-22.46	-2	18.46
Pectin	-35.66	-15.2	5.26
Pectin-DATEM	-32.96	-12.5	7.96
Pectin-Purawave	-34.16	-13.7	6.76
Purawave	-36.11	-15.65	4.81
Xanthan	-6.31	14.15	34.61
Xanthan-DATEM	24.84	45.3	65.76
Xanthan-guar	-20.51	-0.05	20.41
Xanthan-guar-DATEM	25.34	45.8	66.26
Xanthan-guar-Purawave	-14.56	5.9	26.36
Xanthan-Purawave	-9.86	10.6	31.06

Gluten-free bread formulations= LBG-xanthan-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-xanthan-Purawave	-52.66	-32.2	-11.74
Pectin	-65.86	-45.4	-24.94
Pectin-DATEM	-63.16	-42.7	-22.24
Pectin-Purawave	-64.36	-43.9	-23.44
Purawave	-66.31	-45.85	-25.39
Xanthan	-36.51	-16.05	4.41
Xanthan-DATEM	-5.36	15.1	35.56
Xanthan-guar	-50.71	-30.25	-9.79

Xanthan-guar-DATEM	-4.86	15.6	36.06
Xanthan-guar-Purawave	-44.76	-24.3	-3.84
Xanthan-Purawave	-40.06	-19.6	0.86

Gluten-free bread formulations = LBG-xanthan-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Pectin	-33.66	-13.2	7.26
Pectin-DATEM	-30.96	-10.5	9.96
Pectin-Purawave	-32.16	-11.7	8.76
Purawave	-34.11	-13.65	6.81
Xanthan	-4.31	16.15	36.61
Xanthan-DATEM	26.84	47.3	67.76
Xanthan-guar	-18.51	1.95	22.41
Xanthan-guar-DATEM	27.34	47.8	68.26
Xanthan-guar-Purawave	-12.56	7.9	28.36
Xanthan-Purawave	-7.86	12.6	33.06

Gluten-free bread formulations= Pectin subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Pectin-DATEM	-17.76	2.7	23.16
Pectin-Purawave	-18.96	1.5	21.96
Purawave	-20.91	-0.45	20.01
Xanthan	8.89	29.35	49.81
Xanthan-DATEM	40.04	60.5	80.96
Xanthan-guar	-5.31	15.15	35.61

Xanthan-guar-DATEM	40.54	61	81.46
Xanthan-guar-Purawave	0.64	21.1	41.56
Xanthan-Purawave	5.34	25.8	46.26

Gluten-free bread formulations = Pectin-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Pectin-Purawave	-21.66	-1.2	19.26
Purawave	-23.61	-3.15	17.31
Xanthan	6.19	26.65	47.11
Xanthan-DATEM	37.34	57.8	78.26
Xanthan-guar	-8.01	12.45	32.91
Xanthan-guar-DATEM	37.84	58.3	78.76
Xanthan-guar-Purawave	-2.06	18.4	38.86
Xanthan-Purawave	2.64	23.1	43.56

Gluten-free bread formulations = Pectin-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Purawave	-22.41	-1.95	18.51
Xanthan	7.39	27.85	48.31
Xanthan-DATEM	38.54	59	79.46
Xanthan-guar	-6.81	13.65	34.11
Xanthan-guar-DATEM	39.04	59.5	79.96
Xanthan-guar-Purawave	-0.86	19.6	40.06
Xanthan-Purawave	3.84	24.3	44.76

Gluten-free bread formulations = Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan	9.34	29.8	50.26
Xanthan-DATEM	40.49	60.95	81.41
Xanthan-guar	-4.86	15.6	36.06
Xanthan-guar-DATEM	40.99	61.45	81.91
Xanthan-guar-Purawave	1.09	21.55	42.01
Xanthan-Purawave	5.79	26.25	46.71

Gluten-free bread formulations= Xanthan subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-DATEM	10.69	31.15	51.61
Xanthan-guar	-34.66	-14.2	6.26
Xanthan-guar-DATEM	11.19	31.65	52.11
Xanthan-guar-Purawave	-28.71	-8.25	12.21
Xanthan-Purawave	-24.01	-3.55	16.91

Gluten-free bread formulations = Xanthan-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-guar	-65.81	-45.35	-24.89
Xanthan-guar-DATEM	-19.96	0.5	20.96
Xanthan-guar-Purawave	-59.86	-39.4	-18.94
Xanthan-Purawave	-55.16	-34.7	-14.24

Gluten-free bread formulations= Xanthan-guar subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-guar-DATEM	25.39	45.85	66.31
Xanthan-guar-Purawave	-14.51	5.95	26.41
Xanthan-Purawave	-9.81	10.65	31.11

Gluten-free bread formulations = Xanthan-guar-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-guar-Purawave	-60.36	-39.9	-19.44
Xanthan-Purawave	-55.66	-35.2	-14.74

Gluten-free bread formulations = Xanthan-guar-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-Purawave	-15.76	4.7	25.16

Table A. 4. Two-way ANOVA for viscoelastic values of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Emulsifier addition	2	Yes, no
Gum types	7	Xanthan, guar, xanthan-guar, LBG, LBG-guar, HPMC, pectin

Source	DS	SS	MS	F	P
Emulsifier Purawave	1	283813	283813	1364.25	0.000
Gum types	6	3665271	283813	1364.25	0.000
Interaction	6	1088430	181405	871.99	0.000
Error	14	2912	208		
Total	27	5040427			

Source	DS	SS	MS	F	P
Emulsifier DATEM	1	7808064	7808064	20701.97	0.000
Gum types	6	24842364	4140394	39040.32	0.000
Interaction	6	7619803	1269967	6349.84	0.000
Error	14	2800	200		
Total	27	40273031			

Table A. 5. One-way ANOVA for elastic modulus values of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Gluten-free bread formulations	23	Control 2 (wheat), xanthan, xanthan-DATEM, Xanthan-Purawave, guar, guar-Purawave, guar-DATEM, HPMC, HPMC-DATEM, HPMC-Purawave, LBG, LBG-DATEM, LBG-Purawave, pectin, pectin-DATEM, pectin-Purawave, pectin-DATEM, xanthan-guar, xanthan-guar-Purawave, xanthan-guar-DATEM, xanthan-LBG, xanthan-LBG-Purawave, xanthan-LBG-DATEM

Source	DF	SS	MS	F	P
Gluten-free bread formulations	23	46505278	2021969	9422.03	0.000
Error	20	4292	215		
Total	43	465095070			

Level	N	Mean	StDev
Control 2 (wheat)	2	221	14.3
Guar	2	150	14.1
Guar-DATEM	2	1771	15.6
Guar- Purawave	2	200	14.1
HPMC	2	50	14.1
HPMC-datem	2	145	14.1
HPMC- Purawave	2	121	14.7
LBG	2	124	14.1
LBG-DATEM	2	625	14.3
LBG - Purawave	2	25	14.1
LBG-xanthan	2	378	14.6
LBG-xanthan- DATEM	2	945	14.1
LBG-xanthan- Purawave	2	359	14.2
Pectin	2	33	14.1
Pectin- Purawave	1	48	13.8
Pectin- DATEM	1	31	13.7
Pectin-DATEM	1	51	14.0

Pectin-Purawave	1	28	15.0
Xanthan	2	1605	21.2
Xanthan- DATEM	2	3070	14.8
Xanthan-guar	2	721	14.1
Xanthan-guar-DATEM	2	4074	14.6
Xanthan-guar- Purawave	2	662	14.1
Xanthan- Purawave	2	468	14.9

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Gluten free bread formulations = Control 2 (wheat) subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Guar	-132	-71	-10
Guar-DATEM	1489	1550	1611
Guar- Purawave	-82	-21	40
HPMC	-232	-171	-110
HPMC-DATEM	-137	-76	-15
HPMC- Purawave	-161	-100	-39
LBG	-158	-97	-36
LBG-DATEM	343	404	465
LBG - Purawave	-257	-196	-135
LBG-xanthan	96	157	218
LBG-xanthan- DATEM	663	724	785
LBG-xanthan- Purawave	77	138	199
Pectin	-249	-188	-127

Pectin- Purawave	-247.7	-173	-98.3
Pectin- DATEM	-264.7	-190	-115.3
Pectin-DATEM	-244.7	-170	-95.3
Pectin-Purawave	-267.7	-193	-118.3
Xanthan	1323	1384	1445
Xanthan- DATEM	2788	2849	2910
Xanthan-guar	439	500	561
Xanthan-guar-DATEM	3792	3853	3914
Xanthan-guar- Purawave	380	441	502
Xanthan- Purawave	186	247	308

Gluten free bread formulations = Guar subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Guar-DATEM	1560	1621	1682
Guar- Purawave	-11	50	111
HPMC	-161	-100	-39
HPMC-DATEM	-66	-5	56
HPMC- Purawave	-90	-29	32
LBG	-87	-26	35
LBG-DATEM	414	475	536
LBG -Purawave	-186	-125	-64
LBG-xanthan	167	228	289
LBG-xanthan- DATEM	734	795	856
LBG-xanthan- Purawave	148	209	270

Pectin	-178	-117	-56
Pectin- Purawave	-176.7	-102	-27.3
Pectin- DATEM	-193.7	-119	-44.3
Pectin-DATEM	-173.7	-99	-24.3
Pectin-Purawave	-196.7	-122	-47.3
Xanthan	1394	1455	1516
Xanthan- DATEM	2859	2920	2981
Xanthan-guar	510	571	632
Xanthan-guar-DATEM	3863	3924	3985
Xanthan-guar- Purawave	451	512	573
Xanthan- Purawave	257	318	379

Gluten free bread formulations= Guar-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Guar- Purawave	-1632	-1571	-1510
HPMC	-1782	-1721	-1660
HPMC-DATEM	-1687	-1626	-1565
HPMC- Purawave	-1711	-1650	-1589
LBG	-1708	-1647	-1586
LBG-DATEM	-1207	-1146	-1085
LBG -Purawave	-1807	-1746	-1685
LBG-xanthan	-1454	-1393	-1332
LBG-xanthan- DATEM	-887	-826	-765

LBG-xanthan- Purawave	-1473	-1412	-1351
Pectin	-1799	-1738	-1677
Pectin- Purawave	-1797.7	-1723	-1648.3
Pectin- DATEM	-1814.7	-1740	-1665.3
Pectin-DATEM	-1794.7	-1720	-1645.3
Pectin-Purawave	-1817.7	-1743	-1668.3
Xanthan	-227	-166	-105
Xanthan- DATEM	1238	1299	1360
Xanthan-guar	-1111	-1050	-989
Xanthan-guar-DATEM	2242	2303	2364
Xanthan-guar- Purawave	-1170	-1109	-1048
Xanthan- Purawave	-1364	-1303	-1242

Gluten free bread formulations = Guar- Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
HPMC	-211	-150	-89
HPMC-DATEM	-116	-55	6
HPMC- Purawave	-140	-79	-18
LBG	-137	-76	-15
LBG- DATEM	364	425	486
LBG - Purawave	-236	-175	-114
LBG-xanthan	117	178	239
LBG-xanthan- DATEM	684	745	806

LBG-xanthan- Purawave	98	159	220
Pectin	-228	-167	-106
Pectin- Purawave	-226.7	-152	-77.3
Pectin- DATEM	-243.7	-169	-94.3
Pectin-DATEM	-223.7	-149	-74.3
Pectin-Purawave	-246.7	-172	-97.3
Xanthan	1344	1405	1466
Xanthan- DATEM	2809	2870	2931
Xanthan-guar	460	521	582
Xanthan-guar-DATEM	3813	3874	3935
Xanthan-guar- Purawave	401	462	523
Xanthan- Purawave	207	268	329

Gluten free bread formulations =HPMC subtracted from:

Gluten free bread formulations	Lower	Center	Upper
HPMC-DATEM	34	95	156
HPMC- Purawave	10	71	132
LBG	13	74	135
LBG- DATEM	514	575	636
LBG - Purawave	-86	-25	36
LBG-xanthan	267	328	389
LBG-xanthan- DATEM	834	895	956
LBG-xanthan- Purawave	248	309	370
Pectin	-78	-17	44
Pectin- Purawave	-76.7	-2	72.7

Pectin- DATEM	-93.7	-19	55.7
Pectin-DATEM	-73.7	1	75.7
Pectin-Purawave	-96.7	-22	52.7
Xanthan	1494	1555	1616
Xanthan- DATEM	2959	3020	3081
Xanthan-guar	610	671	732
Xanthan-guar-DATEM	3963	4024	4085
Xanthan-guar- Purawave	551	612	673
Xanthan- Purawave	357	418	479

Gluten free bread formulations = HPMC-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
HPMC- Purawave	-85	-24	37
LBG	-82	-21	40
LBG-DATEM	419	480	541
LBG - Purawave	-181	-120	-59
LBG-xanthan	172	233	294
LBG-xanthan- DATEM	739	800	861
LBG-xanthan- Purawave	153	214	275
Pectin	-173	-112	-51
Pectin- Purawave	-171.7	-97	-22.3
Pectin- DATEM	-188.7	-114	-39.3
Pectin-DATEM	-168.7	-94	-19.3
Pectin-Purawave	-191.7	-117	-42.3
Xanthan	1399	1460	1521

Xanthan- DATEM	2864	2925	2986
Xanthan-guar	515	576	637
Xanthan-guar-DATEM	3868	3929	3990
Xanthan-guar- Purawave	456	517	578
Xanthan- Purawave	262	323	384

Gluten free bread formulations = HPMC- Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG	-58	3	64
LBG-DATEM	443	504	565
LBG-Purawave	-157	-96	-35
LBG-xanthan	196	257	318
LBG-xanthan- DATEM	763	824	885
LBG-xanthan- Purawave	177	238	299
Pectin	-149	-88	-27
Pectin- Purawave	-147.7	-73	1.7
Pectin- DATEM	-164.7	-90	-15.3
Pectin-DATEM	-144.7	-70	4.7
Pectin-Purawave	-167.7	-93	-18.3
Xanthan	1423	1484	1545
Xanthan- DATEM	2888	2949	3010
Xanthan-guar	539	600	661
Xanthan-guar-DATEM	3892	3953	4014
Xanthan-guar- Purawave	480	541	602
Xanthan- Purawave	286	347	408

Gluten free bread formulations = LBG subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-DATEM	440	501	562
LBG-Purawave	-160	-99	-38
LBG-xanthan	193	254	315
LBG-xanthan- DATEM	760	821	882
LBG-xanthan- Purawave	174	235	296
Pectin	-152	-91	-30
Pectin- Purawave	-150.7	-76	-1.3
Pectin- DATEM	-167.7	-93	-18.3
Pectin-DATEM	-147.7	-73	1.7
Pectin-Purawave	-170.7	-96	-21.3
Xanthan	1420	1481	1542
Xanthan- DATEM	2885	2946	3007
Xanthan-guar	536	597	658
Xanthan-guar-DATEM	3889	3950	4011
Xanthan-guar- Purawave	477	538	599
Xanthan- Purawave	283	344	405

Gluten free bread formulations = LBG-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-Purawave	-661	-600	-539
LBG-xanthan	-308	-247	-186
LBG-xanthan- DATEM	259	320	381
LBG-xanthan- Purawave	-327	-266	-205

Pectin	-653	-592	-531
Pectin- Purawave	-651.7	-577	-502.3
Pectin- DATEM	-668.7	-594	-519.3
Pectin-DATEM	-648.7	-574	-499.3
Pectin-Purawave	-671.7	-597	-522.3
Xanthan	919	980	1041
Xanthan- DATEM	2384	2445	2506
Xanthan-guar	35	96	157
Xanthan-guar-DATEM	3388	3449	3510
Xanthan-guar- Purawave	-24	37	98
Xanthan- Purawave	-218	-157	-96

Gluten free bread formulations= LBG - Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-xanthan	292	353	414
LBG-xanthan- DATEM	859	920	981
LBG-xanthan- Purawave	273	334	395
Pectin	-53	8	69
Pectin- Purawave	-51.7	23	97.7
Pectin- DATEM	-68.7	6	80.7
Pectin-DATEM	-48.7	26	100.7
Pectin-Purawave	-71.7	3	77.7
Xanthan	1519	1580	1641
Xanthan- DATEM	2984	3045	3106
Xanthan-guar	635	696	757

Xanthan-guar-DATEM	3988	4049	4110
Xanthan-guar- Purawave	576	637	698
Xanthan- Purawave	382	443	504

Gluten free bread formulations=LBG-xanthan subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-xanthan- DATEM	506	567	628
LBG-xanthan- Purawave	-80	-19	42
Pectin	-406	-345	-284
Pectin- Purawave	-404.7	-330	-255.3
Pectin- DATEM	-421.7	-347	-272.3
Pectin-DATEM	-401.7	-327	-252.3
Pectin-Purawave	-424.7	-350	-275.3
Xanthan	1166	1227	1288
Xanthan- DATEM	2631	2692	2753
Xanthan-guar	282	343	404
Xanthan-guar-DATEM	3635	3696	3757
Xanthan-guar- Purawave	223	284	345
Xanthan- Purawave	29	90	151

Gluten free bread formulations = LBG-xanthan- DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-xanthan-Purawave	-647	-586	-525
Pectin	-973	-912	-851
Pectin- Purawave	-971.7	-897	-822.3

Pectin- DATEM	-988.7	-914	-839.3
Pectin-DATEM	-968.7	-894	-819.3
Pectin-Purawave	-991.7	-917	-842.3
Xanthan	599	660	721
Xanthan- DATEM	2064	2125	2186
Xanthan-guar	-285	-224	-163
Xanthan-guar-DATEM	3068	3129	3190
Xanthan-guar- Purawave	-344	-283	-222
Xanthan- Purawave	-538	-477	-416

Gluten free bread formulations = LBG-xanthan- Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Pectin	-387	-326	-265
Pectin- Purawave	-385.7	-311	-236.3
Pectin- DATEM	-402.7	-328	-253.3
Pectin-DATEM	-382.7	-308	-233.3
Pectin-Purawave	-405.7	-331	-256.3
Xanthan	1185	1246	1307
Xanthan- DATEM	2650	2711	2772
Xanthan-guar	301	362	423
Xanthan-guar-DATEM	3654	3715	3776
Xanthan-guar- Purawave	242	303	364
Xanthan- Purawave	48	109	170

Gluten free bread formulations= Pectin subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Pectin- Purawave	-59.7	15	89.7
Pectin- DATEM	-76.7	-2	72.7
Pectin-DATEM	-56.7	18	92.7
Pectin-Purawave	-79.7	-5	69.7
Xanthan	1511	1572	1633
Xanthan- DATEM	2976	3037	3098
Xanthan-guar	627	688	749
Xanthan-guar-DATEM	3980	4041	4102
Xanthan-guar- Purawave	568	629	690
Xanthan- Purawave	374	435	496

Gluten free bread formulations = Pectin- Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Pectin- DATEM	-103.3	-17	69.3
Pectin-DATEM	-83.3	3	89.3
Pectin-Purawave	-106.3	-20	66.3
Xanthan	1482.3	1557	1631.7
Xanthan- DATEM	2947.3	3022	3096.7
Xanthan-guar	598.3	673	747.7
Xanthan-guar-DATEM	3951.3	4026	4100.7
Xanthan-guar- Purawave	539.3	614	688.7
Xanthan- Purawave	345.3	420	494.7

Gluten free bread formulations = Pectin- DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Pectin-DATEM	-66.3	20	106.3
Pectin-Purawave	-89.3	-3	83.3
Xanthan	1499.3	1574	1648.7
Xanthan- DATEM	2964.3	3039	3113.7
Xanthan-guar	615.3	690	764.7
Xanthan-guar-DATEM	3968.3	4043	4117.7
Xanthan-guar- Purawave	556.3	631	705.7
Xanthan- Purawave	362.3	437	511.7

Gluten free bread formulations = Pectin-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Pectin-Purawave	-109.3	-23	63.3
Xanthan	1479.3	1554	1628.7
Xanthan- DATEM	2944.3	3019	3093.7
Xanthan-guar	595.3	670	744.7
Xanthan-guar-DATEM	3948.3	4023	4097.7
Xanthan-guar- Purawave	536.3	611	685.7
Xanthan- Purawave	342.3	417	491.7

Gluten free bread formulations = Pectin-Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan	1502.3	1577	1651.7
Xanthan- DATEM	2967.3	3042	3116.7
Xanthan-guar	618.3	693	767.7
Xanthan-guar-DATEM	3971.3	4046	4120.7
Xanthan-guar- Purawave	559.3	634	708.7
Xanthan- Purawave	365.3	440	514.7

Gluten free bread formulations = Xanthan subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan- DATEM	1404	1465	1526
Xanthan-guar	-945	-884	-823
Xanthan-guar-DATEM	2408	2469	2530
Xanthan-guar- Purawave	-1004	-943	-882
Xanthan- Purawave	-1198	-1137	-1076

Gluten free bread formulations = Xanthan- DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-guar	-2410	-2349	-2288
Xanthan-guar-DATEM	943	1004	1065
Xanthan-guar- Purawave	-2469	-2408	-2347
Xanthan- Purawave	-2663	-2602	-2541

Gluten free bread formulations= Xanthan-guar subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-guar-DATEM	3292	3353	3414
Xanthan-guar- Purawave	-120	-59	2
Xanthan- Purawave	-314	-253	-192

Gluten free bread formulations = Xanthan-guar-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-guar- Purawave	-3473	-3412	-3351
Xanthan- Purawave	-3667	-3606	-3545

Gluten free bread formulations = Xanthan-guar- Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan- Purawave	-255	-194	-133

Table A. 6. Two-way ANOVA for firmness of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Emulsifier addition	2	Yes, no
Gum types	6	Xanthan, guar, xanthan-guar, LBG, LBG-guar, HPMC

Source	DS	SS	MS	F	P
Emulsifier Purawave	1	2.381	2.381	6.12	0.029
Gum types	5	2.454	0.491	1.26	0.342

Interaction	5	0.516	0.103	0.26	0.924
Error	12	4.671	0.389		
Total	23	10.022			

Source	DS	SS	MS	F	P
Emulsifier DATEM	1	7.09	7.09	22.18	0.001
Gum types	5	1.315	0.263	0.82	0.557
Interaction	5	0.541	0.108	0.34	0.880
Error	12	3.836	0.32		
Total	23	12.782			

Factor Levels	Values
Gluten-free bread formulations 20	Control 1 (rice), Control 2 (wheat), xanthan, xanthan-DATEM, xanthan-Purawave, guar, guar-Purawave, guar-DATEM, HPMC, HPMC-DATEM, HPMC-Purawave, LBG, LBG-DATEM, LBG-Purawave, xanthan-guar, xanthan-guar-Purawave, xanthan-guar-DATEM, xanthan-LBG, xanthan-LBG-Purawave, xanthan-LBG-DATEM

Level	N	Mean	StDev
control 1 (rice)	2	3.0068	1.2312
control 2 (wheat)	2	0.4699	0.1271
guar	2	1.4358	0.6366

guar-datem	2	0.5146	0.2794
guar-prowave	2	1.0337	0.281
hpmc	2	1.2238	0.0594
hpmc-datem	2	0.2754	0.0802
hpmc-prowave	2	1.0963	0.3838
l.bean	2	2.2468	1.2357
l.bean-datem	2	0.6718	0.4412
l.bean-prowave	2	1.385	0.1697
l.bean-xanthan	2	1.5851	0.7006
l.bean-xanthan-datem	2	0.3512	0.0428
l.bean-xanthan-prowave	2	0.5663	0.2614
xanthan	2	1.6139	0.7387
xanthan-datem	2	0.3919	0.1553
xanthan-guar	2	1.0778	0.7416
xanthan-guar-datem	2	0.4557	0.0941
xanthan-guar-prowave	2	0.3997	0.0391
xanthan-prowave	2	0.9221	0.9078

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Gluten free bread formulations = Control 1 (rice) subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Control 2 (wheat)	-4.8417	-2.5369	-0.2321
Guar	-3.8758	-1.5710	0.7338
Guar-DATEM	-4.7969	-2.4921	-0.1873

Guar-Purawave	-4.2779	-1.9731	0.3317
HPMC	-4.0878	-1.7830	0.5218
HPMC-DATEM	-5.0362	-2.7314	-0.4266
HPMC-Purawave	-4.2152	-1.9104	0.3943
LBG	-3.0648	-0.7600	1.5448
LBG-DATEM	-4.6398	-2.3350	-0.0302
LBG-Purawave	-3.9265	-1.6217	0.6831
LBG-xanthan	-3.7265	-1.4217	0.8831
LBG-xanthan-DATEM	-4.9604	-2.6556	-0.3508
LBG-xanthan-Purawave	-4.7453	-2.4405	-0.1357
Xanthan	-3.6977	-1.3929	0.9119
Xanthan-DATEM	-4.9197	-2.6149	-0.3101
Xanthan-guar	-4.2338	-1.9290	0.3758
Xanthan-guar-DATEM	-4.8558	-2.5510	-0.2462
Xanthan-guar-Purawave	-4.9118	-2.6070	-0.3022
Xanthan-Purawave	-4.3895	-2.0847	0.2201

Gluten free bread formulations = Control 2 (wheat) subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Guar	-1.3389	0.9659	3.2707
Guar-DATEM	-2.2600	0.0448	2.3495
Guar-Purawave	-1.7410	0.5638	2.8686
HPMC	-1.5509	0.7539	3.0587
HPMC-DATEM	-2.4993	-0.1945	2.1103
HPMC-Purawave	-1.6784	0.6264	2.9312

LBG	-0.5279	1.7769	4.0817
LBG-DATEM	-2.1029	0.2019	2.5067
LBG-Purawave	-1.3896	0.9151	3.2199
LBG-xanthan	-1.1896	1.1152	3.4200
LBG-xanthan-DATEM	-2.4235	-0.1187	2.1861
LBG-xanthan-Purawave	-2.2084	0.0964	2.4012
Xanthan	-1.1608	1.1440	3.4488
Xanthan-DATEM	-2.3828	-0.0780	2.2268
Xanthan-guar	-1.6969	0.6079	2.9127
Xanthan-guar-DATEM	-2.3189	-0.0141	2.2907
Xanthan-guar-Purawave	-2.3749	-0.0701	2.2347
Xanthan-Purawave	-1.8526	0.45220	2.757

Gluten free bread formulations= Guar subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Guar-DATEM	-3.2259	-0.9211	1.3837
Guar-Purawave	-2.7069	-0.4021	1.9027
HPMC	-2.5168	-0.2120	2.0928
HPMC-DATEM	-3.4652	-1.1604	1.1444
HPMC-Purawave	-2.6442	-0.3394	1.9654
LBG	-1.4938	0.8110	3.1158
LBG-DATEM	-3.0688	-0.7640	1.5408
LBG-Purawave	-2.3555	-0.0507	2.2541
LBG-xanthan	-2.1554	0.1494	2.4541
LBG-xanthan-DATEM	-3.3894	-1.0846	1.2202

LBG-xanthan-Purawave	-3.1743	-0.8695	1.4353
Xanthan	-2.1267	0.1781	2.4829
Xanthan-DATEM	-3.3487	-1.0439	1.2609
Xanthan-guar	-2.6628	-0.3580	1.9468
Xanthan-guar-DATEM	-3.2848	-0.9800	1.3248
Xanthan-guar-Purawave	-3.3408	-1.0360	1.2688
Xanthan-Purawave	-2.8184	-0.5137	1.7911

Gluten free bread formulations = Guar-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Guar-Purawave	-2.7069	-0.4021	1.9027
HPMC	-2.5168	-0.2120	2.0928
HPMC-DATEM	-3.4652	-1.1604	1.1444
HPMC-Purawave	-2.6442	-0.3394	1.9654
LBG	-1.4938	0.8110	3.1158
LBG-DATEM	-3.0688	-0.7640	1.5408
LBG-Purawave	-2.3555	-0.0507	2.2541
LBG-xanthan	-2.1554	0.1494	2.4541
LBG-xanthan-DATEM	-3.3894	-1.0846	1.2202
LBG-xanthan-Purawave	-3.1743	-0.8695	1.4353
Xanthan	-2.1267	0.1781	2.4829
Xanthan-DATEM	-3.3487	-1.0439	1.2609
Xanthan-guar	-2.6628	-0.3580	1.9468
Xanthan-guar-DATEM	-3.2848	-0.9800	1.3248
Xanthan-guar-Purawave	-3.3408	-1.0360	1.2688

Xanthan-Purawave	-2.8184	-0.5137	1.7911

Gluten free bread formulations = Guar-Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
HPMC	-2.5168	-0.2120	2.0928
HPMC-DATEM	-3.4652	-1.1604	1.1444
HPMC-Purawave	-2.6442	-0.3394	1.9654
LBG	-1.4938	0.8110	3.1158
LBG-DATEM	-3.0688	-0.7640	1.5408
LBG-Purawave	-2.3555	-0.0507	2.2541
LBG-xanthan	-2.1554	0.1494	2.4541
LBG-xanthan-DATEM	-3.3894	-1.0846	1.2202
LBG-xanthan-Purawave	-3.1743	-0.8695	1.4353
Xanthan	-2.1267	0.1781	2.4829
Xanthan-DATEM	-3.3487	-1.0439	1.2609
Xanthan-guar	-2.6628	-0.3580	1.9468
Xanthan-guar-DATEM	-3.2848	-0.9800	1.3248
Xanthan-guar-Purawave	-3.3408	-1.0360	1.2688
Xanthan-Purawave	-2.8184	-0.5137	1.7911

Gluten free bread formulations = HPMC subtracted from:

Gluten free bread formulations	Lower	Center	Upper
HPMC-DATEM	-3.2532	-0.9484	1.3564
HPMC-Purawave	-2.4323	-0.1275	2.1773
LBG	-1.2818	1.0230	3.3278

LBG-DATEM	-2.8568	-0.5520	1.7528
LBG-Purawave	-2.1436	0.1612	2.466
LBG-xanthan	-1.9435	0.3613	2.6661
LBG-xanthan-DATEM	-3.1774	-0.8726	1.4322
LBG-xanthan-Purawave	-2.9623	-0.6575	1.6473
Xanthan	-1.9147	0.3901	2.6949
Xanthan-DATEM	-3.1367	-0.8319	1.4729
Xanthan-guar	-2.4508	-0.1460	2.1588
Xanthan-guar-DATEM	-3.0728	-0.7680	1.5368
Xanthan-guar-Purawave	-3.1288	-0.8240	1.4808
Xanthan-Purawave	-2.6065	-0.3017	2.0031

Gluten free bread formulations = HPMC-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
HPMC-Purawave	-1.4838	0.8210	3.1257
LBG	-0.3334	1.9714	4.2762
LBG-DATEM	-1.9084	0.3964	2.7012
LBG-Purawave	-1.1951	1.1097	3.4145
LBG-xanthan	-0.9951	1.3097	3.6145
LBG-xanthan-DATEM	-2.229	0.0758	2.3806
LBG-xanthan-Purawave	-2.0139	0.2909	2.5957
Xanthan	-0.9663	1.3385	3.6433
Xanthan-DATEM	-2.1883	0.1165	2.4213
Xanthan-guar	-1.5024	0.8024	3.1072
Xanthan-guar-DATEM	-2.1244	0.1804	2.4852

Xanthan-guar-Purawave	-2.1804	0.1244	2.4292
Xanthan-Purawave	-1.6581	0.6467	2.9515

Gluten free bread formulations = HPMC-Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG	-1.1544	1.1504	3.4552
LBG-DATEM	-2.7293	-0.4245	1.8803
LBG-Purawave	-2.0161	0.2887	2.5935
LBG-xanthan	-1.816	0.4888	2.7936
LBG-xanthan-DATEM	-3.0499	-0.7451	1.5597
LBG-xanthan-Purawave	-2.8348	-0.5300	1.7748
Xanthan	-1.7873	0.5175	2.8223
Xanthan-DATEM	-3.0092	-0.7044	1.6004
Xanthan-guar	-2.3233	-0.0185	2.2863
Xanthan-guar-DATEM	-2.9454	-0.6406	1.6642
Xanthan-guar-Purawave	-3.0014	-0.6966	1.6082
Xanthan-Purawave	-2.479	-0.1742	2.1306

Gluten free bread formulations= LBG subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-DATEM	-3.8797	-1.5750	0.7298
LBG-Purawave	-3.1665	-0.8617	1.4431
LBG-xanthan	-2.9664	-0.6616	1.6432
LBG-xanthan-DATEM	-4.2004	-1.8956	0.4092
LBG-xanthan-Purawave	-3.9853	-1.6805	0.6243

Xanthan	-2.9377	-0.6329	1.6719
Xanthan-DATEM	-4.1597	-1.8549	0.4499
Xanthan-guar	-3.4738	-1.1690	1.1358
Xanthan-guar-DATEM	-4.0958	-1.7910	0.5138
Xanthan-guar-Purawave	-4.1518	-1.8470	0.4578
Xanthan-Purawave	-3.6294	-1.3246	0.9802

Gluten free bread formulations = LBG-DATEMsubtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-Purawave	-1.5916	0.7132	3.018
LBG-xanthan	-1.3915	0.9133	3.2181
LBG-xanthan-DATEM	-2.6254	-0.3206	1.9842
LBG-xanthan-Purawave	-2.4103	-0.1055	2.1993
Xanthan	-1.3627	0.9421	3.2469
Xanthan-DATEM	-2.5847	-0.2799	2.0249
Xanthan-guar	-1.8988	0.4060	2.7108
Xanthan-guar-DATEM	-2.5209	-0.2161	2.0887
Xanthan-guar-Purawave	-2.5768	-0.2721	2.0327
Xanthan-Purawave	-2.0545	0.2503	2.5551

Gluten free bread formulations = LBG-Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-xanthan	-2.1047	0.2001	2.5049
LBG-xanthan-DATEM	-3.3386	-1.0338	1.271
LBG-xanthan-Purawave	-3.1235	-0.8187	1.4861

Xanthan	-2.076	0.2288	2.5336
Xanthan-DATEM	-3.2979	-0.9931	1.3117
Xanthan-guar	-2.612	-0.3072	1.9976
Xanthan-guar-DATEM	-3.2341	-0.9293	1.3755
Xanthan-guar-Purawave	-3.2901	-0.9853	1.3195
Xanthan-Purawave	-2.7677	-0.4629	1.8419

Gluten free bread formulations = LBG-xanthan subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-xanthan-DATEM	-3.5387	-1.2339	1.0709
LBG-xanthan-Purawave	-3.3236	-1.0188	1.2860
Xanthan	-2.2760	0.0287	2.3335
Xanthan-DATEM	-3.4980	-1.1932	1.1116
Xanthan-guar	-2.8121	-0.5073	1.7975
Xanthan-guar-DATEM	-3.4342	-1.1294	1.1754
Xanthan-guar-Purawave	-3.4902	-1.1854	1.1194
Xanthan-Purawave	-2.9678	-0.6630	1.6418

Gluten free bread formulations = LBG-xanthan-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
LBG-xanthan-Purawave	-2.0897	0.2151	2.5199
Xanthan	-1.0421	1.2627	3.5675
Xanthan-DATEM	-2.2641	0.0407	2.3455
Xanthan-guar	-1.5782	0.7266	3.0314
Xanthan-guar-DATEM	-2.2002	0.1045	2.4093

Xanthan-guar-Purawave	-2.2562	0.0486	2.3533
Xanthan-Purawave	-1.7339	0.5709	2.8757

Gluten free bread formulations = LBG-xanthan-Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan	-1.2572	1.0476	3.3524
Xanthan-DATEM	-2.4792	-0.1744	2.1304
Xanthan-guar	-1.7933	0.5115	2.8163
Xanthan-guar-DATEM	-2.4153	-0.1105	2.1942
Xanthan-guar-Purawave	-2.4713	-0.1665	2.1383
Xanthan-Purawave	-1.9490	0.3558	2.6606

Gluten free bread formulations= Xanthan subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-DATEM	-3.5268	-1.2220	1.0828
Xanthan-guar	-2.8409	-0.5361	1.7687
Xanthan-guar-DATEM	-3.4629	-1.1581	1.1467
Xanthan-guar-Purawave	-3.5189	-1.2141	1.0907
Xanthan-Purawave	-2.9965	-0.6918	1.613

Gluten free bread formulations = Xanthan-DATEM subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-guar	-1.6189	0.6859	2.9907
Xanthan-guar-DATEM	-2.2409	0.0639	2.3687
Xanthan-guar-Purawave	-2.2969	0.0079	2.3127

Xanthan-Purawave	-1.7746	0.5302	2.8350

Gluten free bread formulations= Xanthan-guar subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-guar-DATEM	-2.9268	-0.6220	1.6828
Xanthan-guar-Purawave	-2.9828	-0.6780	1.6268
Xanthan-Purawave	-2.4605	-0.1557	2.1491

Gluten free bread formulations = xanthan-guar-datem subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-guar-Purawave	-2.3608	-0.056	2.2488
Xanthan-Purawave	-1.8384	0.4664	2.7712

Gluten free bread formulations= Xanthan-guar-Purawave subtracted from:

Gluten free bread formulations	Lower	Center	Upper
Xanthan-Purawave	-1.7824	0.5224	2.8272

Table A. 7. Two-way ANOVA for specific volume of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Emulsifier addition	2	Yes, no
Gum types	6	Xanthan, guar, xanthan-guar, LBG, LBG-guar, HPMC

Source	DS	SS	MS	F	P
Emulsifier Purawave	1	0.3168	0.3168	10.74	0.007
Gum	5	0.2436	0.0487	1.65	0.220
Interaction	5	0.0644	0.0129	0.44	0.815
Error	12	0.3539	0.0295		
Total	23	0.9787			

Source	DS	SS	MS	F	P
Emulsifier DATEM	1	0.7382	0.7382	23.07	0.000
Gum	5	0.1436	0.0287	0.9	0.513
Interaction	5	0.0329	0.0066	0.21	0.954
Error	12	0.3839	0.032		
Total	23	1.2986			

Factor Levels	Values
Gluten-free bread formulations 20	Control 1 (rice), Control 2 (wheat), xanthan, xanthan-DATEM, xanthan-Purawave, guar, guar-Purawave, guar-DATEM, HPMC, HPMC-DATEM, HPMC-Purawave, LBG, LBG-DATEM, LBG-Purawave, xanthan-guar, xanthan-guar-Purawave, xanthan-guar-DATEM, xanthan-LBG, xanthan-LBG-Purawave, xanthan-LBG-DATEM

Source	DS	SS	MS	F	P
Emulsifier Purawave	19	18.940	0.997	3.06	0.008
Error	20	6.517	0.326		
Total	39	25.457			

Table A. 8. One-way ANOVA for specific volume of gluten-free bread formulations containing different gum types and emulsifier blend.

Source	DF	SS	MS	F	P
Gluten-free bread formulations	19	1.9644	0.1034	4.48	0.001
Error	20	0.4616	0.0231		
Total	39	2.426			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Gluten-free bread formulations= control 2 (wheat) subtracted from:

Level	N	Mean	StDev
Control 1 (rice)	2	0.6250	0.1344
Control 2 (wheat)	2	1.5050	0.1061
Guar	2	0.8630	0.0750
Guar-DATEM	2	1.3270	0.2588
Guar-Purawave	2	1.0020	0.0311
HPMC	2	0.8250	0.1683

HPMC-DATEM	2	1.1140	0.0057
HPMC-Purawave	2	1.0058	0.0506
LBG	2	0.7825	0.2934
LBG-DATEM	2	1.0615	0.0686
LBG-Purawave	2	0.9350	0.1485
LBG-xanthan	2	0.9675	0.1379
LBG-xanthan-DATEM	2	1.2550	0.0354
LBG-xanthan-Purawave	2	1.1315	0.0757
Xanthan	2	0.8400	0.2263
Xanthan-DATEM	2	1.2750	0.0354
Xanthan-guar	2	0.9600	0.3394
Xanthan-guar-DATEM	2	1.3100	0.0651
Xanthan-guar-Purawave	2	1.3725	0.1237
Xanthan-Purawave	2	1.1700	0.0424

Gluten-free bread formulations= Control 1 (rice) subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Control 2 (wheat)	0.2666	0.8800	1.4934
Guar	-0.3754	0.2380	0.8514
Guar-DATEM	0.0886	0.7020	1.3154
Guar-Purawave	-0.2364	0.3770	0.9904
HPMC	-0.4134	0.2000	0.8134
HPMC-DATEM	-0.1244	0.4890	1.1024

HPMC-Purawave	-0.2326	0.3808	0.9942
LBG	-0.4559	0.1575	0.7709
LBG-DATEM	-0.1769	0.4365	1.0499
LBG-Purawave	-0.3034	0.3100	0.9234
LBG-xanthan	-0.2709	0.3425	0.9559
LBG-xanthan-DATEM	0.0166	0.6300	1.2434
LBG-xanthan-Purawave	-0.1069	0.5065	1.1199
Xanthan	-0.3984	0.2150	0.8284
Xanthan-DATEM	0.0366	0.6500	1.2634
Xanthan-guar	-0.2784	0.3350	0.9484
Xanthan-guar-DATEM	0.0716	0.6850	1.2984
Xanthan-guar-Purawave	0.1341	0.7475	1.3609
Xanthan-Purawave	-0.0684	0.5450	1.1584

Gluten-free bread formulations= Control 2 (wheat) subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Guar	-1.2554	-0.6420	-0.0286
Guar-DATEM	-0.7914	-0.1780	0.4354
Guar-Purawave	-1.1164	-0.5030	0.1104
HPMC	-1.2934	-0.6800	-0.0666
HPMC-DATEM	-1.0044	-0.3910	0.2224
HPMC-Purawave	-1.1126	-0.4992	0.1142
LBG	-1.3359	-0.7225	-0.1091
LBG-DATEM	-1.0569	-0.4435	0.1699
LBG-Purawave	-1.1834	-0.5700	0.0434

LBG-xanthan	-1.1509	-0.5375	0.0759
LBG-xanthan-DATEM	-0.8634	-0.2500	0.3634
LBG-xanthan-Purawave	-0.9869	-0.3735	0.2399
Xanthan	-1.2784	-0.6650	-0.0516
Xanthan-DATEM	-0.8434	-0.2300	0.3834
Xanthan-guar	-1.1584	-0.5450	0.0684
Xanthan-guar-DATEM	-0.8084	-0.1950	0.4184
Xanthan-guar-Purawave	-0.7459	-0.1325	0.4809
Xanthan-Purawave	-0.9484	-0.3350	0.2784

Gluten-free bread formulations= Guar subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Guar-DATEM	-0.1494	0.4640	1.0774
Guar-Purawave	-0.4744	0.1390	0.7524
HPMC	-0.6514	-0.0380	0.5754
HPMC-DATEM	-0.3624	0.2510	0.8644
HPMC-Purawave	-0.4706	0.1428	0.7562
LBG	-0.6939	-0.0805	0.5329
LBG-DATEM	-0.4149	0.1985	0.8119
LBG-Purawave	-0.5414	0.0720	0.6854
LBG-xanthan	-0.5089	0.1045	0.7179
LBG-xanthan-DATEM	-0.2214	0.3920	1.0054
LBG-xanthan-Purawave	-0.3449	0.2685	0.8819
Xanthan	-0.6364	-0.0230	0.5904
Xanthan-DATEM	-0.2014	0.4120	1.0254

Xanthan-guar	-0.5164	0.0970	0.7104
Xanthan-guar-DATEM	-0.1664	0.4470	1.0604
Xanthan-guar-Purawave	-0.1039	0.5095	1.1229
Xanthan-Purawave	-0.3064	0.3070	0.9204

Gluten-free bread formulations = Guar-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Guar-Purawave	-0.9384	-0.3250	0.2884
HPMC	-1.1154	-0.5020	0.1114
HPMC-DATEM	-0.8264	-0.2130	0.4004
HPMC-Purawave	-0.9346	-0.3212	0.2922
LBG	-1.1579	-0.5445	0.0689
LBG-DATEM	-0.8789	-0.2655	0.3479
LBG-Purawave	-1.0054	-0.3920	0.2214
LBG-xanthan	-0.9729	-0.3595	0.2539
LBG-xanthan-DATEM	-0.6854	-0.0720	0.5414
LBG-xanthan-Purawave	-0.8089	-0.1955	0.4179
Xanthan	-1.1004	-0.4870	0.1264
Xanthan-DATEM	-0.6654	-0.0520	0.5614
Xanthan-guar	-0.9804	-0.3670	0.2464
Xanthan-guar-DATEM	-0.6304	-0.0170	0.5964
Xanthan-guar-Purawave	-0.5679	0.0455	0.6589
Xanthan-Purawave	-0.7704	-0.1570	0.4564

Gluten-free bread formulations = Guar-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
HPMC	-0.7904	-0.1770	0.4364
HPMC-DATEM	-0.5014	0.1120	0.7254
HPMC-Purawave	-0.6096	0.0038	0.6172
LBG	-0.8329	-0.2195	0.3939
LBG-DATEM	-0.5539	0.0595	0.6729
LBG-Purawave	-0.6804	-0.067	0.5464
LBG-xanthan	-0.6479	-0.0345	0.5789
LBG-xanthan-DATEM	-0.3604	0.2530	0.8664
LBG-xanthan-Purawave	-0.4839	0.1295	0.7429
Xanthan	-0.7754	-0.1620	0.4514
Xanthan-DATEM	-0.3404	0.2730	0.8864
Xanthan-guar	-0.6554	-0.0420	0.5714
Xanthan-guar-DATEM	-0.3054	0.3080	0.9214
Xanthan-guar-Purawave	-0.2429	0.3705	0.9839
Xanthan-Purawave	-0.4454	0.1680	0.7814

Gluten-free bread formulations= HPMC subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
HPMC-DATEM	-0.3244	0.2890	0.9024
HPMC-Purawave	-0.4326	0.1808	0.7942
LBG	-0.6559	-0.0425	0.5709
LBG-DATEM	-0.3769	0.2365	0.8499
LBG-Purawave	-0.5034	0.1100	0.7234

LBG-xanthan	-0.4709	0.1425	0.7559
LBG-xanthan-DATEM	-0.1834	0.4300	1.0434
LBG-xanthan-Purawave	-0.3069	0.3065	0.9199
Xanthan	-0.5984	0.0150	0.6284
Xanthan-DATEM	-0.1634	0.4500	1.0634
Xanthan-guar	-0.4784	0.1350	0.7484
Xanthan-guar-DATEM	-0.1284	0.4850	1.0984
Xanthan-guar-Purawave	-0.0659	0.5475	1.1609
Xanthan-Purawave	-0.2684	0.3450	0.9584

Gluten-free bread formulations = HPMC-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
HPMC-Purawave	-0.7216	-0.1082	0.5052
LBG	-0.9449	-0.3315	0.2819
LBG-DATEM	-0.6659	-0.0525	0.5609
LBG-Purawave	-0.7924	-0.1790	0.4344
LBG-xanthan	-0.7599	-0.1465	0.4669
LBG-xanthan-DATEM	-0.4724	0.1410	0.7544
LBG-xanthan-Purawave	-0.5959	0.0175	0.6309
Xanthan	-0.8874	-0.274	0.3394
Xanthan-DATEM	-0.4524	0.1610	0.7744
Xanthan-guar	-0.7674	-0.1540	0.4594
Xanthan-guar-DATEM	-0.4174	0.1960	0.8094
Xanthan-guar-Purawave	-0.3549	0.2585	0.8719
Xanthan-Purawave	-0.5574	0.0560	0.6694

Gluten-free bread formulations = HPMC-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG	-0.8367	-0.2233	0.3901
LBG-DATEM	-0.5577	0.0557	0.6691
LBG-Purawave	-0.6842	-0.0708	0.5426
LBG-xanthan	-0.6517	-0.0383	0.5751
LBG-xanthan-DATEM	-0.3642	0.2492	0.8626
LBG-xanthan-Purawave	-0.4877	0.1257	0.7391
Xanthan	-0.7792	-0.1658	0.4476
Xanthan-DATEM	-0.3442	0.2692	0.8826
Xanthan-guar	-0.6592	-0.0458	0.5676
Xanthan-guar-DATEM	-0.3092	0.3042	0.9176
Xanthan-guar-Purawave	-0.2467	0.3667	0.9801
Xanthan-Purawave	-0.4492	0.1642	0.7776

Gluten-free bread formulations = LBG subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-DATEM	-0.3344	0.2790	0.8924
LBG-Purawave	-0.4609	0.1525	0.7659
LBG-xanthan	-0.4284	0.1850	0.7984
LBG-xanthan-DATEM	-0.1409	0.4725	1.0859
LBG-xanthan-Purawave	-0.2644	0.3490	0.9624
Xanthan	-0.5559	0.0575	0.6709
Xanthan-DATEM	-0.1209	0.4925	1.1059

Xanthan-guar	-0.4359	0.1775	0.7909
Xanthan-guar-DATEM	-0.0859	0.5275	1.1409
Xanthan-guar-Purawave	-0.0234	0.5900	1.2034
Xanthan-Purawave	-0.2259	0.3875	1.0009

Gluten-free bread formulations = LBG-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-Purawave	-0.7399	-0.1265	0.4869
LBG-xanthan	-0.7074	-0.094	0.5194
LBG-xanthan-DATEM	-0.4199	0.1935	0.8069
LBG-xanthan-Purawave	-0.5434	0.0700	0.6834
Xanthan	-0.8349	-0.2215	0.3919
Xanthan-DATEM	-0.3999	0.2135	0.8269
Xanthan-guar	-0.7149	-0.1015	0.5119
Xanthan-guar-DATEM	-0.3649	0.2485	0.8619
Xanthan-guar-Purawave	-0.3024	0.3110	0.9244
Xanthan-Purawave	-0.5049	0.1085	0.7219

Gluten-free bread formulations = LBG-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-xanthan	-0.5809	0.0325	0.6459
LBG-xanthan-DATEM	-0.2934	0.3200	0.9334
LBG-xanthan-Purawave	-0.4169	0.1965	0.8099
Xanthan	-0.7084	-0.095	0.5184
Xanthan-DATEM	-0.2734	0.3400	0.9534

Xanthan-guar	-0.5884	0.0250	0.6384
Xanthan-guar-DATEM	-0.2384	0.3750	0.9884
Xanthan-guar-Purawave	-0.1759	0.4375	1.0509
Xanthan-Purawave	-0.3784	0.2350	0.8484

Gluten-free bread formulations= LBG-xanthan subtracted from:,

Gluten-free bread formulations	Lower	Center	Upper
LBG-xanthan-DATEM	-0.3259	0.2875	0.9009
LBG-xanthan-Purawave	-0.4494	0.1640	0.7774
Xanthan	-0.7409	-0.1275	0.4859
Xanthan-DATEM	-0.3059	0.3075	0.9209
Xanthan-guar	-0.6209	-0.0075	0.6059
Xanthan-guar-DATEM	-0.2709	0.3425	0.9559
Xanthan-guar-Purawave	-0.2084	0.4050	1.0184
Xanthan-Purawave	-0.4109	0.2025	0.8159

Gluten-free bread formulations = LBG-xanthan-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
LBG-xanthan-Purawave	-0.7369	-0.1235	0.4899
Xanthan	-1.0284	-0.415	0.1984
Xanthan-DATEM	-0.5934	0.0200	0.6334
Xanthan-guar	-0.9084	-0.295	0.3184
Xanthan-guar-DATEM	-0.5584	0.0550	0.6684
Xanthan-guar-Purawave	-0.4959	0.1175	0.7309
Xanthan-Purawave	-0.6984	-0.0850	0.5284

Gluten-free bread formulations= LBG-xanthan-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan	-0.9049	-0.2915	0.3219
Xanthan-DATEM	-0.4699	0.1435	0.7569
Xanthan-guar	-0.7849	-0.1715	0.4419
Xanthan-guar-DATEM	-0.4349	0.1785	0.7919
Xanthan-guar-Purawave	-0.3724	0.2410	0.8544
Xanthan-Purawave	-0.5749	0.0385	0.6519

Gluten-free bread formulations= Xanthan subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-DATEM	-0.1784	0.435	1.0484
Xanthan-guar	-0.4934	0.1200	0.7334
Xanthan-guar-DATEM	-0.1434	0.4700	1.0834
Xanthan-guar-Purawave	-0.0809	0.5325	1.1459
Xanthan-Purawave	-0.2834	0.3300	0.9434

Gluten-free bread formulations = Xanthan-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-guar	-0.9284	-0.3150	0.2984
Xanthan-guar-DATEM	-0.5784	0.0350	0.6484
Xanthan-guar-Purawave	-0.5159	0.0975	0.7109
Xanthan-Purawave	-0.7184	-0.1050	0.5084

Gluten-free bread formulations= Xanthan-guar subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-guar-DATEM	-0.2634	0.3500	0.9634
Xanthan-guar-Purawave	-0.2009	0.4125	1.0259
Xanthan-Purawave	-0.4034	0.2100	0.8234

Gluten-free bread formulations= Xanthan-guar-DATEM subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-guar-Purawave	-0.5509	0.0625	0.6759
Xanthan-Purawave	-0.7534	-0.1400	0.4734

Gluten-free bread formulations= Xanthan-guar-Purawave subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
Xanthan-Purawave	-0.8159	-0.2025	0.4109

Table A. 9. One-way ANOVA for sensory analysis of gluten-free bread formulations containing different gum types and emulsifier blend.

Factor	Levels	Values
Gluten-free bread formulations	5	Control 1(rice), guar-DATEM, xanthan-DATEM, xanthan-guar-DATEM, xanthan-LBG-DATEM

Flavour versus gluten-free bread formualations

Source	DF	SS	MS	F	P
Gluten-free bread formulations	4	3.520	0.880	2.40	0.064
Error	45	16.500	0.367		
Total	49	20.020			

Level	N	Mean	StDev
Control 1 (rice)	10	3.5000	0.7071
Guar	10	3.6000	0.6992
Xanthan-DATEM	10	4.0000	0.4714
Xanthan-guar-DATEM	10	4.0000	0.4714
Xanthan-LBG-DATEM	10	4.2000	0.6325

Flavour versus texture

Source	DF	SS	MS	F	P
Texture	3	1.415	0.472	1.17	0.333
Error	46	18.605	0.404		
Total	49	20.020			

Level	N	Mean	StDev
2	10	3.8000	0.7888
3	19	3.6842	0.5824

4	11	4.0000	0.7746
5	10	4.1000	0.3162

Texture versus gluten-free bread formualations

Source	DF	SS	MS	F	P
Gluten-free bread formulations	4	42.080	10.520	46.87	0.000
Error	45	10.100	0.224		
Total	49	52.180			

Flavour versus gluten-free bread formualations

Source	DF	SS	MS	F	P
Gluten-free bread formulations	4	3.520	0.880	2.40	0.064
Error	45	16.500	0.367		
Total	49	20.020			

Level	N	Mean	StDev
Control 1 (rice)	10	3.5000	0.7071
Guar	10	3.6000	0.6992
Xanthan-DATEM	10	4.0000	0.4714
Xanthan-guar-DATEM	10	4.0000	0.4714
Xanthan-LBG-DATEM	10	4.2000	0.6325

Table A. 10. One-way ANOVA for specific volume of gluten-free bread formulations containing different chestnut flour content (%) and gum types-DATEM mixture

Factor Levels	Values
Gluten-free bread formulations 15	0%, 10%, 10% CF-X-G-D, 10% CF-X-LBG-D, 100%, 20%, 20% CF-X-G-D, 20% CF-X-LBG-D, 30%, 30% CF-X-G-D, 30% CF-X-LBG-D, 40%, 40% CF-X-G-D, 40% CF-X-LBG-D, 50%

Source	DF	SS	MS	F	P
Gluten-free bread formulations	14	1.81448	0.12961	50.75	0.000
Error	15	0.03830	0.00255		
Total	29	1.85278			

Level	N	Mean	StDev
0%	2	0.6370	0.0170
10%	2	0.6640	0.0198
10% CF-X-G-D	2	0.8200	0.0156
10% CF-X-LBG-D	2	0.7105	0.0148
100%	2	0.5775	0.0163
20%	2	0.9160	0.0113
20% CF-X-G-D	2	1.1750	0.0495
20% CF-X-L-D	2	1.0565	0.0898
30%	2	0.9655	0.0106
30% CF-X-G-D	2	1.4255	0.0035
30% CF-X-L-D	2	1.3220	0.0396
40%	2	0.8275	0.0148
40% CF-X-G-D	2	1.1010	0.1541
40% CF-X-L-D	2	0.9155	0.0219
50%	2	0.7050	0.0099

Gluten-free bread formulations	N	Mean	Grouping
30% CF-X-G-D	2	1.4255	A
30% CF-X-L-D	2	1.3220	A B
20% CF-X-G-D	2	1.1750	B C
40% CF-X-G-D	2	1.1010	C D
20% CF-X-L-D	2	1.05665	C D
30%	2	0.9655	D E

20%	2	0.9160	D E
40% CF-X-L-D	2	0.9155	D E
40%	2	0.8275	E F
10% CF-X-G-D	2	0.8200	E F
10% CF-X-L-D	2	0.7105	F G
50%	2	0.7050	F G
10%	2	0.6640	F G
0%	2	0.6370	F G
100%	2	0.5775	G

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Gluten-free bread formulations = 0% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
10%	-0.1749	0.0270	0.2289
10% CF-X-G-D	-0.0189	0.1830	0.3849
10% CF-X-L-D	-0.1284	0.0735	0.2754
100%	-0.2614	-0.0595	0.1424
20%	0.0771	0.2790	0.4809
20% CF-X-G-D	0.3361	0.5380	0.7399
20% CF-X-L-D	0.2176	0.4195	0.6214
30%	0.1266	0.3285	0.5304
30% CF-X-G-D	0.5866	0.7885	0.9904
30% CF-X-L-D	0.4831	0.6850	0.8869
40%	-0.0114	0.1905	0.3924

40% CF-X-G-D	0.2621	0.4640	0.6659
40% CF-X-L-D	0.0766	0.2785	0.4804
50%	-0.1339	0.0680	0.2699

Gluten-free bread formulations = 10% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
10% CF-X-G-D	-0.0459	0.1560	0.3579
10% CF-X-L-D	-0.1554	0.0465	0.2484
100%	-0.2884	-0.0865	0.1154
20%	0.0501	0.2520	0.4539
20% CF-X-G-D	0.3091	0.5110	0.7129
20% CF-X-L-D	0.1906	0.3925	0.5944
30%	0.0996	0.3015	0.5034
30% CF-X-G-D	0.5596	0.7615	0.9634
30% CF-X-L-D	0.4561	0.6580	0.8599
40%	-0.0384	0.1635	0.3654
40% CF-X-G-D	0.2351	0.4370	0.6389
40% CF-X-L-D	0.0496	0.2515	0.4534
50%	-0.1609	0.0410	0.2429

Gluten-free bread formulations = 10% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
10% CF-X-L-D	-0.3114	-0.1095	0.0924

100%	-0.4444	-0.2425	-0.0406
20%	-0.1059	0.0960	0.2979
20% CF-X-G-D	0.1531	0.3550	0.5569
20% CF-X-L-D	0.0346	0.2365	0.4384
30%	-0.0564	0.1455	0.3474
30% CF-X-G-D	0.4036	0.6055	0.8074
30% CF-X-L-D	0.3001	0.5020	0.7039
40%	-0.1944	0.0075	0.2094
40% CF-X-G-D	0.0791	0.2810	0.4829
40% CF-X-L-D	-0.1064	0.0955	0.2974
50%	-0.3169	-0.1150	0.0869

Gluten-free bread formulations = 10% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
100%	-0.3349	-0.1330	0.0689
20%	0.0036	0.2055	0.4074
20% CF-X-G-D	0.2626	0.4645	0.6664
20% CF-X-L-D	0.1441	0.3460	0.5479
30%	0.0531	0.2550	0.4569
30% CF-X-G-D	0.5131	0.7150	0.9169
30% CF-X-L-D	0.4096	0.6115	0.8134

40%	-0.0849	0.1170	0.3189
40% CF-X-G-D	0.1886	0.3905	0.5924
40% CF-X-L-D	0.0031	0.2050	0.4069
50%	-0.2074	-0.0055	0.1964

Gluten-free bread formulations = 100% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
20%	0.1366	0.3385	0.5404
20% CF-X-G-D	0.3956	0.5975	0.7994
20% CF-X-L-D	0.2771	0.4790	0.6809
30%	0.1861	0.3880	0.5899
30% CF-X-G-D	0.6461	0.8480	10.499
30% CF-X-L-D	0.5426	0.7445	0.9464
40%	0.0481	0.2500	0.4519
40% CF-X-G-D	0.3216	0.5235	0.7254
40% CF-X-L-D	0.1361	0.3380	0.5399
50%	-0.0744	0.1275	0.3294

Gluten-free bread formulations = 20% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
20% CF-X-G-D	0.0571	0.2590	0.4609
20% CF-X-L-D	-0.0614	0.1405	0.3424
30%	-0.1524	0.0495	0.2514
30% CF-X-G-D	0.3076	0.5095	0.7114

30% CF-X-L-D	0.2041	0.4060	0.6079
40%	-0.2904	-0.0885	0.1134
40% CF-X-G-D	-0.0169	0.1850	0.3869
40% CF-X-L-D	-0.2024	-0.0005	0.2014
50%	-0.4129	-0.2110	-0.0091

Gluten-free bread formulations = 20% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
20% CF-X-L-D	-0.3204	-0.1185	0.0834
30%	-0.4114	-0.2095	-0.0076
30% CF-X-G-D	0.0486	0.2505	0.4524
30% CF-X-L-D	-0.0549	0.1470	0.3489
40%	-0.5494	-0.3475	-0.1456
40% CF-X-G-D	-0.2759	-0.0740	0.1279
40% CF-X-L-D	-0.4614	-0.2595	-0.0576
50%	-0.6719	-0.4700	-0.2681

Gluten-free bread formulations = 20% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
30%	-0.2929	-0.0910	0.1109
30% CF-X-G-D	0.1671	0.3690	0.5709
30% CF-X-L-D	0.0636	0.2655	0.4674
40%	-0.4309	-0.2290	-0.0271
40% CF-X-G-D	-0.1574	0.0445	0.2464

40% CF-X-L-D	-0.3429	-0.1410	0.0609
50%	-0.5534	-0.3515	-0.1496

Gluten-free bread formulations = 30% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
30% CF-X-G-D	0.2581	0.4600	0.6619
30% CF-X-L-D	0.1546	0.3565	0.5584
40%	-0.3399	-0.1380	0.0639
40% CF-X-G-D	-0.0664	0.1355	0.3374
40% CF-X-L-D	-0.2519	-0.0500	0.1519
50%	-0.4624	-0.2605	-0.0586

Gluten-free bread formulations = 30% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
30% CF-X-L-D	-0.3054	-0.1035	0.0984
40%	-0.7999	-0.5980	-0.3961
40% CF-X-G-D	-0.5264	-0.3245	-0.1226
40% CF-X-L-D	-0.7119	-0.5100	-0.3081
50%	-0.9224	-0.7205	-0.5186

Gluten-free bread formulations = 30% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
40%	-0.6964	-0.4945	-0.2926

40% CF-X-G-D	-0.4229	-0.2210	-0.0191
40% CF-X-L-D	-0.6084	-0.4065	-0.2046
50%	-0.8189	-0.6170	-0.4151

Gluten-free bread formulations = 40% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
40% CF-X-G-D	0.0716	0.2735	0.4754
40% CF-X-L-D	-0.1139	0.0880	0.2899
50%	-0.3244	-0.1225	0.0794

Gluten-free bread formulations = 40% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
40% CF-X-L-D	-0.3874	-0.1855	0.0164
50%	-0.5979	-0.3960	-0.1941

Gluten-free bread formulations = 40% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
50%	-0.4124	-0.2105	-0.0086

Table A. 11. Two-way ANOVA for specific volume of gluten-free bread formulations containing different chestnut:rice flour ratio and gum types-DATEM mixture

Source	DF	SS	MS	F	P

chestnut:rice flour ratio	3	0.87142	0.290472	63.57	0.000
gum blend-DATEM mixture	1	0.39605	0.396050	86.68	0.000
Interaction	3	0.10293	0.034310	7.51	0.001
Error	24	0.10966	0.004569		
Total	31	148.006			

Factor	Type	Levels	Values
chestnut:rice flour ratio	fixed	4	10:9, 20:80, 30:70, 40:60
gum blend-DATEM mixture	fixed	2	no. yes

Source	DF	Seq SS	Adj SS	Adj MS	F	P
chestnut:rice flour ratio	3	0.87142	0.87142	0.29047	63.57	0.000
gum blend-DATEM mixture	1	0.39605	0.39605	0.39605	86.68	0.000
chestnut:rice flour ratio* gum blend-DATEM mixture	3	0.10293	0.10293	0.03431	7.51	0.001
Error	24	0.10966	0.10966	0.00457		
Total	31	148.006				

chestnut:rice flour ratio	N	Mean	Grouping
30:70	8	1.2	A

10:90	8	1.0	B
40:60	8	0.9	C
20:80	8	0.7	D

gum blend-DATEM mixture	N	Mean	Grouping
yes	16	1.1	A
no	16	0.8	B

chestnut:rice flour ratio	gum blend-DATEM mixture	N	Mean	Grouping
30:70	yes	4	1.4	A
20:80	yes	4	1.1	B
40:60	yes	4	1.0	B C
30:70	no	4	1.0	B C D
20:80	no	4	0.9	C D E
40:60	no	4	0.8	D E
10:90	yes	4	0.8	E F
10:90	no	4	0.7	G

Table A. 12. One-way ANOVA for firmness of gluten-free bread formulations containing different chestnut flour content (%) and gum types-DATEM mixture

Factor Levels	Values
Gluten-free bread formulations 15	0%, 10%, 10% CF-X-G-D, 10% CF-X-LBG-D, 100%, 20%, 20% CF-X-G-D, 20% CF-X-LBG-D, 30%, 30% CF-X-G-D, 30% CF-X-LBG-D, 40%, 40% CF-X-G-D, 40% CF-X-LBG-D, 50%

Source	DF	SS	MS	F	P
Gluten-free bread formulations	14	25.32966	1.80926	342.93	0.000
Error	15	0.07914	0.00528		
Total	29	25.40880			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Gluten-free bread formulations = 0% subtracted from:

Level	N	Mean	StDev
0%	2	3.1080	0.1442
10%	2	2.7600	0.0849
10% CF-X-G-D	2	1.7100	0.1414
10% CF-X-L-D	2	2.0250	0.1061
100%	2	3.4450	0.0919
20%	2	1.1250	0.0354
20% CF-X-G-D	2	0.6950	0.0212

20% CF-X-L-D	2	0.8970	0.0523
30%	2	0.9305	0.0134
30% CF-X-G-D	2	0.4000	0.0141
30% CF-X-L-D	2	0.5460	0.0226
40%	2	0.3750	0.0354
40% CF-X-G-D	2	0.7500	0.0424
40% CF-X-L-D	2	1.0900	0.0424
50%	2	1.7150	0.0354

Gluten-free bread formulations	N	Mean	Grouping
100%	2	3.4450	A
0%	2	3.1080	B
10%	2	2.7600	C
10% CF-X-L-D	2	2.0250	D
50%	2	1.7150	E
10% CF-X-G-D	2	1.7100	E
40%	2	1.3750	F
20%	2	1.1250	F G
40% CF-X-L-D	2	1.0900	F G
30%	2	0.9305	G H
20% CF-X-L-D	2	0.8970	G H
40% CF-X-G-D	2	0.7500	H I
20% CF-X-G-D	2	0.6950	H I
30% CF-X-L-D	2	0.5460	I J
30% CF-X-G-D	2	0.4000	J

Gluten-free bread formulations= 0% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
10%	-0.6382	-0.3480	-0.0578
10% CF-X-G-D	-1.6882	-1.3980	-1.1078
10% CF-X-L-D	-1.3732	-1.0830	-0.7928
100%	0.0468	0.3370	0.6272
20%	-2.2732	-1.9830	-1.6928
20% CF-X-G-D	-2.7032	-2.4130	-2.1228
20% CF-X-L-D	-2.5012	-2.2110	-1.9208
30%	-2.4677	-2.1775	-1.8873
30% CF-X-G-D	-2.9982	-2.7080	-2.4178
30% CF-X-L-D	-2.8522	-2.5620	-2.2718
40%	-2.0232	-1.7330	-1.4428
40% CF-X-G-D	-2.6482	-2.3580	-2.0678
40% CF-X-L-D	-2.3082	-2.0180	-1.7278
50%	-1.6832	-1.3930	-1.1028

Gluten-free bread formulations = 10% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
10% CF-X-G-D	-1.3402	-1.0500	-0.7598
10% CF-X-L-D	-1.0252	-0.7350	-0.4448
100%	0.3948	0.6850	0.9752
20%	-1.9252	-1.6350	-1.3448
20% CF-X-G-D	-2.3552	-2.0650	-1.7748
20% CF-X-L-D	-2.1532	-1.8630	-1.5728

30%	-2.1197	-1.8295	-1.5393
30% CF-X-G-D	-2.6502	-2.3600	-2.0698
30% CF-X-L-D	-2.5042	-2.2140	-1.9238
40%	-1.6752	-1.3850	-1.0948
40% CF-X-G-D	-2.3002	-2.0100	-1.7198
40% CF-X-L-D	-1.9602	-1.6700	-1.3798
50%	-1.3352	-1.045	-0.7548

Gluten-free bread formulations = 10% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
10% CF-X-L-D	0.0248	0.3150	0.6052
100%	1.4448	1.7350	2.0252
20%	-0.8752	-0.5850	-0.2948
20% CF-X-G-D	-1.3052	-1.0150	-0.7248
20% CF-X-L-D	-1.1032	-0.8130	-0.5228
30%	-1.0697	-0.7795	-0.4893
30% CF-X-G-D	-1.6002	-1.3100	-1.0198
30% CF-X-L-D	-1.4542	-1.1640	-0.8738
40%	-0.6252	-0.3350	-0.0448
40% CF-X-G-D	-1.2502	-0.9600	-0.6698
40% CF-X-L-D	-0.9102	-0.6200	-0.3298
50%	-0.2852	0.0050	0.2952

Gluten-free bread formulations = 10% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper

100%	1.1298	1.4200	1.7102
20%	-1.1902	-0.9000	-0.6098
20% CF-X-G-D	-1.6202	-1.3300	-1.0398
20% CF-X-L-D	-1.4182	-1.1280	-0.8378
30%	-1.3847	-1.0945	-0.8043
30% CF-X-G-D	-1.9152	-1.6250	-1.3348
30% CF-X-L-D	-1.7692	-1.4790	-1.1888
40%	-0.9402	-0.6500	-0.3598
40% CF-X-G-D	-1.5652	-1.2750	-0.9848
40% CF-X-L-D	-1.2252	-0.9350	-0.6448
50%	-0.6002	-0.3100	-0.0198

Gluten-free bread formulations = 100% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
20%	-2.6102	-2.3200	-2.0298
20% CF-X-G-D	-3.0402	-2.7500	-2.4598
20% CF-X-L-D	-2.8382	-2.5480	-2.2578
30%	-2.8047	-2.5145	-2.2243
30% CF-X-G-D	-3.3352	-3.0450	-2.7548
30% CF-X-L-D	-3.1892	-2.8990	-2.6088
40%	-2.3602	-2.0700	-1.7798
40% CF-X-G-D	-2.9852	-2.6950	-2.4048
40% CF-X-L-D	-2.6452	-2.3550	-2.0648
50%	-2.0202	-1.7300	-1.4398

Gluten-free bread formulations = 20% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
20% CF-X-G-D	-0.7202	-0.4300	-0.1398
20% CF-X-L-D	-0.5182	-0.2280	0.0622
30%	-0.4847	-0.1945	0.0957
30% CF-X-G-D	-1.0152	-0.7250	-0.4348
30% CF-X-L-D	-0.8692	-0.5790	-0.2888
40%	-0.0402	0.2500	0.5402
40% CF-X-G-D	-0.6652	-0.3750	-0.0848
40% CF-X-L-D	-0.3252	-0.0350	0.2552
50%	0.2998	0.5900	0.8802

Gluten-free bread formulations= 20% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
20% CF-X-L-D	-0.0882	0.2020	0.4922
30%	-0.0547	0.2355	0.5257
30% CF-X-G-D	-0.5852	-0.2950	-0.0048
30% CF-X-L-D	-0.4392	-0.1490	0.1412
40%	0.3898	0.6800	0.9702
40% CF-X-G-D	-0.2352	0.0550	0.3452
40% CF-X-L-D	0.1048	0.3950	0.6852
50%	0.7298	1.0200	1.3102

Gluten-free bread formulations = 20% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
30%	-0.2567	0.0335	0.3237
30% CF-X-G-D	-0.7872	-0.4970	-0.2068
30% CF-X-L-D	-0.6412	-0.3510	-0.0608
40%	0.1878	0.4780	0.7682
40% CF-X-G-D	-0.4372	-0.1470	0.1432
40% CF-X-L-D	-0.0972	0.1930	0.4832
50%	0.5278	0.8180	1.1082

Gluten-free bread formulations = 30% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
30% CF-X-G-D	-0.8207	-0.5305	-0.2403
30% CF-X-L-D	-0.6747	-0.3845	-0.0943
40%	0.1543	0.4445	0.7347
40% CF-X-G-D	-0.4707	-0.1805	0.1097
40% CF-X-L-D	-0.1307	0.1595	0.4497
50%	0.4943	0.7845	10.747

Gluten-free bread formulations = 30% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
30% CF-X-L-D	-0.1442	0.1460	0.4362
40%	0.6848	0.9750	1.2652
40% CF-X-G-D	0.0598	0.3500	0.6402
40% CF-X-L-D	0.3998	0.6900	0.9802

50%	1.0480	1.3150	1.6052

Gluten-free bread formulations = 30% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
40%	0.5388	0.8290	1.1192
40% CF-X-G-D	-0.0862	0.2040	0.4942
40% CF-X-L-D	0.2538	0.5440	0.8342
50%	0.8788	1.1690	1.4592

Gluten-free bread formulations = 40% subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
40% CF-X-G-D	-0.9152	-0.6250	-0.3348
40% CF-X-L-D	-0.5752	-0.2850	0.0052
50%	0.0498	0.3400	0.6302

Gluten-free bread formulations = 40% CF-X-G-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
40% CF-X-L-D	0.0498	0.3400	0.6302
50%	0.6748	0.9650	1.2552

Gluten-free bread formulations = 40% CF-X-L-D subtracted from:

Gluten-free bread formulations	Lower	Center	Upper
50%	0.3348	0.6250	0.9152

Table A. 13. Two-way ANOVA for firmness of gluten-free bread formulations containing different chestnut:rice flour ratio and gum types-DATEM mixture.

Source	DF	SS	MS	F	P
chestnut:rice flour ratio	3	12.2206	4.07354	273.26	0.000
gum blend-DATEM mixture	1	2.3199	2.31986	155.62	0.000
Interaction	3	0.3593	0.11978	8.04	0.001
Error	24	0.3578	0.01491		
Total	31	15.2576			

Factor	Type	Levels	Values
chestnut:rice flour ratio	fixed	4	10:90. 20:80. 30:70. 40:60
gum blend-DATEM mixture	fixed	2	no. yes

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

chestnut:rice flour ratio	N	Mean	Grouping
10:90	8	2.3	A
40:60	8	1.1	B
20:80	8	1.0	C
30:70	8	0.7	D

gum blend-DATEM mixture	N	Mean	Grouping
no	16	1.5	A
yes	16	1.0	B

chestnut:rice flour ratio	gum blend-DATEM mixture	N	Mean	Grouping
10:90	no	4	2.8	A
10:90	yes	4	1.9	B
40:60	no	4	1.4	C
20:80	no	4	1.1	C D
30:70	no	4	0.9	D E
40:60	yes	4	0.9	D E
20:80	yes	4	0.8	E
30:70	yes	4	0.5	F

Table A. 14. One-way ANOVA for L values of gluten-free bread formulations containing different chestnut:rice flour ratios and gum types-DATEM mixture.

Source	DF	SS	MS	F	P
chestnut:rice flour ratio	6	642.333	107.056	153.28	0.000
Error	7	4.889	0.698		
Total	13	647.222			

Level	N	Mean	StDev
0:100	2	52.525	1.860
10:90	2	48.560	0.792
100:00	2	31.980	0.028
20:80	2	44.100	0.566
30:70	2	42.500	0.424
40:60	2	38.940	0.382
50:50	2	34.720	0.396

chestnut:rice flour ratio	N	Mean	Grouping
0:100	2	52.525	A
10:90	2	48.560	B
20:80	2	44.100	C
30:70	2	42.500	C
40:60	2	38.940	D
50:50	2	34.720	E
100:0	2	31.980	E

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

chestnut:rice flour ratio type = 0:100 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
10:90	-7.280	-3.965	-0.650
100:0	-23.860	-20.545	-17.230
20:80	-11.740	-8.425	-5.110

30:70	-13.340	-10.025	-6.710
40:60	-16.900	-13.585	-10.270
50:50	-21.120	-17.805	-14.490

chestnut:rice flour ratio type = 10:90 subtracted from

chestnut:rice flour ratio	Lower	Center	Upper
100:0	-19.895	-16.580	-13.365
20:80	-7.775	-4.460	-1.145
30:70	-9.375	-6.060	-2.745
40:60	-12.935	-9.620	-6.305
50:50	-17.155	-13.840	-10.525

chestnut:rice flour ratio type = 100:0 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
20:80	8.805	12.120	15.435
30:70	7.205	10.520	13.835
40:60	3.645	6.960	10.275
50:50	-0.575	2.740	6.055

chestnut:rice flour ratio type = 20:80 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
30:70	-4.915	-1.600	1.715
40:60	-8.475	-5.160	-1.845
50:50	-12.695	-9.380	-6.065

chestnut:rice flour ratio type = 30:70 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
40:60	-6.875	-3.560	-0.245
50:50	-11.095	-7.780	-4.465

chestnut:rice flour ratio type = 40:60 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
50:50	-7.535	-4.220	-0.905

Table A. 15. One-way ANOVA for a values of gluten-free bread formulations containing different chestnut:rice flour ratios and gum types-DATEM mixture.

Source	DF	SS	MS	F	P
chestnut:rice flour ratio	6	222.774	37.129	170.39	0.000
Error	7	1.525	0.218		
Total	13	224.299			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Level	N	Mean	StDev
0:100	2	9.915	0.262
10:90	2	10.900	0.424
100:00	2	21.990	0.438
20:80	2	15.200	0.424
30:70	2	16.825	0.530

40:60	2	18.065	0.615
50:50	2	18.630	0.495

chestnut:rice flour ratio	N	Mean	Grouping
100:0	2	21.990	A
50:50	2	18.630	B
40:60	2	18.065	B
30:70	2	16.825	B C
20:80	2	15.200	C
10:90	2	10.900	D
0:100	2	9.915	D

chestnut:rice flour ratio type = 0:100 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
10:90	-0.867	0.985	2.837
100:0	10.223	12.075	13.927
20:80	3.433	5.285	7.137
30:70	5.058	6.910	8.762
40:60	6.298	8.150	10.002
50:50:00	6.863	8.715	10.567

chestnut:rice flour ratio type = 10:90 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
100:0	9.238	11.090	12.942
20:80	2.448	4.300	6.152

30:70	4.073	5.925	7.777
40:60	5.313	7.165	9.017
50:50	5.878	7.730	9.582

chestnut:rice flour ratio type = 100:0 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
20:80	-8.642	-6.790	-4.938
30:70	-7.017	-5.165	-3.313
40:60	-5.777	-3.925	-2.073
50:50	-5.212	-3.360	-1.508

chestnut:rice flour ratio type = 20:80 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
30:70	-0.227	1.625	3.477
40:60	1.013	2.865	4.717
50:50:00	1.578	3.430	5.282

chestnut:rice flour ratio type = 30:70 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
40:60	-0.612	1.240	3.092
50:50	-0.047	1.805	3.657

chestnut:rice flour ratio type = 40:60 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper

50:50	-1.287	0.565	2.417

Table A. 16. One-way ANOVA for b values of gluten-free bread formulations containing different chestnut:rice flour ratios and gum types-DATEM mixture**.**

Source	DF	SS	MS	F	P
chestnut:rice flour ratio	6	24.851	4.142	6.38	0.014
Error	7	4.543	0.649		
Total	13	29.394			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Level	N	Mean	StDev
0:100	2	34.900	0.424
10:90	2	36.000	0.990
100:0	2	38.770	0.325
20:80	2	36.710	0.410
30:70	2	38.140	1.075
40:60	2	38.615	1.252
50:50	2	37.540	0.622

chestnut:rice flour ratio	N	Mean	Grouping
100:0	2	387.700	A
40:60	2	386.150	A
30:70	2	381.400	A
50:50	2	375.400	A B
20:80	2	367.100	A B

10:90	2	360.000	A B
0:100	2	349.000	B

chestnut:rice flour ratio type = 0:100 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
10:90	-2.0957	1.1000	4.2957
100:0	0.6743	3.8700	7.0657
20:80	-1.3857	1.8100	5.0057
30:70	0.0443	3.2400	6.4357
40:60	0.5193	3.7150	6.9107
50:50	-0.5557	2.6400	5.8357

chestnut:rice flour ratio type = 10:90 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
100:0	-0.4257	2.7700	5.9657
20:80	-2.4857	0.7100	3.9057
30:70	-1.0557	2.1400	5.3357
40:60	-0.5807	2.6150	5.8107
50:50	-1.6557	15400	4.7357

chestnut:rice flour ratio type = 100:0 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
20:80	-5.2557	-2.0600	1.1357
30:70	-3.8257	-0.6300	2.5657
40:60	-3.3507	-0.1550	3.0407

50:50	-4.4257	-1.2300	1.9657

chestnut:rice flour ratio type = 20:80 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
30:70	-1.7657	1.4300	4.6257
40:60	-1.2907	1.9050	5.1007
50:50	-2.3657	0.8300	4.0257

chestnut:rice flour ratio type = 30:70 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
40:60	-2.7207	0.4750	3.6707
50:50	-3.7957	-0.6000	2.5957

chestnut:rice flour ratio type = 40:60 subtracted from:

chestnut:rice flour ratio	Lower	Center	Upper
50:50	-42.707	-10.750	21.207

Table A. 17. One-way ANOVA for sensory values of gluten-free bread formulations containing different chestnut:rice flour ratios and different gum blend-DATEM mixture

Texture versus gluten-free bread formulaitons

Source	DF	SS	MS	F	P
gluten-free bread formulations	4	9.8730	2.4682	241.04	0.000
Error	5	0.0512	0.0102		
Total	9	9.9242			

Level	N	Mean	StDev
0:100 CF:RF	2	2.1900	0.1273
100:0 CF:RF	2	2.3000	0.1414
30:70 CF:RF	2	3.5500	0.0707
30:70 CF:RF-X-G-E	2	4.7500	0.0707
30:70 CF:RF-X-LBG-E	2	4.0500	0.0707

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

gluten-free bread formulations	N	Mean	Grouping
30:70 CF:RF-X-G-E	2	4.7500	A
30:70 CF:RF-X-LBG-E	2	4.0500	B
30:70 CF:RF	2	3.5500	C
100:0 CF:RF	2	2.3000	D
0:100 CF:RF	2	2.1900	D

gluten-free bread formulations = 0:100 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
100:0 CF:RF	-0.2957	0.1100	0.5157
30:70 CF:RF	0.9543	1.3600	1.7657
30:70 CF:RF-X-G-E	2.1543	2.5600	2.9657
30:70 CF:RF-X-LBG-E	1.4543	1.8600	2.2657

gluten-free bread formulations = 100:0 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF	0.8443	1.2500	1.6557
30:70 CF:RF-X-G-E	2.0443	2.4500	2.8557
30:70 CF:RF-X-LBG-E	1.3443	1.7500	2.1557

gluten-free bread formulations = 30:70 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF-X-G-E	0.7943	1.2000	1.6057
30:70 CF:RF-X-LBG-E	0.0943	0.5000	0.9057

gluten-free bread formulations = 30:70 CF:RF-X-G-E subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF-X-LBG-E	-1.1057	-0.7000	-0.2943

Flavour versus gluten-free bread formulations

Source	DF	SS	MS	F	P
gluten-free bread formulations	4	4.7360	1.1840	56.38	0.000

Error	5	0.1050	0.0210
Total	9	4.8410	

Level	N	Mean	StDev
0:100 CF:RF	2	2.6000	0.1414
100:0 CF:RF	2	3.8000	0.1414
30:70 CF:RF	2	4.3000	0.0000
30:70 CF:RF-X-G-E	2	4.0500	0.2121
30:70 CF:RF-X-LBG-E	2	4.6000	0.1414

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

gluten-free bread formulations	N	Mean	Grouping
30:70 CF:RF-X-LBG-E	2	4.6000	A
30:70 CF:RF	2	4.3000	A
30:70 CF:RF-X-G-E	2	4.0500	A B
100:0 CF:RF	2	3.8000	B
0:100 CF:RF	2	2.6000	C

gluten-free bread formulations = 0:100 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
100:0 CF:RF	0.6190	1.2000	1.7810
30:70 CF:RF	1.1190	1.7000	2.2810
30:70 CF:RF-X-G-E	0.8690	1.4500	2.0310
30:70 CF:RF-X-LBG-E	1.4190	2.0000	2.5810

gluten-free bread formulations = 100:0 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF	-0.0810	0.5000	1.0810
30:70 CF:RF-X-G-E	-0.3310	0.2500	0.8310
30:70 CF:RF-X-LBG-E	0.2190	0.8000	1.3810

gluten-free bread formulations = 30:70 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF-X-G-E	-0.8310	-0.2500	0.3310
30:70 CF:RF-X-LBG-E	-0.2810	0.3000	0.8810

gluten-free bread formulations = 30:70 CF:RF-X-G-E subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF-X-LBG-E	-0.0310	0.5500	11.310

Color versus gluten-free bread formulations

Source	DF	SS	MS	F	P
gluten-free bread formulations	4	8.4060	2.1015	210.15	0.000
Error	5	0.0500	0.0100		
Total	9	8.4560			

Level	N	Mean	StDev
0:100 CF:RF	2	2.1000	0.1414
100:0 CF:RF	2	3.2000	0.1414

30:70 CF:RF	2	4.3500	0.0707
30:70 CF:RF-X-G-E	2	4.5500	0.0707
30:70 CF:RF-X-LBG-E	2	4.2000	0.0000

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

gluten-free bread formulations	N	Mean	Grouping
30:70 CF:RF-X-G-E	2	4.5500	A
30:70 CF:RF	2	4.3500	A
30:70 CF:RF-X-LBG-E	2	4.2000	A
100:0 CF:RF	2	3.2000	B
0:100 CF:RF	2	2.1000	C

gluten-free bread formulations = 0:100 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
100:0 CF:RF	0.6991	1.1000	1.5009
30:70 CF:RF	1.8491	2.2500	2.6509
30:70 CF:RF-X-G-E	2.0491	2.4500	2.8509
30:70 CF:RF-X-LBG-E	1.6991	2.1000	2.5009

gluten-free bread formulations = 100:0 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF	0.7491	1.1500	1.5509
30:70 CF:RF-X-G-E	0.9491	1.3500	1.7509
30:70 CF:RF-X-LBG-E	0.5991	1.0000	1.4009

gluten-free bread formulations = 30:70 CF:RF subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF-X-G-E	-0.2009	0.2000	0.6009
30:70 CF:RF-X-LBG-E	-0.5509	-0.1500	0.2509

gluten-free bread formulations = 30:70 CF:RF-X-G-E subtracted from:

gluten-free bread formulations	Lower	Center	Upper
30:70 CF:RF-X-LBG-E	-0.7509	-0.3500	0.0509

Table A. 18. Two-way ANOVA for weight loss values of gluten-free bread formulations containing different tigernut:rice flour ratios and baked in different ovens

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Tigernut:rice flour ratio	5	194.50	194.50	38.90	117.14	0.000
oven type	1	874.83	874.83	874.83	2634.38	0.000
Tigernut:rice flour ratio*oven type	5	55.10	55.10	11.02	33.19	0.000
Error	12	3.99	3.99	0.33		
Total	23	1128.43				

Source	DF	SS	MS	F	P
Tigernut:rice flour ratio	5	194.50	38.901	117.14	0.000
oven type	1	874.83	874.834	2634.38	0.000
Interaction	5	55.10	11.021	33.19	0.000
Error	12	3.98	0.332		

Total	23	1128.43		

Factor	Type	Levels	Values
Tigernut:rice flour ratio	fixed	6	0:100, 5:95, 10:90, 15:85, 20:80, 25:75
oven type	fixed	2	conv. inf-mw

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Tigernut:rice flour ratio	N	Mean	Grouping
0:100	4	21.4	A
5:95	4	17.3	B
10:90	4	15.1	C
25:75	4	14.01	C D
15:85	4	14.0	C D
20:80	4	12.08	D

oven type	N	Mean	Grouping
inf-mw	12	21.8	A
conv	12	9.8	B

Tigernut:rice flour ratio	oven type	N	Mean	Grouping
0:100	inf-mw	2	28.9	A
5:95	inf-mw	2	24.8	B

10:90	inf-mw	2	22.3	C
15:85	inf-mw	2	19.6	D
25:75	inf-mw	2	18.6	D E
20:80	inf-mw	2	16.5	E
0:100	conv	2	13.8	F
5:95	conv	2	9.9	G
25:75	conv	2	9.6	G
20:80	conv	2	9.1	G
15:85	conv	2	8.4	G
10:90	conv	2	7.9	G

Table A. 19. Two-way ANOVA for firmness values of gluten-free bread formulations containing different tigernut:rice flour ratios and baked in different ovens

Factor	Type	Levels	Values
Tigernut:rice flour ratio	fixed	6	0:100. 5:95. 10:90. 15:85. 20:80. 25:75
oven type	fixed	2	conv. inf-mw

Source	DF	SS	MS	F	P
Tigernut:rice flour ratio	5	0.156321	0.031264	24.93	0.000
oven type	1	0.168337	0.168337	134.22	0.000
Interaction	5	0.402388	0.080478	64.17	0.000
Error	12	0.01505	0.001254		

		0
Total	23	0.74209 6

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Tigernut:rice flour ratio	N	Mean	Grouping
0:100	4	0.9	A
25:75	4	0.9	A B
5:95	4	0.9	B
20:80	4	0.7	C
10:90	4	0.7	C
15:85	4	0.7	C

oven type	N	Mean	Grouping
inf-mw	12	0.9	A
conv	12	0.7	B

Tigernut:rice flour ratio	oven type	N	Mean	Grouping
0:100	inf-mw	2	1.2	A
5:95	inf-mw	2	1.1	A B
25:75	conv	2	0.9	B C
10:90	inf-mw	2	0.9	C D
20:80	conv	2	0.8	C D E
25:75	inf-mw	2	0.8	C D E
15:85	inf-mw	2	0.8	D E F
0:100	conv	2	0.7	E F G
15:85	conv	2	0.7	E F G
20:80	inf-mw	2	0.7	F G
5:95	conv	2	0.6	F G
10:90	conv	2	0.6	G

Table A. 20. Two-way ANOVA for specific volume values of gluten-free bread formulations containing different tigernut:rice flour ratios and baked in different ovens

Factor	Type	Levels	Values
Tigernut:rice flour ratio	fixed	6	0:100, 5:95, 10:90, 15:85, 20:80, 25:75
oven type	fixed	2	conv. inf-mw

Source	DF	SS	MS	F	P
Tigernut:rice flour ratio	5	0.219121	0.0438242	66.15	0.000
oven type	1	0.000104	0.0001042	0.16	0.699
Interaction	5	0.065921	0.0131842	19.90	0.000

Error	12	0.007950	0.0006625
Total	23	0.293096	

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulations

Tigernut:rice flour ratio	N	Mean	Grouping
15:85	4	1.3	A
20:80	4	1.3	A
10:90	4	1.3	A
25:75	4	1.2	B
5:95	4	1.2	B
0:100	4	1.0	C

oven type	N	Mean	Grouping
inf-mw	12	1.2	A
conv	12	1.2	A

Tigernut:rice flour ratio	oven type	N	Mean	Grouping
20:80	inf-mw	2	1.4	A
10:90	conv	2	1.3	A
15:85	inf-mw	2	1.3	A B
15:85	conv	2	1.3	A B C
25:75	inf-mw	2	1.2	B C D

10:90	inf-mw	2	1.2	C D E
20:80	conv	2	1.2	C D E
5:95	conv	2	1.2	D E F
25:75	conv	2	1.2	D E F
5:95	inf-mw	2	1.1	E F
0:100	conv	2	1.1	F
0:100	inf-mw	2	1.0	G

Table A. 21. Two-way ANOVA for crust color values of gluten-free bread formulations containing different tigernut:rice flour ratios and baked in different ovens

Factor	Type	Levels	Values
Tigernut:rice flour ratio	fixed	6	0:100, 5:95, 10:90, 15:85, 20:80, 25:75
oven type	fixed	2	conv. inf-mw

Source	DF	SS	MS	F	P
Tigernut:rice flour ratio	5	1048.52	209.703	321.18	0.000
oven type	1	278.12	278.120	425.97	0.000
Interaction	5	9.55	1.909	2.92	0.009
Error	12	7.84	0.653		
Total	23	1344.02			

Source	DF	Seq SS	Adj SS	Adj MS	F	P
tigernut flour ratio (%)	5	1048.52	1048.52	209.70	321.18	0.000

oven type	1	278.12	278.12	278.12	425.97	0.000
tigernut flour ratio (%)*oven type	5	9l.55	20.333	1.91	2.92	0.059
Error	12	7.84	9.55	0.65		
Total	23	1344.02	7.84			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulation

Tigernut:rice flour ratio	N	Mean	Grouping
25:75	4	49.8	A
20:80	4	47.0	B
15:85	4	44.4	C
10:90	4	40.3	D
5:95	4	37.3	E
0:100	4	29.9	F

oven type	N	Mean	Grouping
inf-mw	12	44.9	A
conv	12	38.0	B

Tigernut:rice flour ratio	oven type	N	Mean	Grouping
25:75	conv	2	53.9	A
20:80	conv	2	51.0	A B
15:85	conv	2	48.0	B C

25:75	inf-mw	2	45.8	C D
10:90	conv	2	43.6	D E
20:80	inf-mw	2	43.0	D E
15:85	inf-mw	2	40.9	E
5:95	conv	2	40.8	E
10:90	inf-mw	2	37.0	F
5:95	inf-mw	2	33.8	G
0:100	conv	2	32.0	G
0:100	inf-mw	2	27.7	H

Table A. 22. One-way ANOVA for porosity values of X-ray microtomograpy images of gluten-free rice bread containing different gum types and DATEM.

Source	DF	SS	MS	F	P
Gluten-free bread formulation	9	0.14745	0.01638	12.73	0.000
Error	10	0.01287	0.00129		
Total	19	0.16032			

Level	N	Mean	StDev
A	2	0.65600	0.07637
CMC	2	0.44700	0.03394
Control	2	0.59250	0.03465
G	2	0.52650	0.02333
HPMC	2	0.39250	0.01485
LBG	2	0.55350	0.02051
MC	2	0.65900	0.04243

X	2	0.46750	0.02051
X-G	2	0.44800	0.03536
X-LBG	2	0.50600	0.00566

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulation

formulation	N	Mean	Grouping
MC	2	0.65900	A
A	2	0.65600	A
Control	2	0.59250	A
LBG	2	0.55350	B
G	2	0.52650	B
X-LBG	2	0.50600	C
X	2	0.46750	C
X-G	2	0.44800	C
CMC	2	0.44700	C
HPMC	2	0.39250	C

Gluten-free bread formulation = A subtracted from:

formulation	Lower	Center	Upper
CMC	-0.35107	-0.20900	-0.06693
Control	-0.20557	-0.06350	0.07857
G	-0.27157	-0.12950	-0.01257
HPMC	-0.40557	-0.26350	-0.12143
LBG	-0.24457	-0.10250	-0.03957

MC	-0.13907	0.00300	0.14507
X	-0.33057	-0.18850	-0.04643
X-G	-0.35007	-0.20800	-0.06593
X-LBG	-0.29207	-0.15000	-0.00793

Gluten-free bread formulation = CMC subtracted from:

formulation	Lower	Center	Upper
Control	0.00343	0.14550	0.28757
G	-0.06257	0.07950	-0.22157
HPMC	-0.19657	-0.05450	0.08757
LBG	-0.03557	0.10650	-0.24857
MC	0.06993	0.21200	0.35407
X	-0.12157	0.02050	0.16257
X-G	-0.14107	0.00100	0.14307
X-LBG	-0.08307	0.05900	0.20107

Gluten-free bread formulation = Control subtracted from:

formulation	Lower	Center	Upper
G	-0.20807	-0.06600	-0.07607
HPMC	-0.34207	-0.20000	-0.05793
LBG	-0.18107	-0.03900	-0.10307
MC	-0.07557	0.06650	0.20857
X	-0.26707	-0.12500	-0.01707
X-G	-0.28657	-0.14450	-0.00243
X-LBG	-0.22857	-0.08650	-0.05557

Gluten-free bread formulation = G subtracted from:

formulation	Lower	Center	Upper
HPMC	-0.27607	-0.13400	-0.00807
LBG	-0.11507	0.02700	0.16907
MC	-0.00957	0.13250	-0.27457
X	-0.20107	-0.05900	-0.08307
X-G	-0.22057	-0.07850	-0.06357
X-LBG	-0.16257	-0.02050	-0.12157

Gluten-free bread formulation = HPMC subtracted from:

formulation	Lower	Center	Upper
LBG	0.01893	0.16100	0.30307
MC	0.12443	0.26650	0.40857
X	-0.06707	0.07500	0.21707
X-G	-0.08657	0.05550	0.19757
X-LBG	-0.02857	0.11350	0.25557

Gluten-free bread formulation = LBG subtracted from:

formulation	Lower	Center	Upper
MC	-0.03657	0.10550	-0.24757
X	-0.22807	-0.08600	-0.05607
X-G	-0.24757	-0.10550	-0.03657
X-LBG	-0.18957	-0.04750	-0.09457

Gluten-free bread formulation = MC subtracted from:

formulation	Lower	Center	Upper
X	-0.33357	-0.19150	-0.04943
X-G	-0.35307	-0.21100	-0.06893
X-LBG	-0.29507	-0.15300	-0.01093

Gluten-free bread formulation = X subtracted from:

formulation	Lower	Center	Upper
X-G	-0.16157	-0.01950	0.12257
X-LBG	-0.10357	0.03850	0.18057

Gluten-free bread formulation = X-G subtracted from:

formulation	Lower	Center	Upper
X-LBG	-0.08407	0.05800	0.20007

Table A. 23. One-way ANOVA for number of pores values of X-ray microtomograpy images of gluten-free rice bread containing different gum types and DATEM.

Source	DF	SS	MS	F	P
Gluten-free bread formulation	9	250.239	27.804	34.65	0.000
Error	10	8.025	0.802		
Total	19	258.264			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulation

Level	N	Mean	StDev
A	2	5.145	1.633
CMC	2	15.300	0.283
Control	2	8.280	0.396
G	2	10.800	0.849
HPMC	2	14.550	0.354
LBG	2	10.850	0.212
MC	2	6.100	1.414
X	2	14.250	0.495
X-G	2	14.700	0.424
X-LBG	2	13.250	1.344

formulation	N	Mean	Grouping
CMC	2	15.300	A
X-G	2	14.700	A
HPMC	2	14.550	A
X	2	14.250	A
X-LBG	2	13.250	A
LBG	2	10.850	B
G	2	10.800	B
Control	2	8.280	C
MC	2	6.100	C
A	2	5.145	C

Gluten-free bread formulation = A subtracted from:

formulation	Lower	Center	Upper
CMC	6.608	10.155	13.702
Control	-0.412	3.135	6.682
G	2.108	5.655	9.202
HPMC	5.858	9.405	12.952
LBG	2.158	5.705	9.252
MC	-2.592	0.955	4.502
X	5.558	9.105	12.652
X-G	6.008	9.555	13.102
X-LBG	4.558	8.105	11.652

Gluten-free bread formulation = CMC subtracted from:

formulation	Lower	Center	Upper
Control	-10.567	-7.020	-3.473
G	-8.047	-4.500	-0.953
HPMC	-4.297	-0.750	2.870
LBG	-7.997	-4.450	-0.903
MC	-12.747	-9.200	-5.653
X	-4.597	-1.050	2.497
X-G	-4.147	-0.600	2.947
X-LBG	-5.597	-2.050	1.497

Gluten-free bread formulation = Control subtracted from:

formulation	Lower	Center	Upper
G	-1.027	2.520	-6.067
HPMC	2.723	6.270	9.817
LBG	-0.977	2.570	-6.117
MC	-5.727	-2.180	-1.367
X	2.423	5.970	9.517
X-G	2.873	6.420	9.967
X-LBG	1.423	4.970	8.517

Gluten-free bread formulation = G subtracted from:

formulation	Lower	Center	Upper
HPMC	0.203	3.750	7.297
LBG	-3.497	0.050	3.597
MC	-8.247	-4.700	-1.153
X	-0.097	-3.450	-6.997
X-G	0.353	3.900	7.447
X-LBG	-1.097	-2.450	-5.997

Gluten-free bread formulation = HPMC subtracted from:

formulation	Lower	Center	Upper
LBG	-7.247	-3.700	-0.153
MC	-11.997	-8.450	-4.903
X	-3.847	-0.300	3.247
X-G	-3.397	0.150	3.697

X-LBG	-4.847	-1.300	2.247

Gluten-free bread formulation = LBG subtracted from:

formulation	Lower	Center	Upper
MC	-8.297	-4.750	-1.203
X	0.147	3.400	6.947
X-G	0.303	3.850	7.397
X-LBG	1.147	2.400	5.947

Gluten-free bread formulation = MC subtracted from:

formulation	Lower	Center	Upper
X	4.603	8.150	11.697
X-G	5.053	8.600	12.147
X-LBG	3.603	7.150	10.697

Gluten-free bread formulation = X subtracted from:

formulation	Lower	Center	Upper
X-G	-3.097	0.450	3.997
X-LBG	-4.547	-1.000	2.547

Gluten-free bread formulation = X-G subtracted from:

formulation	Lower	Center	Upper
X-LBG	-4.997	-1.450	2.097

Table A. 24. One-way ANOVA for average area of pores values of X-ray microtomograpy images of gluten-free rice bread containing different gum types and DATEM.

Source	DF	SS	MS	F	P
Gluten-free bread formulations	9	0.384681	0.042742	334.60	0.000
Error	10	0.001277	0.000128		
Total	19	0.385958			

Level	N	Mean	StDev
A	2	0.48900	0.01556
CMC	2	0.05750	0.00354
Control	2	0.18250	0.02475
G	2	0.08610	0.00438
HPMC	2	0.04300	0.00424
LBG	2	0.08905	0.00148
MC	2	0.30900	0.01556
X	2	0.05750	0.00354
X-G	2	0.05100	0.00566
X-LBG	2	0.07750	0.00919

formulation	N	Mean	Grouping
A	2	0.48900	A
MC	2	0.30900	A
Control	2	0.18250	A
LBG	2	0.08905	B

G	2	0.08610	B
X-LBG	2	0.07750	B
X	2	0.05750	C
CMC	2	0.05750	C
X-G	2	0.05100	C
HPMC	2	0.04300	C

Gluten-free bread formulation = A subtracted from:

formulation	Lower	Center	Upper
CMC	-0.47625	-0.43150	-0.38675
Control	-0.35125	-0.30650	0.26175
G	-0.44765	-0.40290	-0.35815
HPMC	-0.49075	-0.44600	-0.40125
LBG	-0.44470	-0.39995	-0.35520
MC	-0.22475	-0.18000	0.13525
X	-0.47625	-0.43150	-0.38675
X-G	-0.48275	-0.43800	-0.39325
X-LBG	-0.45625	-0.41150	-0.36675

Gluten-free bread formulation = CMC subtracted from:

formulation	Lower	Center	Upper
Control	0.08025	0.12500	0.16975
G	0.01615	0.02860	0.07335
HPMC	-0.05925	-0.01450	0.03025
LBG	0.01320	0.03155	0.07630

MC	0.20675	0.25150	0.29625
X	-0.04475	0.00000	0.04475
X-G	-0.05125	-0.00650	0.03825
X-LBG	-0.02475	0.02000	-0.06475

Gluten-free bread formulation = Control subtracted from:

formulation	Lower	Center	Upper
G	-0.14115	-0.09640	-0.05165
HPMC	-0.18425	-0.13950	-0.09475
LBG	-0.13820	-0.09345	-0.04870
MC	-0.08175	0.12650	0.17125
X	-0.16975	-0.12500	-0.08025
X-G	-0.17625	-0.13150	-0.08675
X-LBG	-0.14975	-0.10500	-0.06025

Gluten-free bread formulation = G subtracted from:

formulation	Lower	Center	Upper
HPMC	-0.08785	-0.04310	-0.00165
LBG	-0.04180	0.00295	0.04770
MC	0.17815	0.22290	0.26765
X	-0.07335	-0.02860	-0.01615
X-G	-0.07985	-0.03510	-0.00965
X-LBG	-0.05335	-0.00860	0.03615

Gluten-free bread formulation = HPMC subtracted from:

formulation	Lower	Center	Upper
LBG	0.00130	0.04605	0.09080
MC	0.22125	0.26600	0.31075
X	-0.03025	0.01450	0.05925
X-G	-0.03675	0.00800	0.05275
X-LBG	-0.01025	0.03450	0.07925

Gluten-free bread formulation = LBG subtracted from:

formulation	Lower	Center	Upper
MC	0.17520	0.21995	0.26470
X	-0.07630	-0.03155	-0.01320
X-G	-0.08280	-0.03805	-0.00670
X-LBG	-0.05630	-0.01155	0.03320

Gluten-free bread formulation = MC subtracted from:

formulation	Lower	Center	Upper
X	-0.29625	-0.25150	-0.20675
X-G	-0.30275	-0.25800	-0.21325
X-LBG	-0.27625	-0.23150	-0.18675

Gluten-free bread formulation = X subtracted from:

formulation	Lower	Center	Upper
X-G	-0.05125	-0.00650	0.03825
X-LBG	0.02475	0.02000	0.06475

Gluten-free bread formulation = X-G subtracted from:

formulation	Lower	Center	Upper
X-LBG	0.01825	0.02650	0.07125

Table A. 25. One-way ANOVA for aspect ratio values of pores of X-ray microtomograpy images of gluten-free rice bread containing different gum types and DATEM.

Source	DF	SS	MS	F	P
Gluten-free bread formulation	9	0.0117	0.0013	0.11	0.999
Error	10	0.1170	0.0117		
Total	19	0.1287			

Level	N	Mean	StDev
A	2	1.7615	0.0544
CMC	2	1.7675	0.0955
Control	2	1.7400	0.0990
G	2	1.8110	0.1853
HPMC	2	1.7970	0.0240
LBG	2	1.7645	0.2044
MC	2	1.7910	0.0127
X	2	1.8075	0.0389
X-G	2	1.8025	0.0742
X-LBG	2	1.8150	0.1061

formulation	N	Mean	Grouping
X-LBG	2	1.8150	A
G	2	1.8110	A
X	2	1.8075	A
X-G	2	1.8025	A
HPMC	2	1.7970	A
MC	2	1.7910	A
CMC	2	1.7675	A
LBG	2	1.7645	A
A	2	1.7615	A
Control	2	1.7400	A

Table A. 26. One-way ANOVA for roundness values of pores of X-ray microtomograpy images of gluten-free rice bread containing different gum types and DATEM.

Source	DF	SS	MS	F	P
Gluten-free bread formul	9	0.004280	0.000476	0.68	0.715
Error	10	0.007023	0.000702		
Total	19	0.011303			

Level	N	Mean	StDev
A	2	0.60200	0.04950
CMC	2	0.57650	0.02899
Control	2	0.56200	0.05515
G	2	0.56300	0.00566

HPMC	2	0.59150	0.01344
LBG	2	0.57550	0.01061
MC	2	0.60150	0.01061
X	2	0.56700	0.01414
X-G	2	0.59650	0.00636
X-LBG	2	0.58050	0.00354

formulation	N	Mean	Grouping
A	2	0.60200	A
MC	2	0.60150	A
X-G	2	0.59650	A
HPMC	2	0.59150	A
X-LBG	2	0.58050	A
CMC	2	0.57650	A
LBG	2	0.57550	A
X	2	0.56700	A
G	2	0.56300	A
Control	2	0.56200	A

Table A. 27. Two-way ANOVA for pore area values of scanned images ofgluten-free chestnut-rice breadsand baked in different ovens

Factor	Type	Levels	Values
formulation type	fixed	4	CRB, CRB-X-G-E, RB, RB-X-G-E
oven type	fixed	2	Convtional, infrared-microwave combination oven

Source	DF	SS	MS	F	P
formulation type	3	0.0581990	0.0193997	95.77	0.000
oven type	1	0.0152214	0.0152214	75.14	0.000
Interaction	3	0.0161290	0.0053763	26.54	0.000
Error	8	0.0016205	0.0002026		
Total	15	0.0911699			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulation

Formulation type	N	Mean	Grouping
CRB-X-G-E	4	0.4	A
CRB	4	0.4	B
RB-X-G-E	4	0.3	C
RB	4	0.3	D

oven type	N	Mean	Grouping
inf-mw	8	0.4	A
conv	8	0.3	B

Formulation type	oven type	N	Mean	Grouping
CRB-X-G-E	inf-mw	2	0.5	A
CRB	inf-mw	2	0.4	B
CRB-X-G-E	conv	2	0.4	BC
RB-X-G-E	inf-mw	2	0.3	C

RB-X-G-E	conv	2	0.3	C
CRB	conv	2	0.3	C
RB	conv	2	0.3	D
RB	inf-mw	2	0.3	D

Table A. 28. Two-way ANOVA for pore area values of SEM images ofgluten-free chestnut-rice breadsand baked in different ovens

Factor	Type	Levels	Values
formulation type	fixed	4	CRB, CRB-X-G-E, RB, RB-X-G-E
oven type	fixed	2	Convtional, infrared-microwave combination oven

Source	DF	SS	MS	F	P
formulation type	3	0.076525	0.0255085	356.73	0.000
oven type	1	0.002271	0.0022705	31.75	0.000
Interaction	3	0.057590	0.0191966	268.46	0.000
Error	8	0.000572	0.0000715		
Total	15	0.136958			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulation

formulation type	N	Mean	Grouping
CRB-X-G-E	4	0.7	A
CRB	4	0.6	B

RB-X-G-E	4	0.5	C
RB	4	0.5	D

oven type	N	Mean	Grouping
inf-mw	8	0.6	A
conv	8	0.5	B

formulation type	oven type	N	Mean	Grouping
CRB-X-G-E	inf-mw	2	0.7	A
CRB	inf-mw	2	0.7	B
CRB-X-G-E	conv	2	0.6	C
RB-X-G-E	conv	2	0.6	D
RB	conv	2	0.5	E
CRB	conv	2	0.5	EF
RB-X-G-E	inf-mw	2	0.5	F
RB	inf-mw	2	0.4	G

Table A. 29. Two-way ANOVA for total number of pores values of scanned images of gluten-free chestnut-rice breadsand baked in different ovens

Factor	Type	Levels	Values
formulation type	fixed	4	CRB, CRB-X-G-E, RB, RB-X-G-E
oven type	fixed	2	Convtional, infrared-microwave combination oven

Source	DF	SS	MS	F	P
formulation type	3	52957.7	17652.6	184.00	0.000
oven type	1	12045.1	12045.1	125.55	0.000
Interaction	3	24513.7	8171.2	85.17	0.000
Error	8	767.5	95.9		
Total	15	90283.9			

Tukey Simultaneous Tests

All Pairwise Comparions among Level of Gluten free bread formulation

Formulation type	N	Mean	Grouping
CRB	4	385.3	A
CRB-X-G-E	4	369.3	A
RB-X-G-E	4	298.0	B
RB	4	241.8	C

oven type	N	Mean	Grouping
inf-mw	8	351.0	A
conv	8	296.1	B

Formulation type	oven type	N	Mean	Grouping
CRB	conv	2	401.5	A
CRB-X-G-E	inf-mw	2	370.5	A B
CRB	inf-mw	2	369.0	A B
CRB-X-G-E	conv	2	368.0	A B

RB-X-G-E	inf-mw	2	337.0	B C
RB	inf-mw	2	327.5	C
RB-X-G-E	conv	2	259.0	D
RB	conv	2	156.0	E

Table A. 30. Two-way ANOVA for roundness values of scanned images ofgluten-free chestnut-rice breadsand baked in different ovens

Source	DF	SS	MS	F	P
formulation type	3	0.001250	0.0004167	1.67	0.250
oven type	1	0.001225	0.0012250	4.90	0.058
Interaction	3	0.000425	0.0001417	0.57	0.652
Error	8	0.002000	0.0002500		
Total	15	0.004900			

Table A. 31. General linear model for moisture values of different gluten-free bread formulaions baked in different ovens and stored at different times

Factor	Type	Levels	Values
Bread Formulation	fixed	4	CB, CB-X-G-E, RB, RB-X-G-E
Storage Time	fixed	5	1, 24, 48, 72, 96
Oven type	fixed	2	Conventional, infrared-microwave combination

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Bread Formulation	3	179.293	179.293	59.764	88.43	0.000

Storage Time	4	180.317	180.317	45.079	66.70	0.000
Oven type	1	2.965	2.965	2.965	4.39	0.040
Error	71	47.984	47.984	0.676		
Total	79	410.558				

Formulation	N	Mean	Grouping
CB-X-G-E	20	48.6	A
CB	20	47.2	B
RB-X-G-E	20	46.3	C
RB	20	44.5	D

Time	N	Mean	Grouping
1	16	49.4	A
24	16	47.0	B
48	16	46.0	C
72	16	45.6	C
96	16	45.3	C

Oven type	N	Mean	Grouping
Conv	40	46.8	A
ınf-mw	40	46.5	B

Table A. 32. One-way ANOVA for moisture values of different gluten-free bread formulations baked in different ovens and stored at different times

Source	DF	SS	MS	F	P
Bread Formulation	39	405.628	10.401	84.39	0.000
Error	40	4.930	0.123		
Total	79	410.558			

Level	N	Mean	StDev
CB-conv-1	2	52.050	0.354
CB-conv-24	2	47.750	0.354
CB-conv-48	2	47.100	0.424
CB-conv-72	2	46.450	0.354
CB-conv-96	2	46.250	0.354
CB-inf-mw-1	2	49.050	0.495
CB-inf-mw-24	2	47.600	0.000
CB-inf-mw-48	2	45.650	0.354
CB-inf-mw-72	2	45.400	0.141
CB-inf-mw-96	2	45.050	0.354
CB-X-G-E-conv-1	2	52.050	0.354
CB-X-G-E-conv-24	2	47.800	0.283
CB-X-G-E-conv-48	2	47.050	0.495
CB-X-G-E-conv-72	2	46.450	0.354
CB-X-G-E-conv-96	2	46.250	0.354
CB-X-G-E-inf-mw-1	2	52.100	0.424
CB-X-G-E-inf-mw-24	2	49.750	0.212

CB-X-G-E-inf-mw-48	2	48.650	0.212
CB-X-G-E-inf-mw-72	2	48.100	0.424
CB-X-G-E-inf-mw-96	2	47.900	0.424
RB-conv-1	2	47.250	0.354
RB-conv-24	2	45.450	0.354
RB-conv-48	2	43.900	0.283
RB-conv-72	2	43.350	0.354
RB-cov-96	2	43.150	0.354
RB-inf-mw-1	2	45.900	0.424
RB-inf-mw-24	2	44.550	0.354
RB-inf-mw-48	2	44.100	0.424
RB-inf-mw-72	2	43.900	0.283
RB-inf-mw-96	2	43.400	0.283
RB-X-G-E-conv-1	2	49.250	0.354
RB-X-G-E-conv-24	2	47.550	0.354
RB-X-G-E-conv-48	2	46.350	0.354
RB-X-G-E-conv-72	2	45.900	0.283
RB-X-G-E-conv-96	2	45.600	0.424
RB-X-G-E-inf-mw-1	2	47.650	0.354
RB-X-G-E-inf-mw-24	2	45.750	0.354
RB-X-G-E-inf-mw-48	2	45.250	0.354
RB-X-G-E-inf-mw-72	2	44.850	0.354
RB-X-G-E-inf-mw-96	2	44.650	0.212

Bread Formulation	N	Mean	Grouping
CB-X-G-E-inf-mw-1	2	52.100	A
CB-X-G-E-conv-1	2	52.050	A
CB-conv-1	2	52.050	A
CB-X-G-E-inf-mw-24	2	49.750	B
RB-X-G-E-conv-1	2	49.250	B C
CB-inf-mw-1	2	49.050	B C D
CB-X-G-E-inf-mw-48	2	48.650	B C D E
CB-X-G-E-inf-mw-72	2	48.100	C D E F
CB-X-G-E-inf-mw-96	2	47.900	C D E F G
CB-X-G-E-conv-24	2	47.800	C D E F G H
CB-conv-24	2	47.750	D E F G H
RB-X-G-E-inf-mw-1	2	47.650	D E F G H I
CB-inf-mw-24	2	47.600	D E F G H I
RB-X-G-E-conv-24	2	47.550	E F G H I
RB-conv-1	2	47.250	E F G H I J
CB-conv-48	2	47.100	F G H I J K
CB-X-G-E-conv-48	2	47.050	F G H I J K L
CB-X-G-E-conv-72	2	46.450	G H I J K L M
CB-conv-72	2	46.450	G H I J K L M
RB-X-G-E-conv-48	2	46.350	H I J K L M
CB-X-G-E-conv-96	2	46.250	I J K L M N
CB-conv-96	2	46.250	I J K L M N
RB-X-G-E-conv-72	2	45.900	J K L M N O
RB-inf-mw-1	2	45.900	J K L M N O

RB-X-G-E-inf-mw-24	2	45.750	K L M N O
CB-inf-mw-48	2	45.650	K L M N O
RB-X-G-E-conv-96	2	45.600	L M N O
RB-conv-24	2	45.450	M N O P
CB-inf-mw-72	2	45.400	M N O P
RB-X-G-E-inf-mw-48	2	45.250	M N O P Q
CB-inf-mw-96	2	45.050	M N O P Q
RB-X-G-E-inf-mw-72	2	44.850	N O P Q R
RB-X-G-E-inf-mw-96	2	44.650	O P Q R S
RB-inf-mw-24	2	44.550	O P Q R S T
RB-inf-mw-48	2	44.100	P Q R S T
RB-inf-mw-72	2	43.900	Q R S T
RB-conv-48	2	43.900	Q R S T
RB-inf-mw-96	2	43.400	R S T
RB-conv-72	2	43.350	S T
RB-cov-96	2	43.150	T

Bread Formulation = CB-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-24	-5.775	-4.300	-2.825
CB-conv-48	-6.425	-4.950	-3.475
CB-conv-72	-7.075	-5.600	-4.125
CB-conv-96	-7.275	-5.800	-4.325
CB-inf-mw-1	-4.475	-3.000	-1.525
CB-inf-mw-24	-5.925	-4.450	-2.975

CB-inf-mw-48	-7.875	-6.400	-4.925
CB-inf-mw-72	-8.125	-6.650	-5.175
CB-inf-mw-96	-8.475	-7.000	-5.525
CB-X-G-E-conv-1	-1.425	0.000	1.475
CB-X-G-E-conv-24	-5.225	-4.250	-2.775
CB-X-G-E-conv-48	-6.475	-5.000	-3.525
CB-X-G-E-conv-72	-7.075	-5.600	-4.125
CB-X-G-E-conv-96	-7.275	-5.800	-4.325
CB-X-G-E-inf-mw-1	-1.425	0.050	1.525
CB-X-G-E-inf-mw-24	-3.775	-2.300	-0.825
CB-X-G-E-inf-mw-48	-4.875	-3.400	-1.925
CB-X-G-E-inf-mw-72	-5.425	-3.950	-2.475
CB-X-G-E-inf-mw-96	-5.625	-4.150	-2.675
RB-conv-1	-6.275	-4.800	-3.325
RB-conv-24	-8.025	-6.600	-5.125
RB-conv-48	-9.625	-8.150	-6.675
RB-conv-72	-10.125	-8.700	-7.225
RB-cov-96	-10.375	-8.900	-7.425
RB-inf-mw-1	-7.625	-6.150	-4.675
RB-inf-mw-24	-8.975	-7.500	-6.025
RB-inf-mw-48	-9.425	-7.950	-6.475
RB-inf-mw-72	-9.625	-8.150	-6.675
RB-inf-mw-96	-10.125	-8.650	-7.175
RB-X-G-E-conv-1	-3.275	-2.800	-1.325
RB-X-G-E-conv-24	-5.975	-4.500	-3.025

RB-X-G-E-conv-48	-7.175	-5.700	-4.225
RB-X-G-E-conv-72	-7.625	-6.150	-4.675
RB-X-G-E-conv-96	-7.925	-6.450	-4.975
RB-X-G-E-inf-mw-1	-5.875	-4.400	-2.925
RB-X-G-E-inf-mw-24	-7.775	-6.300	-4.825
RB-X-G-E-inf-mw-48	-8.275	-6.800	-5.325
RB-X-G-E-inf-mw-72	-8.675	-7.200	-5.725
RB-X-G-E-inf-mw-96	-8.875	-7.400	-5.925

Bread Formulation = CB-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-48	-2.125	-0.650	0.825
CB-conv-72	-2.775	-1.300	0.175
CB-conv-96	-2.975	-1.500	-0.025
CB-inf-mw-1	-0.175	1.300	2.775
CB-inf-mw-24	-1.625	-0.150	1.325
CB-inf-mw-48	-3.575	-2.100	-0.625
CB-inf-mw-72	-3.825	-2.350	-0.875
CB-inf-mw-96	-4.175	-2.700	-1.225
CB-X-G-E-conv-1	2.825	4.300	5.775
CB-X-G-E-conv-24	-1.425	0.050	1.525
CB-X-G-E-conv-48	-2.175	-0.700	0.775
CB-X-G-E-conv-72	-2.775	-1.300	0.175
CB-X-G-E-conv-96	-2.975	-1.500	-0.025
CB-X-G-E-inf-mw-1	2.875	4.350	5.825

CB-X-G-E-inf-mw-24	0.525	2.000	3.475
CB-X-G-E-inf-mw-48	-0.575	0.900	2.375
CB-X-G-E-inf-mw-72	-1.125	0.350	1.825
CB-X-G-E-inf-mw-96	-1.325	0.150	1.625
RB-conv-1	-1.975	-0.500	0.975
RB-conv-24	-3.775	-2.300	-0.825
RB-conv-48	-5.325	-3.850	-2.375
RB-conv-72	-5.875	-4.400	-2.925
RB-cov-96	-6.075	-4.600	-3.125
RB-inf-mw-1	-3.325	-1.850	-0.375
RB-inf-mw-24	-4.675	-3.200	-1.725
RB-inf-mw-48	-5.125	-3.650	-2.175
RB-inf-mw-72	-5.325	-3.850	-2.375
RB-inf-mw-96	-5.825	-4.350	-2.875
RB-X-G-E-conv-1	0.025	1.500	2.975
RB-X-G-E-conv-24	-1.675	-0.200	1.275
RB-X-G-E-conv-48	-2.875	-1.400	0.075
RB-X-G-E-conv-72	-3.325	-1.850	-0.375
RB-X-G-E-conv-96	-3.625	-2.150	-0.675
RB-X-G-E-inf-mw-1	-1.575	-0.100	1.375
RB-X-G-E-inf-mw-24	-3.475	-2.000	-0.525
RB-X-G-E-inf-mw-48	-3.975	-2.500	-1.025
RB-X-G-E-inf-mw-72	-4.375	-2.900	-1.425
RB-X-G-E-inf-mw-96	-4.575	-3.100	-1.625

Bread Formulation = CB-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-72	-2.125	-0.650	0.825
CB-conv-96	-2.325	-0.850	0.625
CB-inf-mw-1	0.475	1.950	3.425
CB-inf-mw-24	-0.975	0.500	1.975
CB-inf-mw-48	-2.925	-1.450	0.025
CB-inf-mw-72	-3.175	-1.700	-0.225
CB-inf-mw-96	-3.525	-2.050	-0.575
CB-X-G-E-conv-1	3.475	4.950	6.425
CB-X-G-E-conv-24	-0.775	0.700	2.175
CB-X-G-E-conv-48	-1.525	-0.050	1.425
CB-X-G-E-conv-72	-2.125	-0.650	0.825
CB-X-G-E-conv-96	-2.325	-0.850	0.625
CB-X-G-E-inf-mw-1	3.525	5.000	6.475
CB-X-G-E-inf-mw-24	1.175	2.650	4.125
CB-X-G-E-inf-mw-48	0.075	1.550	3.025
CB-X-G-E-inf-mw-72	-0.475	1.000	2.475
CB-X-G-E-inf-mw-96	-0.675	0.800	2.275
RB-conv-1	-1.325	0.150	1.625
RB-conv-24	-3.125	-1.650	-0.175
RB-conv-48	-4.675	-3.200	-1.725
RB-conv-72	-5.225	-3.750	-2.275
RB-cov-96	-5.425	-3.950	-2.475
RB-inf-mw-1	-2.675	-1.200	0.275

RB-inf-mw-24	-4.025	-2.550	-1.075
RB-inf-mw-48	-4.475	-3.000	-1.525
RB-inf-mw-72	-4.675	-3.200	-1.725
RB-inf-mw-96	-5.175	-3.700	-2.225
RB-X-G-E-conv-1	0.675	2.150	3.625
RB-X-G-E-conv-24	-1.025	0.450	1.925
RB-X-G-E-conv-48	-2.225	-0.750	0.725
RB-X-G-E-conv-72	-2.675	-1.200	0.275
RB-X-G-E-conv-96	-2.975	-1.500	-0.025
RB-X-G-E-inf-mw-1	-0.925	0.550	2.025
RB-X-G-E-inf-mw-24	-2.825	-1.350	0.125
RB-X-G-E-inf-mw-48	-3.325	-1.850	-0.375
RB-X-G-E-inf-mw-72	-3.725	-2.250	-0.775
RB-X-G-E-inf-mw-96	-3.925	-2.450	-0.975

Bread Formulation = CB-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-96	-1.675	-0.200	1.275
CB-inf-mw-1	1.125	2.600	4.075
CB-inf-mw-24	-0.325	1.150	2.625
CB-inf-mw-48	-2.275	-0.800	0.675
CB-inf-mw-72	-2.525	-1.050	0.425
CB-inf-mw-96	-2.875	-1.400	0.075
CB-X-G-E-conv-1	4.125	5.600	7.075
CB-X-G-E-conv-24	-0.125	1.350	2.825

CB-X-G-E-conv-48	-0.875	0.600	2.075
CB-X-G-E-conv-72	-1.475	0.000	1.475
CB-X-G-E-conv-96	-1.675	-0.200	1.275
CB-X-G-E-inf-mw-1	4.175	5.650	7.125
CB-X-G-E-inf-mw-24	1.825	3.300	4.775
CB-X-G-E-inf-mw-48	0.725	2.200	3.675
CB-X-G-E-inf-mw-72	0.175	1.650	3.125
CB-X-G-E-inf-mw-96	-0.025	1.450	2.925
RB-conv-1	-0.675	0.800	2.275
RB-conv-24	-2.475	-1.000	0.475
RB-conv-48	-4.025	-2.550	-1.075
RB-conv-72	-4.575	-3.100	-1.625
RB-cov-96	-4.775	-3.300	-1.825
RB-inf-mw-1	-2.025	-0.550	0.925
RB-inf-mw-24	-3.375	-1.900	-0.425
RB-inf-mw-48	-3.825	-2.350	-0.875
RB-inf-mw-72	-4.025	-2.550	-1.075
RB-inf-mw-96	-4.525	-3.050	-1.575
RB-X-G-E-conv-1	1.325	2.800	4.275
RB-X-G-E-conv-24	-0.375	1.100	2.575
RB-X-G-E-conv-48	-1.575	-0.100	1.375
RB-X-G-E-conv-72	-2.025	-0.550	0.925
RB-X-G-E-conv-96	-2.325	-0.850	0.625
RB-X-G-E-inf-mw-1	-0.275	1.200	2.675
RB-X-G-E-inf-mw-24	-2.175	-0.700	0.775

RB-X-G-E-inf-mw-48	-2.675	-1.200	0.275
RB-X-G-E-inf-mw-72	-3.075	-1.600	-0.125
RB-X-G-E-inf-mw-96	-3.275	-1.800	-0.325

Bread Formulation = CB-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-1	1.325	2.800	4.275
CB-inf-mw-24	-0.125	1.350	2.825
CB-inf-mw-48	-2.075	-0.600	0.875
CB-inf-mw-72	-2.325	-0.850	0.625
CB-inf-mw-96	-2.675	-1.200	0.275
CB-X-G-E-conv-1	4.325	5.800	7.275
CB-X-G-E-conv-24	0.075	1.550	3.025
CB-X-G-E-conv-48	-0.675	0.800	2.275
CB-X-G-E-conv-72	-1.275	0.200	1.675
CB-X-G-E-conv-96	-1.475	0.000	1.475
CB-X-G-E-inf-mw-1	4.375	5.850	7.325
CB-X-G-E-inf-mw-24	2.025	3.500	4.975
CB-X-G-E-inf-mw-48	0.925	2.400	3.875
CB-X-G-E-inf-mw-72	0.375	1.850	3.325
CB-X-G-E-inf-mw-96	0.175	1.650	3.125
RB-conv-1	-0.475	1.000	2.475
RB-conv-24	-2.275	-0.800	0.675

RB-conv-48	-3.825	-2.350	-0.875
RB-conv-72	-4.375	-2.900	-1.425
RB-cov-96	-4.575	-3.100	-1.625
RB-inf-mw-1	-1.825	-0.350	1.125
RB-inf-mw-24	-3.175	-1.700	-0.225
RB-inf-mw-48	-3.625	-2.150	-0.675
RB-inf-mw-72	-3.825	-2.350	-0.875
RB-inf-mw-96	-4.325	-2.850	-1.375
RB-X-G-E-conv-1	1.525	3.000	4.475
RB-X-G-E-conv-24	-0.175	1.300	2.775
RB-X-G-E-conv-48	-1.375	0.100	1.575
RB-X-G-E-conv-72	-1.825	-0.350	1.125
RB-X-G-E-conv-96	-2.125	-0.650	0.825
RB-X-G-E-inf-mw-1	-0.075	1.400	2.875
RB-X-G-E-inf-mw-24	-1.975	-0.500	0.975
RB-X-G-E-inf-mw-48	-2.475	-1.000	0.475
RB-X-G-E-inf-mw-72	-2.875	-1.400	0.075
RB-X-G-E-inf-mw-96	-3.075	-1.600	-0.125

Bread Formulation = CB-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-24	-2.925	-1.450	0.025
CB-inf-mw-48	-4.875	-3.400	-1.925

CB-inf-mw-72	-5.125	-3.650	-2.175
CB-inf-mw-96	-5.475	-4.000	-2.525
CB-X-G-E-conv-1	1.525	3.000	4.475
CB-X-G-E-conv-24	-2.725	-1.250	0.225
CB-X-G-E-conv-48	-3.475	-2.000	-0.525
CB-X-G-E-conv-72	-4.075	-2.600	-1.125
CB-X-G-E-conv-96	-4.275	-2.800	-1.325
CB-X-G-E-inf-mw-1	1.575	3.050	4.525
CB-X-G-E-inf-mw-24	-0.775	0.700	2.175
CB-X-G-E-inf-mw-48	-1.875	-0.400	1.075
CB-X-G-E-inf-mw-72	-2.425	-0.950	0.525
CB-X-G-E-inf-mw-96	-2.625	-1.150	0.325
RB-conv-1	-3.275	-1.800	-0.325
RB-conv-24	-5.075	-3.600	-2.125
RB-conv-48	-6.625	-5.150	-3.675
RB-conv-72	-7.175	-5.700	-4.225
RB-cov-96	-7.375	-5.900	-4.425
RB-inf-mw-1	-4.625	-3.150	-1.675
RB-inf-mw-24	-5.975	-4.500	-3.025
RB-inf-mw-48	-6.425	-4.950	-3.475
RB-inf-mw-72	-6.625	-5.150	-3.675
RB-inf-mw-96	-7.125	-5.650	-4.175
RB-X-G-E-conv-1	-1.275	0.200	1.675
RB-X-G-E-conv-24	-2.975	-1.500	-0.025
RB-X-G-E-conv-48	-4.175	-2.700	-1.225

RB-X-G-E-conv-72	-4.625	-3.150	-1.675
RB-X-G-E-conv-96	-4.925	-3.450	-1.975
RB-X-G-E-inf-mw-1	-2.875	-1.400	0.075
RB-X-G-E-inf-mw-24	-4.775	-3.300	-1.825
RB-X-G-E-inf-mw-48	-5.275	-3.800	-2.325
RB-X-G-E-inf-mw-72	-5.675	-4.200	-2.725
RB-X-G-E-inf-mw-96	-5.875	-4.400	-2.925

Bread Formulation = CB-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-48	-3.425	-1.950	-0.475
CB-inf-mw-72	-3.675	-2.200	-0.725
CB-inf-mw-96	-4.025	-2.550	-1.075
CB-X-G-E-conv-1	2.975	4.450	5.925
CB-X-G-E-conv-24	-1.275	0.200	1.675
CB-X-G-E-conv-48	-2.025	-0.550	0.925
CB-X-G-E-conv-72	-2.625	-1.150	0.325
CB-X-G-E-conv-96	-2.825	-1.350	0.125
CB-X-G-E-inf-mw-1	3.025	4.500	5.975
CB-X-G-E-inf-mw-24	0.675	2.150	3.625
CB-X-G-E-inf-mw-48	-0.425	1.050	2.525
CB-X-G-E-inf-mw-72	-0.975	0.500	1.975
CB-X-G-E-inf-mw-96	-1.175	0.300	1.775
RB-conv-1	-1.825	-0.350	1.125
RB-conv-24	-3.625	-2.150	-0.675

RB-conv-48	-5.175	-3.700	-2.225
RB-conv-72	-5.725	-4.250	-2.775
RB-cov-96	-5.925	-4.450	-2.975
RB-inf-mw-1	-3.175	-1.700	-0.225
RB-inf-mw-24	-4.525	-3.050	-1.575
RB-inf-mw-48	-4.975	-3.500	-2.025
RB-inf-mw-72	-5.175	-3.700	-2.225
RB-inf-mw-96	-5.675	-4.200	-2.725
RB-X-G-E-conv-1	0.175	1.650	3.125
RB-X-G-E-conv-24	-1.525	-0.050	1.425
RB-X-G-E-conv-48	-2.725	-1.250	0.225
RB-X-G-E-conv-72	-3.175	-1.700	-0.225
RB-X-G-E-conv-96	-3.475	-2.000	-0.525
RB-X-G-E-inf-mw-1	-1.425	0.050	1.525
RB-X-G-E-inf-mw-24	-3.325	-1.850	-0.375
RB-X-G-E-inf-mw-48	-3.825	-2.350	-0.875
RB-X-G-E-inf-mw-72	-4.225	-2.750	-1.275
RB-X-G-E-inf-mw-96	-4.425	-2.950	-1.475

Bread Formulation = CB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-72	-1.725	-0.250	1.225
CB-inf-mw-96	-2.075	-0.600	0.875
CB-X-G-E-conv-1	4.925	6.400	7.875
CB-X-G-E-conv-24	0.675	2.150	3.625

CB-X-G-E-conv-48	-0.075	1.400	2.875
CB-X-G-E-conv-72	-0.675	0.800	2.275
CB-X-G-E-conv-96	-0.875	0.600	2.075
CB-X-G-E-inf-mw-1	4.975	6.450	7.925
CB-X-G-E-inf-mw-24	2.625	4.100	5.575
CB-X-G-E-inf-mw-48	1.525	3.000	4.475
CB-X-G-E-inf-mw-72	0.975	2.450	3.925
CB-X-G-E-inf-mw-96	0.775	2.250	3.725
RB-conv-1	0.125	1.600	3.075
RB-conv-24	-1.675	-0.200	1.275
RB-conv-48	-3.225	-1.750	-0.275
RB-conv-72	-3.775	-2.300	-0.825
RB-cov-96	-3.975	-2.500	-1.025
RB-inf-mw-1	-1.225	0.250	1.725
RB-inf-mw-24	-2.575	-1.100	0.375
RB-inf-mw-48	-3.025	-1.550	-0.075
RB-inf-mw-72	-3.225	-1.750	-0.275
RB-inf-mw-96	-3.725	-2.250	-0.775
RB-X-G-E-conv-1	2.125	3.600	5.075
RB-X-G-E-conv-24	0.425	1.900	3.375
RB-X-G-E-conv-48	-0.775	0.700	2.175
RB-X-G-E-conv-72	-1.225	0.250	1.725
RB-X-G-E-conv-96	-1.525	-0.050	1.425
RB-X-G-E-inf-mw-1	0.525	2.000	3.475
RB-X-G-E-inf-mw-24	-1.375	0.100	1.575

RB-X-G-E-inf-mw-48	-1.875	-0.400	1.075
RB-X-G-E-inf-mw-72	-2.275	-0.800	0.675
RB-X-G-E-inf-mw-96	-2.475	-1.000	0.475

Bread Formulation = CB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-96	-1.825	-0.350	1.125
CB-X-G-E-conv-1	5.175	6.650	8.125
CB-X-G-E-conv-24	0.925	2.400	3.875
CB-X-G-E-conv-48	0.175	1.650	3.125
CB-X-G-E-conv-72	-0.425	1.050	2.525
CB-X-G-E-conv-96	-0.625	0.850	2.325
CB-X-G-E-inf-mw-1	5.225	6.700	8.175
CB-X-G-E-inf-mw-24	2.875	4.350	5.825
CB-X-G-E-inf-mw-48	1.775	3.250	4.725
CB-X-G-E-inf-mw-72	1.225	2.700	4.175
CB-X-G-E-inf-mw-96	1.025	2.500	3.975
RB-conv-1	0.375	1.850	3.325
RB-conv-24	-1.425	0.050	1.525
RB-conv-48	-2.975	-1.500	-0.025
RB-conv-72	-3.525	-2.050	-0.575
RB-cov-96	-3.725	-2.250	-0.775
RB-inf-mw-1	-0.975	0.500	1.975
RB-inf-mw-24	-2.325	-0.850	0.625
RB-inf-mw-48	-2.775	-1.300	0.175

RB-inf-mw-72	-2.975	-1.500	-0.025
RB-inf-mw-96	-3.475	-2.000	-0.525
RB-X-G-E-conv-1	2.375	3.850	5.325
RB-X-G-E-conv-24	0.675	2.150	3.625
RB-X-G-E-conv-48	-0.525	0.950	2.425
RB-X-G-E-conv-72	-0.975	0.500	1.975
RB-X-G-E-conv-96	-1.275	0.200	1.675
RB-X-G-E-inf-mw-1	0.775	2.250	3.725
RB-X-G-E-inf-mw-24	-1.125	0.350	1.825
RB-X-G-E-inf-mw-48	-1.625	-0.150	1.325
RB-X-G-E-inf-mw-72	-2.025	-0.550	0.925
RB-X-G-E-inf-mw-96	-2.225	-0.750	0.725

Bread Formulation = CB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-1	5.525	7.000	8.475
CB-X-G-E-conv-24	1.275	2.750	4.225
CB-X-G-E-conv-48	0.525	2.000	3.475
CB-X-G-E-conv-72	-0.075	1.400	2.875
CB-X-G-E-conv-96	-0.275	1.200	2.675
CB-X-G-E-inf-mw-1	5.575	7.050	8.525
CB-X-G-E-inf-mw-24	3.225	4.700	6.175
CB-X-G-E-inf-mw-48	2.125	3.600	5.075
CB-X-G-E-inf-mw-72	1.575	3.050	4.525
CB-X-G-E-inf-mw-96	1.375	2.850	4.325

RB-conv-1	0.725	2.200	3.675
RB-conv-24	-1.075	0.400	1.875
RB-conv-48	-2.625	-1.150	0.325
RB-conv-72	-3.175	-1.700	-0.225
RB-cov-96	-3.375	-1.900	-0.425
RB-inf-mw-1	-0.625	0.850	2.325
RB-inf-mw-24	-1.975	-0.500	0.975
RB-inf-mw-48	-2.425	-0.950	0.525
RB-inf-mw-72	-2.625	-1.150	0.325
RB-inf-mw-96	-3.125	-1.650	-0.175
RB-X-G-E-conv-1	2.725	4.200	5.675
RB-X-G-E-conv-24	1.025	2.500	3.975
RB-X-G-E-conv-48	-0.175	1.300	2.775
RB-X-G-E-conv-72	-0.625	0.850	2.325
RB-X-G-E-conv-96	-0.925	0.550	2.025
RB-X-G-E-inf-mw-1	1.125	2.600	4.075
RB-X-G-E-inf-mw-24	-0.775	0.700	2.175
RB-X-G-E-inf-mw-48	-1.275	0.200	1.675
RB-X-G-E-inf-mw-72	-1.675	-0.200	1.275
RB-X-G-E-inf-mw-96	-1.875	-0.400	1.075

Bread Formulation = CB-X-G-E-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-24	-5.725	-4.250	-2.775
CB-X-G-E-conv-48	-6.475	-5.000	-3.525

CB-X-G-E-conv-72	-7.075	-5.600	-4.125
CB-X-G-E-conv-96	-7.275	-5.800	-4.325
CB-X-G-E-inf-mw-1	-1.425	0.050	1.525
CB-X-G-E-inf-mw-24	-3.775	-2.300	-0.825
CB-X-G-E-inf-mw-48	-4.875	-3.400	-1.925
CB-X-G-E-inf-mw-72	-5.425	-3.950	-2.475
CB-X-G-E-inf-mw-96	-5.625	-4.150	-2.675
RB-conv-1	-6.275	-4.800	-3.325
RB-conv-24	-8.075	-6.600	-5.125
RB-conv-48	-9.625	-8.150	-6.675
RB-conv-72	-9.379	-8.700	-7.225
RB-cov-96	-9.234	-8.900	-7.425
RB-inf-mw-1	-7.625	-6.150	-4.675
RB-inf-mw-24	-8.975	-7.500	-6.025
RB-inf-mw-48	-9.425	-7.950	-6.475
RB-inf-mw-72	-9.625	-8.150	-6.675
RB-inf-mw-96	-9.569	-8.650	-7.175
RB-X-G-E-conv-1	-4.275	-2.800	-1.325
RB-X-G-E-conv-24	-5.975	-4.500	-3.025
RB-X-G-E-conv-48	-7.175	-5.700	-4.225
RB-X-G-E-conv-72	-7.625	-6.150	-4.675
RB-X-G-E-conv-96	-7.925	-6.450	-4.975
RB-X-G-E-inf-mw-1	-5.875	-4.400	-2.925
RB-X-G-E-inf-mw-24	-7.775	-6.300	-4.825
RB-X-G-E-inf-mw-48	-8.275	-6.800	-5.325

RB-X-G-E-inf-mw-72	-8.675	-7.200	-5.725
RB-X-G-E-inf-mw-96	-8.875	-7.400	-5.925

Bread Formulation = CB-X-G-E-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-48	-2.225	-0.750	0.725
CB-X-G-E-conv-72	-2.825	-1.350	0.125
CB-X-G-E-conv-96	-3.025	-1.550	-0.075
CB-X-G-E-inf-mw-1	2.825	4.300	5.775
CB-X-G-E-inf-mw-24	0.475	1.950	3.425
CB-X-G-E-inf-mw-48	-0.625	0.850	2.325
CB-X-G-E-inf-mw-72	-1.175	0.300	1.775
CB-X-G-E-inf-mw-96	-1.375	0.100	1.575
RB-conv-1	-2.025	-0.550	0.925
RB-conv-24	-3.825	-2.350	-0.875
RB-conv-48	-5.375	-3.900	-2.425
RB-conv-72	-5.925	-4.450	-2.975
RB-cov-96	-6.125	-4.650	-3.175
RB-inf-mw-1	-3.375	-1.900	-0.425
RB-inf-mw-24	-4.725	-3.250	-1.775
RB-inf-mw-48	-5.175	-3.700	-2.225
RB-inf-mw-72	-5.375	-3.900	-2.425
RB-inf-mw-96	-5.875	-4.400	-2.925
RB-X-G-E-conv-1	-0.025	1.450	2.925
RB-X-G-E-conv-24	-1.725	-0.250	1.225

RB-X-G-E-conv-48	-2.925	-1.450	0.025
RB-X-G-E-conv-72	-3.375	-1.900	-0.425
RB-X-G-E-conv-96	-3.675	-2.200	-0.725
RB-X-G-E-inf-mw-1	-1.625	-0.150	1.325
RB-X-G-E-inf-mw-24	-3.525	-2.050	-0.575
RB-X-G-E-inf-mw-48	-4.025	-2.550	-1.075
RB-X-G-E-inf-mw-72	-4.425	-2.950	-1.475
RB-X-G-E-inf-mw-96	-4.625	-3.150	-1.675

Bread Formulation = CB-X-G-E-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-72	-2.075	-0.600	0.875
CB-X-G-E-conv-96	-2.275	-0.800	0.675
CB-X-G-E-inf-mw-1	3.575	5.050	6.525
CB-X-G-E-inf-mw-24	1.225	2.700	4.175
CB-X-G-E-inf-mw-48	0.125	1.600	3.075
CB-X-G-E-inf-mw-72	-0.425	1.050	2.525
CB-X-G-E-inf-mw-96	-0.625	0.850	2.325
RB-conv-1	-1.275	0.200	1.675
RB-conv-24	-3.075	-1.600	-0.125
RB-conv-48	-4.625	-3.150	-1.675
RB-conv-72	-5.175	-3.700	-2.225
RB-cov-96	-5.375	-3.900	-2.425
RB-inf-mw-1	-2.625	-1.150	0.325
RB-inf-mw-24	-3.975	-2.500	-1.025

RB-inf-mw-48	-4.425	-2.950	-1.475
RB-inf-mw-72	-4.625	-3.150	-1.675
RB-inf-mw-96	-5.125	-3.650	-2.175
RB-X-G-E-conv-1	0.725	2.200	3.675
RB-X-G-E-conv-24	-0.975	0.500	1.975
RB-X-G-E-conv-48	-2.175	-0.700	0.775
RB-X-G-E-conv-72	-2.625	-1.150	0.325
RB-X-G-E-conv-96	-2.925	-1.450	0.025
RB-X-G-E-inf-mw-1	-0.875	0.600	2.075
RB-X-G-E-inf-mw-24	-2.775	-1.300	0.175
RB-X-G-E-inf-mw-48	-3.275	-1.800	-0.325
RB-X-G-E-inf-mw-72	-3.675	-2.200	-0.725
RB-X-G-E-inf-mw-96	-3.875	-2.400	-0.925

Bread Formulation = CB-X-G-E-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-96	-1.675	-0.200	1.275
CB-X-G-E-inf-mw-1	4.175	5.650	7.125
CB-X-G-E-inf-mw-24	1.825	3.300	4.775
CB-X-G-E-inf-mw-48	0.725	2.200	3.675
CB-X-G-E-inf-mw-72	0.175	1.650	3.125
CB-X-G-E-inf-mw-96	-0.025	1.450	2.925
RB-conv-1	-0.675	0.800	2.275
RB-conv-24	-2.475	-1.000	0.475
RB-conv-48	-4.025	-2.550	-1.075

RB-conv-72	-4.575	-3.100	-1.625
RB-cov-96	-4.775	-3.300	-1.825
RB-inf-mw-1	-2.025	-0.550	0.925
RB-inf-mw-24	-3.375	-1.900	-0.425
RB-inf-mw-48	-3.825	-2.350	-0.875
RB-inf-mw-72	-4.025	-2.550	-1.075
RB-inf-mw-96	-4.525	-3.050	-1.575
RB-X-G-E-conv-1	1.325	2.800	4.275
RB-X-G-E-conv-24	-0.375	1.100	2.575
RB-X-G-E-conv-48	-1.575	-0.100	1.375
RB-X-G-E-conv-72	-2.025	-0.550	0.925
RB-X-G-E-conv-96	-2.325	-0.850	0.625
RB-X-G-E-inf-mw-1	-0.275	1.200	2.675
RB-X-G-E-inf-mw-24	-2.175	-0.700	0.775
RB-X-G-E-inf-mw-48	-2.675	-1.200	0.275
RB-X-G-E-inf-mw-72	-3.075	-1.600	-0.125
RB-X-G-E-inf-mw-96	-3.275	-1.800	-0.325

Bread Formulation = CB-X-G-E-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-1	4.375	5.850	7.325
CB-X-G-E-inf-mw-24	2.025	3.500	4.975
CB-X-G-E-inf-mw-48	0.925	2.400	3.875
CB-X-G-E-inf-mw-72	0.375	1.850	3.325
CB-X-G-E-inf-mw-96	0.175	1.650	3.125

RB-conv-1	-0.475	1.000	2.475
RB-conv-24	-2.275	-0.800	0.675
RB-conv-48	-3.825	-2.350	-0.875
RB-conv-72	-4.375	-2.900	-1.425
RB-cov-96	-4.575	-3.100	-1.625
RB-inf-mw-1	-1.825	-0.350	1.125
RB-inf-mw-24	-3.175	-1.700	-0.225
RB-inf-mw-48	-3.625	-2.150	-0.675
RB-inf-mw-72	-3.825	-2.350	-0.875
RB-inf-mw-96	-4.325	-2.850	-1.375
RB-X-G-E-conv-1	1.525	3.000	4.475
RB-X-G-E-conv-24	-0.175	1.300	2.775
RB-X-G-E-conv-48	-1.375	0.100	1.575
RB-X-G-E-conv-72	-1.825	-0.350	1.125
RB-X-G-E-conv-96	-2.125	-0.650	0.825
RB-X-G-E-inf-mw-1	-0.075	1.400	2.875
RB-X-G-E-inf-mw-24	-1.975	-0.500	0.975
RB-X-G-E-inf-mw-48	-2.475	-1.000	0.475
RB-X-G-E-inf-mw-72	-2.875	-1.400	0.075
RB-X-G-E-inf-mw-96	-3.075	-1.600	-0.125

Bread Formulation = CB-X-G-E-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-24	-3.825	-2.350	-0.875
CB-X-G-E-inf-mw-48	-4.925	-3.450	-1.975

CB-X-G-E-inf-mw-72	-5.475	-4.000	-2.525
CB-X-G-E-inf-mw-96	-5.675	-4.200	-2.725
RB-conv-1	-6.325	-4.850	-3.375
RB-conv-24	-8.125	-6.650	-5.175
RB-conv-48	-9.675	-8.200	-6.725
RB-conv-72	-10.225	-8.750	-7.275
RB-cov-96	-10.425	-8.950	-7.475
RB-inf-mw-1	-7.675	-6.200	-4.725
RB-inf-mw-24	-9.025	-7.550	-6.075
RB-inf-mw-48	-9.475	-8.000	-6.525
RB-inf-mw-72	-9.675	-8.200	-6.725
RB-inf-mw-96	-10.175	-8.700	-7.225
RB-X-G-E-conv-1	-4.325	-2.850	-1.375
RB-X-G-E-conv-24	-6.025	-4.550	-3.075
RB-X-G-E-conv-48	-7.225	-5.750	-4.275
RB-X-G-E-conv-72	-7.675	-6.200	-4.725
RB-X-G-E-conv-96	-7.975	-6.500	-5.025
RB-X-G-E-inf-mw-1	-5.925	-4.450	-2.975
RB-X-G-E-inf-mw-24	-7.825	-6.350	-4.875
RB-X-G-E-inf-mw-48	-8.325	-6.850	-5.375
RB-X-G-E-inf-mw-72	-8.725	-7.250	-5.775
RB-X-G-E-inf-mw-96	-8.925	-7.450	-5.975

Bread Formulation = CB-X-G-E-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-48	-2.575	-1.100	0.375
CB-X-G-E-inf-mw-72	-3.125	-1.650	-0.175
CB-X-G-E-inf-mw-96	-3.325	-1.850	-0.375
RB-conv-1	-3.975	-2.500	-1.025
RB-conv-24	-5.775	-4.300	-2.825
RB-conv-48	-7.325	-5.850	-4.375
RB-conv-72	-7.875	-6.400	-4.925
RB-cov-96	-8.075	-6.600	-5.125
RB-inf-mw-1	-5.325	-3.850	-2.375
RB-inf-mw-24	-6.675	-5.200	-3.725
RB-inf-mw-48	-7.125	-5.650	-4.175
RB-inf-mw-72	-7.325	-5.850	-4.375
RB-inf-mw-96	-7.825	-6.350	-4.875
RB-X-G-E-conv-1	-1.975	-0.500	0.975
RB-X-G-E-conv-24	-3.675	-2.200	-0.725
RB-X-G-E-conv-48	-4.875	-3.400	-1.925
RB-X-G-E-conv-72	-5.325	-3.850	-2.375
RB-X-G-E-conv-96	-5.625	-4.150	-2.675
RB-X-G-E-inf-mw-1	-3.575	-2.100	-0.625
RB-X-G-E-inf-mw-24	-5.475	-4.000	-2.525
RB-X-G-E-inf-mw-48	-5.975	-4.500	-3.025
RB-X-G-E-inf-mw-72	-6.375	-4.900	-3.425
RB-X-G-E-inf-mw-96	-6.575	-5.100	-3.625

Bread Formulation = CB-X-G-E-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-72	-2.025	-0.550	0.925
CB-X-G-E-inf-mw-96	-2.225	-0.750	0.725
RB-conv-1	-2.875	-1.400	0.075
RB-conv-24	-4.675	-3.200	-1.725
RB-conv-48	-6.225	-4.750	-3.275
RB-conv-72	-6.775	-5.300	-3.825
RB-cov-96	-6.975	-5.500	-4.025
RB-inf-mw-1	-4.225	-2.750	-1.275
RB-inf-mw-24	-5.575	-4.100	-2.625
RB-inf-mw-48	-6.025	-4.550	-3.075
RB-inf-mw-72	-6.225	-4.750	-3.275
RB-inf-mw-96	-6.725	-5.250	-3.775
RB-X-G-E-conv-1	-0.875	0.600	2.075
RB-X-G-E-conv-24	-2.575	-1.100	0.375
RB-X-G-E-conv-48	-3.775	-2.300	-0.825
RB-X-G-E-conv-72	-4.225	-2.750	-1.275
RB-X-G-E-conv-96	-4.525	-3.050	-1.575
RB-X-G-E-inf-mw-1	-2.475	-1.000	0.475
RB-X-G-E-inf-mw-24	-4.375	-2.900	-1.425
RB-X-G-E-inf-mw-48	-4.875	-3.400	-1.925
RB-X-G-E-inf-mw-72	-5.275	-3.800	-2.325
RB-X-G-E-inf-mw-96	-5.475	-4.000	-2.525

Bread Formulation = CB-X-G-E-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-96	-1.675	-0.200	1.275
RB-conv-1	-2.325	-0.850	0.625
RB-conv-24	-4.125	-2.650	-1.175
RB-conv-48	-5.675	-4.200	-2.725
RB-conv-72	-6.225	-4.750	-3.275
RB-cov-96	-6.425	-4.950	-3.475
RB-inf-mw-1	-3.675	-2.200	-0.725
RB-inf-mw-24	-5.025	-3.550	-2.075
RB-inf-mw-48	-5.475	-4.000	-2.525
RB-inf-mw-72	-5.675	-4.200	-2.725
RB-inf-mw-96	-6.175	-4.700	-3.225
RB-X-G-E-conv-1	-0.325	1.150	2.625
RB-X-G-E-conv-24	-2.025	-0.550	0.925
RB-X-G-E-conv-48	-3.225	-1.750	-0.275
RB-X-G-E-conv-72	-3.675	-2.200	-0.725
RB-X-G-E-conv-96	-3.975	-2.500	-1.025
RB-X-G-E-inf-mw-1	-1.925	-0.450	1.025
RB-X-G-E-inf-mw-24	-3.825	-2.350	-0.875
RB-X-G-E-inf-mw-48	-4.325	-2.850	-1.375
RB-X-G-E-inf-mw-72	-4.725	-3.250	-1.775
RB-X-G-E-inf-mw-96	-4.925	-3.450	-1.975

Bread Formulation = CB-X-G-E-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-1	-2.125	-0.650	0.825
RB-conv-24	-3.925	-2.450	-0.975
RB-conv-48	-5.475	-4.000	-2.525
RB-conv-72	-6.025	-4.550	-3.075
RB-cov-96	-6.225	-4.750	-3.275
RB-inf-mw-1	-3.475	-2.000	-0.525
RB-inf-mw-24	-4.825	-3.350	-1.875
RB-inf-mw-48	-5.275	-3.800	-2.325
RB-inf-mw-72	-5.475	-4.000	-2.525
RB-inf-mw-96	-5.975	-4.500	-3.025
RB-X-G-E-conv-1	-0.125	1.350	2.825
RB-X-G-E-conv-24	-1.825	-0.350	1.125
RB-X-G-E-conv-48	-3.025	-1.550	-0.075
RB-X-G-E-conv-72	-3.475	-2.000	-0.525
RB-X-G-E-conv-96	-3.775	-2.300	-0.825
RB-X-G-E-inf-mw-1	-1.725	-0.250	1.225
RB-X-G-E-inf-mw-24	-3.625	-2.150	-0.675
RB-X-G-E-inf-mw-48	-4.125	-2.650	-1.175
RB-X-G-E-inf-mw-72	-4.525	-3.050	-1.575
RB-X-G-E-inf-mw-96	-4.725	-3.250	-1.775

Bread Formulation = RB-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-24	-3.275	-1.800	-0.325
RB-conv-48	-4.825	-3.350	-1.875
RB-conv-72	-5.375	-3.900	-2.425
RB-cov-96	-5.575	-4.100	-2.625
RB-inf-mw-1	-2.825	-1.350	0.125
RB-inf-mw-24	-4.175	-2.700	-1.225
RB-inf-mw-48	-4.625	-3.150	-1.675
RB-inf-mw-72	-4.825	-3.350	-1.875
RB-inf-mw-96	-5.325	-3.850	-2.375
RB-X-G-E-conv-1	0.525	2.000	3.475
RB-X-G-E-conv-24	-1.175	0.300	1.775
RB-X-G-E-conv-48	-2.375	-0.900	0.575
RB-X-G-E-conv-72	-2.825	-1.350	0.125
RB-X-G-E-conv-96	-3.125	-1.650	-0.175
RB-X-G-E-inf-mw-1	-1.075	0.400	1.875
RB-X-G-E-inf-mw-24	-2.975	-1.500	-0.025
RB-X-G-E-inf-mw-48	-3.475	-2.000	-0.525
RB-X-G-E-inf-mw-72	-3.875	-2.400	-0.925
RB-X-G-E-inf-mw-96	-4.075	-2.600	-1.125

Bread Formulation = RB-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-48	-3.025	-1.550	-0.075

RB-conv-72	-3.575	-2.100	-0.625
RB-cov-96	-3.775	-2.300	-0.825
RB-inf-mw-1	-1.025	0.450	1.925
RB-inf-mw-24	-2.375	-0.900	0.575
RB-inf-mw-48	-2.825	-1.350	0.125
RB-inf-mw-72	-3.025	-1.550	-0.075
RB-inf-mw-96	-3.525	-2.050	-0.575
RB-X-G-E-conv-1	2.325	3.800	5.275
RB-X-G-E-conv-24	0.625	2.100	3.575
RB-X-G-E-conv-48	-0.575	0.900	2.375
RB-X-G-E-conv-72	-1.025	0.450	1.925
RB-X-G-E-conv-96	-1.325	0.150	1.625
RB-X-G-E-inf-mw-1	0.725	2.200	3.675
RB-X-G-E-inf-mw-24	-1.175	0.300	1.775
RB-X-G-E-inf-mw-48	-1.675	-0.200	1.275
RB-X-G-E-inf-mw-72	-2.075	-0.600	0.875
RB-X-G-E-inf-mw-96	-2.275	-0.800	0.675

Bread Formulation = RB-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-72	-2.025	-0.550	0.925
RB-cov-96	-2.225	-0.750	0.725
RB-inf-mw-1	0.525	2.000	3.475
RB-inf-mw-24	-0.825	0.650	2.125
RB-inf-mw-48	-1.275	0.200	1.675

RB-inf-mw-72	-1.475	0.000	1.475
RB-inf-mw-96	-1.975	-0.500	0.975
RB-X-G-E-conv-1	3.875	5.350	6.825
RB-X-G-E-conv-24	2.175	3.650	5.125
RB-X-G-E-conv-48	0.975	2.450	3.925
RB-X-G-E-conv-72	0.525	2.000	3.475
RB-X-G-E-conv-96	0.225	1.700	3.175
RB-X-G-E-inf-mw-1	2.275	3.750	5.225
RB-X-G-E-inf-mw-24	0.375	1.850	3.325
RB-X-G-E-inf-mw-48	-0.125	1.350	2.825
RB-X-G-E-inf-mw-72	-0.525	0.950	2.425
RB-X-G-E-inf-mw-96	-0.725	0.750	2.225

Bread Formulation = RB-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-cov-96	-1.675	-0.200	1.275
RB-inf-mw-1	1.075	2.550	4.025
RB-inf-mw-24	-0.275	1.200	2.675
RB-inf-mw-48	-0.725	0.750	2.225
RB-inf-mw-72	-0.925	0.550	2.025
RB-inf-mw-96	-1.425	0.050	1.525
RB-X-G-E-conv-1	4.425	5.900	7.375
RB-X-G-E-conv-24	2.725	4.200	5.675
RB-X-G-E-conv-48	1.525	3.000	4.475
RB-X-G-E-conv-72	1.075	2.550	4.025

RB-X-G-E-conv-96	0.775	2.250	3.725
RB-X-G-E-inf-mw-1	2.825	4.300	5.775
RB-X-G-E-inf-mw-24	0.925	2.400	3.875
RB-X-G-E-inf-mw-48	0.425	1.900	3.375
RB-X-G-E-inf-mw-72	0.025	1.500	2.975

Bread Formulation = RB-cov-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-1	1.275	2.750	4.225
RB-inf-mw-24	-0.075	1.400	2.875
RB-inf-mw-48	-0.525	0.950	2.425
RB-inf-mw-72	-0.725	0.750	2.225
RB-inf-mw-96	-1.225	0.250	1.725
RB-X-G-E-conv-1	4.625	6.100	7.575
RB-X-G-E-conv-24	2.925	4.400	5.875
RB-X-G-E-conv-48	1.725	3.200	4.675
RB-X-G-E-conv-72	1.275	2.750	4.225
RB-X-G-E-conv-96	0.975	2.450	3.925
RB-X-G-E-inf-mw-1	3.025	4.500	5.975
RB-X-G-E-inf-mw-24	1.125	2.600	4.075
RB-X-G-E-inf-mw-48	0.625	2.100	3.575
RB-X-G-E-inf-mw-72	0.225	1.700	3.175
RB-X-G-E-inf-mw-96	0.025	1.500	2.975

Bread Formulation = RB-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-24	-2.825	-1.350	0.125
RB-inf-mw-48	-3.275	-1.800	-0.325
RB-inf-mw-72	-3.475	-2.000	-0.525
RB-inf-mw-96	-3.975	-2.500	-1.025
RB-X-G-E-conv-1	1.875	3.350	4.825
RB-X-G-E-conv-24	0.175	1.650	3.125
RB-X-G-E-conv-48	-1.025	0.450	1.925
RB-X-G-E-conv-72	-1.475	0.000	1.475
RB-X-G-E-conv-96	-1.775	-0.300	1.175
RB-X-G-E-inf-mw-1	0.275	1.750	3.225
RB-X-G-E-inf-mw-24	-1.625	-0.150	1.325
RB-X-G-E-inf-mw-48	-2.125	-0.650	0.825
RB-X-G-E-inf-mw-72	-2.525	-1.050	0.425
RB-X-G-E-inf-mw-96	-2.725	-1.250	0.225

Bread Formulation = RB-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-48	-1.925	-0.450	1.025
RB-inf-mw-72	-2.125	-0.650	0.825
RB-inf-mw-96	-2.625	-1.150	0.325
RB-X-G-E-conv-1	3.225	4.700	6.175
RB-X-G-E-conv-24	1.525	3.000	4.475
RB-X-G-E-conv-48	0.325	1.800	3.275

RB-X-G-E-conv-72	-0.125	1.350	2.825
RB-X-G-E-conv-96	-0.425	1.050	2.525
RB-X-G-E-inf-mw-1	1.625	3.100	4.575
RB-X-G-E-inf-mw-24	-0.275	1.200	2.675
RB-X-G-E-inf-mw-48	-0.775	0.700	2.175
RB-X-G-E-inf-mw-72	-1.175	0.300	1.775
RB-X-G-E-inf-mw-96	-1.375	0.100	1.575

Bread Formulation = RB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-72	-1.675	-0.200	1.275
RB-inf-mw-96	-2.175	-0.700	0.775
RB-X-G-E-conv-1	3.675	5.150	6.625
RB-X-G-E-conv-24	1.975	3.450	4.925
RB-X-G-E-conv-48	0.775	2.250	3.725
RB-X-G-E-conv-72	0.325	1.800	3.275
RB-X-G-E-conv-96	0.025	1.500	2.975
RB-X-G-E-inf-mw-1	2.075	3.550	5.025
RB-X-G-E-inf-mw-24	0.175	1.650	3.125
RB-X-G-E-inf-mw-48	-0.325	1.150	2.625
RB-X-G-E-inf-mw-72	-0.725	0.750	2.225
RB-X-G-E-inf-mw-96	-0.925	0.550	2.025

Bread Formulation = RB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-96	-1.975	-0.500	0.975
RB-X-G-E-conv-1	3.875	5.350	6.825
RB-X-G-E-conv-24	2.175	3.650	5.125
RB-X-G-E-conv-48	0.975	2.450	3.925
RB-X-G-E-conv-72	0.525	2.000	3.475
RB-X-G-E-conv-96	0.225	1.700	3.175
RB-X-G-E-inf-mw-1	2.275	3.750	5.225
RB-X-G-E-inf-mw-24	0.375	1.850	3.325
RB-X-G-E-inf-mw-48	-0.125	1.350	2.825
RB-X-G-E-inf-mw-72	-0.525	0.950	2.425
RB-X-G-E-inf-mw-96	-0.725	0.750	2.225

Bread Formulation = RB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-1	4.375	5.850	7.325
RB-X-G-E-conv-24	2.675	4.150	5.625
RB-X-G-E-conv-48	1.475	2.950	4.425
RB-X-G-E-conv-72	1.025	2.500	3.975
RB-X-G-E-conv-96	0.725	2.200	3.675
RB-X-G-E-inf-mw-1	2.775	4.250	5.725
RB-X-G-E-inf-mw-24	0.875	2.350	3.825
RB-X-G-E-inf-mw-48	0.375	1.850	3.325
RB-X-G-E-inf-mw-72	-0.025	1.450	2.925

RB-X-G-E-inf-mw-96	-0.225	1.250	2.725

Bread Formulation = RB-X-G-E-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-24	-3.175	-1.700	-0.225
RB-X-G-E-conv-48	-4.375	-2.900	-1.425
RB-X-G-E-conv-72	-4.825	-3.350	-1.875
RB-X-G-E-conv-96	-5.125	-3.650	-2.175
RB-X-G-E-inf-mw-1	-3.075	-1.600	-0.125
RB-X-G-E-inf-mw-24	-4.975	-3.500	-2.025
RB-X-G-E-inf-mw-48	-5.475	-4.000	-2.525
RB-X-G-E-inf-mw-72	-5.875	-4.400	-2.925
RB-X-G-E-inf-mw-96	-6.075	-4.600	-3.125

Bread Formulation = RB-X-G-E-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-48	-2.675	-1.200	0.275
RB-X-G-E-conv-72	-3.125	-1.650	-0.175
RB-X-G-E-conv-96	-3.425	-1.950	-0.475
RB-X-G-E-inf-mw-1	-1.375	0.100	1.575
RB-X-G-E-inf-mw-24	-3.275	-1.800	-0.325
RB-X-G-E-inf-mw-48	-3.775	-2.300	-0.825
RB-X-G-E-inf-mw-72	-4.175	-2.700	-1.225
RB-X-G-E-inf-mw-96	-4.375	-2.900	-1.425

Bread Formulation = RB-X-G-E-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-72	-1.925	-0.450	1.025
RB-X-G-E-conv-96	-2.225	-0.750	0.725
RB-X-G-E-inf-mw-1	-0.175	1.300	2.775
RB-X-G-E-inf-mw-24	-2.075	-0.600	0.875
RB-X-G-E-inf-mw-48	-2.575	-1.100	0.375
RB-X-G-E-inf-mw-72	-2.975	-1.500	-0.025
RB-X-G-E-inf-mw-96	-3.175	-1.700	-0.225

Bread Formulation = RB-X-G-E-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-96	-1.775	-0.300	1.175
RB-X-G-E-inf-mw-1	0.275	1.750	3.225
RB-X-G-E-inf-mw-24	-1.625	-0.150	1.325
RB-X-G-E-inf-mw-48	-2.125	-0.650	0.825
RB-X-G-E-inf-mw-72	-2.525	-1.050	0.425
RB-X-G-E-inf-mw-96	-2.725	-1.250	0.225

Bread Formulation = RB-X-G-E-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-1	0.575	2.050	3.525
RB-X-G-E-inf-mw-24	-1.325	0.150	1.625
RB-X-G-E-inf-mw-48	-1.825	-0.350	1.125
RB-X-G-E-inf-mw-72	-2.225	-0.750	0.725

RB-X-G-E-inf-mw-96	-2.425	-0.950	0.525

Bread Formulation = RB-X-G-E-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-24	-3.375	-1.900	-0.425
RB-X-G-E-inf-mw-48	-3.875	-2.400	-0.925
RB-X-G-E-inf-mw-72	-4.275	-2.800	-1.325
RB-X-G-E-inf-mw-96	-4.475	-3.000	-1.525

Bread Formulation = RB-X-G-E-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-48	-1.975	-0.500	0.975
RB-X-G-E-inf-mw-72	-2.375	-0.900	0.575
RB-X-G-E-inf-mw-96	-2.575	-1.100	0.375

Bread Formulation = RB-X-G-E-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-72	-1.875	-0.400	1.075
RB-X-G-E-inf-mw-96	-2.075	-0.600	0.875

Bread Formulation = RB-X-G-E-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-96	-1.675	-0.200	1.275

Table A. 33. General linear model for firmness values of different gluten-free bread formulations baked in different ovens and stored at different times

Factor	Type	Levels	Values
Bread Formulation	fixed	4	CB, CB-X-G-E, R, RB-X-G-E
Storage Time	fixed	5	1, 24, 48, 72,96
Oven type	fixed	2	Conv, ınf-mw

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Bread Formulation	3	159.682	159.682	53.227	582.98	0.000
Storage Time	4	233.607	233.607	58.402	639.65	0.000
Oven type	1	4.508	4.508	4.508	49.37	0.000
Error	71	6.482	6.482	0.091		
Total	79	404.280				

Formulation	N	Mean	Grouping
RB	20	41.339	A
CB	20	41.489	B
RB-X-G-E	20	41.308	C
CB-X-G-E	20	41.396	D

Time	N	Mean	Grouping
96	16	5.9	A
72	16	5.5	B
48	16	4.1	C
24	16	2.8	D

1	16	1.3	E

Oven type	N	Mean	Grouping
ınf-mw	40	4.2	A
Conv	40	3.7	B

Table A. 34. One-way for firmness values of different gluten-free bread formulaions baked in different ovens and stored at different times

Source	DF	SS	MS	F	P
Bread Formulation	39	403.9962	103.589	1461.83	0.000
Error	40	0.2835	0.0071		
Total	79	404.2796			

Level	N	Mean	StDev
CB-conv-1	2	0.9050	0.0495
CB-conv-24	2	2.3600	0.0707
CB-conv-48	2	3.4650	0.0778
CB-conv-72	2	5.2900	0.1131
CB-conv-96	2	5.7700	0.0424
CB-inf-mw-1	2	1.3150	0.0354
CB-inf-mw-24	2	3.0600	0.0849
CB-inf-mw-48	2	4.2850	0.0354
CB-inf-mw-72	2	5.6700	0.0707
CB-inf-mw-96	2	5.9550	0.0919
CB-X-G-E-conv-1	2	0.4150	0.0212

CB-X-G-E-conv-24	2	1.2200	0.0849
CB-X-G-E-conv-48	2	2.0550	0.1061
CB-X-G-E-conv-72	2	3.5900	0.0990
CB-X-G-E-conv-96	2	4.1050	0.1344
CB-X-G-E-inf-mw-1	2	0.6550	0.0495
CB-X-G-E-inf-mw-24	2	1.7150	0.0354
CB-X-G-E-inf-mw-48	2	2.8850	0.0636
CB-X-G-E-inf-mw-72	2	3.9900	0.1414
CB-X-G-E-inf-mw-96	2	4.4150	0.0495
RB-conv-1	2	2.7800	0.0707
RB-conv-24	2	4.9000	0.0707
RB-conv-48	2	6.7300	0.0707
RB-conv-72	2	7.7700	0.0707
RB-cov-96	2	8.0800	0.0849
RB-inf-mw-1	2	3.1750	0.1061
RB-inf-mw-24	2	5.2950	0.1202
RB-inf-mw-48	2	6.8050	0.0636
RB-inf-mw-72	2	8.4200	0.0849
RB-inf-mw-96	2	8.5850	0.1202
RB-X-G-E-conv-1	2	0.5400	0.0566
RB-X-G-E-conv-24	2	1.6200	0.0707
RB-X-G-E-conv-48	2	2.8050	0.0636
RB-X-G-E-conv-72	2	4.5850	0.0636
RB-X-G-E-conv-96	2	5.0850	0.1626
RB-X-G-E-inf-mw-1	2	0.9200	0.0707

RB-X-G-E-inf-mw-24	2	2.3700	0.0424
RB-X-G-E-inf-mw-48	2	3.5200	0.0990
RB-X-G-E-inf-mw-72	2	5.0650	0.1061
RB-X-G-E-inf-mw-96	2	5.4650	0.0778

Bread Formulation	N	Mean
RB-inf-mw-96	2	8.5850
RB-inf-mw-72	2	8.4200
RB-cov-96	2	8.0800
RB-conv-72	2	7.7700
RB-inf-mw-48	2	6.8050
RB-conv-48	2	6.7300
CB-inf-mw-96	2	5.9550
CB-conv-96	2	5.7700
CB-inf-mw-72	2	5.6700
RB-X-G-E-inf-mw-96	2	5.4650
RB-inf-mw-24	2	5.2950
CB-conv-72	2	5.2900
RB-X-G-E-conv-96	2	5.0850
RB-X-G-E-inf-mw-72	2	5.0650
RB-conv-24	2	4.9000
RB-X-G-E-conv-72	2	4.5850
CB-X-G-E-inf-mw-96	2	4.4150
CB-inf-mw-48	2	4.2850
CB-X-G-E-conv-96	2	4.1050

CB-X-G-E-inf-mw-72	2	3.9900
CB-X-G-E-conv-72	2	3.5900
RB-X-G-E-inf-mw-48	2	3.5200
CB-conv-48	2	3.4650
RB-inf-mw-1	2	3.1750
CB-inf-mw-24	2	3.0600
CB-X-G-E-inf-mw-48	2	2.8850
RB-X-G-E-conv-48	2	2.8050
RB-conv-1	2	2.7800
RB-X-G-E-inf-mw-24	2	2.3700
CB-conv-24	2	2.3600
CB-X-G-E-conv-48	2	2.0550
CB-X-G-E-inf-mw-24	2	1.7150
RB-X-G-E-conv-24	2	1.6200
CB-inf-mw-1	2	1.3150
CB-X-G-E-conv-24	2	1.2200
RB-X-G-E-inf-mw-1	2	0.9200
CB-conv-1	2	0.9050
CB-X-G-E-inf-mw-1	2	0.6550
RB-X-G-E-conv-1	2	0.5400
CB-X-G-E-conv-1	2	0.4150

Bread Formulation	Grouping
RB-inf-mw-96	A
RB-inf-mw-72	A B

RB-cov-96	B C
RB-conv-72	C
RB-inf-mw-48	D
RB-conv-48	D
CB-inf-mw-96	E
CB-conv-96	E F
CB-inf-mw-72	E F
RB-X-G-E-inf-mw-96	F G
RB-inf-mw-24	G H
CB-conv-72	G H
RB-X-G-E-conv-96	H I
RB-X-G-E-inf-mw-72	H I
RB-conv-24	I J
RB-X-G-E-conv-72	J K
CB-X-G-E-inf-mw-96	K L
CB-inf-mw-48	K L M
CB-X-G-E-conv-96	L M
CB-X-G-E-inf-mw-72	M
CB-X-G-E-conv-72	N
RB-X-G-E-inf-mw-48	N O
CB-conv-48	N O
RB-inf-mw-1	O P
CB-inf-mw-24	P Q
CB-X-G-E-inf-mw-48	P Q
RB-X-G-E-conv-48	Q

RB-conv-1	Q
RB-X-G-E-inf-mw-24	R
CB-conv-24	R
CB-X-G-E-conv-48	R S
CB-X-G-E-inf-mw-24	S T
RB-X-G-E-conv-24	T U
CB-inf-mw-1	U V
CB-X-G-E-conv-24	V W
RB-X-G-E-inf-mw-1	W X
CB-conv-1	W X
CB-X-G-E-inf-mw-1	X Y
RB-X-G-E-conv-1	Y
CB-X-G-E-conv-1	Y

Bread Formulation = CB-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-24	1.1014	1.4550	1.8086
CB-conv-48	2.2064	2.5600	2.9136
CB-conv-72	4.0314	4.3850	4.7386
CB-conv-96	4.5114	4.8650	5.2186
CB-inf-mw-1	0.0564	0.4100	0.7636
CB-inf-mw-24	1.8014	2.1550	2.5086
CB-inf-mw-48	3.0264	3.3800	3.7336
CB-inf-mw-72	4.4114	4.7650	5.1186
CB-inf-mw-96	4.6964	5.0500	5.4036

CB-X-G-E-conv-1	-0.8436	-0.4900	-0.1364
CB-X-G-E-conv-24	-0.0386	0.3150	0.6686
CB-X-G-E-conv-48	0.7964	1.1500	1.5036
CB-X-G-E-conv-72	2.3314	2.6850	3.0386
CB-X-G-E-conv-96	2.8464	3.2000	3.5536
CB-X-G-E-inf-mw-1	-0.6036	-0.2500	0.1036
CB-X-G-E-inf-mw-24	0.4564	0.8100	1.1636
CB-X-G-E-inf-mw-48	1.6214	1.9800	2.3336
CB-X-G-E-inf-mw-72	2.7314	3.0850	3.4386
CB-X-G-E-inf-mw-96	3.1564	3.5100	3.8636
RB-conv-1	1.5214	1.8750	2.2286
RB-conv-24	3.6414	3.9950	4.3486
RB-conv-48	5.4714	5.8250	6.1786
RB-conv-72	6.5114	6.8650	7.2186
RB-cov-96	6.8214	7.1750	7.5286
RB-inf-mw-1	1.9164	2.2700	2.6236
RB-inf-mw-24	4.0364	4.3900	4.7436
RB-inf-mw-48	5.5464	5.9000	6.2536
RB-inf-mw-72	7.1614	7.5150	7.8686
RB-inf-mw-96	7.3264	7.6800	8.0336
RB-X-G-E-conv-1	-0.7186	-0.3650	-0.0114
RB-X-G-E-conv-24	0.3614	0.7150	1.0686
RB-X-G-E-conv-48	1.5464	1.9000	2.2536
RB-X-G-E-conv-72	3.3264	3.6800	4.0336
RB-X-G-E-conv-96	3.8264	4.1800	4.5336

RB-X-G-E-inf-mw-1	-0.3386	0.0150	0.3686
RB-X-G-E-inf-mw-24	1.1114	1.4650	1.8186
RB-X-G-E-inf-mw-48	2.2614	2.6150	2.9686
RB-X-G-E-inf-mw-72	3.8064	4.1600	4.5136
RB-X-G-E-inf-mw-96	4.2064	4.5600	4.9136

Bread Formulation = CB-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-48	0.7514	1.1050	1.4586
CB-conv-72	2.5764	2.9300	3.2836
CB-conv-96	3.0564	3.4100	3.7636
CB-inf-mw-1	-1.3986	-1.0450	-0.6914
CB-inf-mw-24	0.3464	0.7000	1.0536
CB-inf-mw-48	1.5714	1.9250	2.2786
CB-inf-mw-72	2.9564	3.3100	3.6636
CB-inf-mw-96	3.2414	3.5950	3.9486
CB-X-G-E-conv-1	-2.2986	-1.9450	-1.5914
CB-X-G-E-conv-24	-1.4936	-1.1400	-0.7864
CB-X-G-E-conv-48	-0.6586	-0.3050	0.0486
CB-X-G-E-conv-72	0.8764	1.2300	1.5836
CB-X-G-E-conv-96	1.3914	1.7450	2.0986
CB-X-G-E-inf-mw-1	-2.0586	-1.7050	-1.3514
CB-X-G-E-inf-mw-24	-0.9986	-0.6450	-0.2914
CB-X-G-E-inf-mw-48	0.1714	0.5250	0.8786

CB-X-G-E-inf-mw-72	1.2764	1.6300	1.9836
CB-X-G-E-inf-mw-96	1.7014	2.0550	2.4086
RB-conv-1	0.0664	0.4200	0.7736
RB-conv-24	2.1864	2.5400	2.8936
RB-conv-48	4.0164	4.3700	4.7236
RB-conv-72	5.0564	5.4100	5.7636
RB-cov-96	5.3664	5.7200	6.0736
RB-inf-mw-1	0.4614	0.8150	1.1686
RB-inf-mw-24	2.5814	2.9350	3.2886
RB-inf-mw-48	4.0914	4.4450	4.7986
RB-inf-mw-72	5.7064	6.0600	6.4136
RB-inf-mw-96	5.8714	6.2250	6.5786
RB-X-G-E-conv-1	-2.1736	-1.8200	-1.4664
RB-X-G-E-conv-24	-1.0936	-0.7400	-0.3864
RB-X-G-E-conv-48	0.0914	0.4450	0.7986
RB-X-G-E-conv-72	1.8714	2.2250	2.5786
RB-X-G-E-conv-96	2.3714	2.7250	3.0786
RB-X-G-E-inf-mw-1	-1.7936	-1.4400	-1.0864
RB-X-G-E-inf-mw-24	-0.3436	0.0100	0.3636
RB-X-G-E-inf-mw-48	0.8064	1.1600	1.5136
RB-X-G-E-inf-mw-72	2.3514	2.7050	3.0586
RB-X-G-E-inf-mw-96	2.7514	3.1050	3.4586

Bread Formulation = CB-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-72	1.4714	1.8250	2.1786
CB-conv-96	1.9514	2.3050	2.6586
CB-inf-mw-1	-2.5036	-2.1500	-1.7964
CB-inf-mw-24	-0.7586	-0.4050	-0.0514
CB-inf-mw-48	0.4664	0.8200	1.1736
CB-inf-mw-72	1.8514	2.2050	2.5586
CB-inf-mw-96	2.1364	2.4900	2.8436
CB-X-G-E-conv-1	-3.4036	-3.0500	-2.6964
CB-X-G-E-conv-24	-2.5986	-2.2450	-1.8914
CB-X-G-E-conv-48	-1.7636	-1.4100	-1.0564
CB-X-G-E-conv-72	-0.2286	0.1250	0.4786
CB-X-G-E-conv-96	0.2864	0.6400	0.9936
CB-X-G-E-inf-mw-1	-3.1636	-2.8100	-2.4564
CB-X-G-E-inf-mw-24	-2.1036	-1.7500	-1.3964
CB-X-G-E-inf-mw-48	-0.9336	-0.5800	-0.2264
CB-X-G-E-inf-mw-72	0.1714	0.5250	0.8786
CB-X-G-E-inf-mw-96	0.5964	0.9500	1.3036
RB-conv-1	-1.0386	-0.6850	-0.3314
RB-conv-24	1.0814	1.4350	1.7886
RB-conv-48	2.9114	3.2650	3.6186
RB-conv-72	3.9514	4.3050	4.6586
RB-cov-96	4.2614	4.6150	4.9686
RB-inf-mw-1	-0.6436	-0.2900	0.0636

RB-inf-mw-24	1.4764	1.8300	2.1836
RB-inf-mw-48	2.9864	3.3400	3.6936
RB-inf-mw-72	4.6014	4.9550	5.3086
RB-inf-mw-96	4.7664	5.1200	5.4736
RB-X-G-E-conv-1	-3.2786	-2.9250	-2.5714
RB-X-G-E-conv-24	-2.1986	-1.8450	-1.4914
RB-X-G-E-conv-48	-1.0136	-0.6600	-0.3064
RB-X-G-E-conv-72	0.7664	1.1200	1.4736
RB-X-G-E-conv-96	1.2664	1.6200	1.9736
RB-X-G-E-inf-mw-1	-2.8986	-2.5450	-2.1914
RB-X-G-E-inf-mw-24	-1.4486	-1.0950	-0.7414
RB-X-G-E-inf-mw-48	-0.2986	0.0550	0.4086
RB-X-G-E-inf-mw-72	1.2464	1.6000	1.9536
RB-X-G-E-inf-mw-96	1.6464	2.0000	2.3536

Bread Formulation = CB-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-96	0.1264	0.4800	0.8336
CB-inf-mw-1	-4.3286	-3.9750	-3.6214
CB-inf-mw-24	-2.5836	-2.2300	-1.8764
CB-inf-mw-48	-1.3586	-1.0050	-0.6514
CB-inf-mw-72	0.0264	0.3800	0.7336
CB-inf-mw-96	0.3114	0.6650	1.0186
CB-X-G-E-conv-1	-5.2286	-4.8750	-4.5214
CB-X-G-E-conv-24	-4.4236	-4.0700	-3.7164

CB-X-G-E-conv-48	-3.5886	-3.2350	-2.8814
CB-X-G-E-conv-72	-2.0536	-1.7000	-1.3464
CB-X-G-E-conv-96	-1.5386	-1.1850	-0.8314
CB-X-G-E-inf-mw-1	-4.9886	-4.6350	-4.2814
CB-X-G-E-inf-mw-24	-3.9286	-3.5750	-3.2214
CB-X-G-E-inf-mw-48	-2.7586	-2.4050	-2.0514
CB-X-G-E-inf-mw-72	-1.6536	-1.3000	-0.9464
CB-X-G-E-inf-mw-96	-1.2286	-0.8750	-0.5214
RB-conv-1	-2.8636	-2.5100	-2.1564
RB-conv-24	-0.7436	-0.3900	-0.0364
RB-conv-48	1.0864	1.4400	1.7936
RB-conv-72	2.1264	2.4800	2.8336
RB-cov-96	2.4364	2.7900	3.1436
RB-inf-mw-1	-2.4686	-2.1150	-1.7614
RB-inf-mw-24	-0.3486	0.0050	0.3586
RB-inf-mw-48	1.1614	1.5150	1.8686
RB-inf-mw-72	2.7764	3.1300	3.4836
RB-inf-mw-96	2.9414	3.2950	3.6486
RB-X-G-E-conv-1	-5.1036	-4.7500	-4.3964
RB-X-G-E-conv-24	-4.0236	-3.6700	-3.3164
RB-X-G-E-conv-48	-2.8386	-2.4850	-2.1314
RB-X-G-E-conv-72	-1.0586	-0.7050	-0.3514
RB-X-G-E-conv-96	-0.5586	-0.2050	0.1486
RB-X-G-E-inf-mw-1	-4.7236	-4.3700	-4.0164
RB-X-G-E-inf-mw-24	-3.2736	-2.9200	-2.5664

RB-X-G-E-inf-mw-48	-2.1236	-1.7700	-1.4164
RB-X-G-E-inf-mw-72	-0.5786	-0.2250	0.1286
RB-X-G-E-inf-mw-96	-0.1786	0.1750	0.5286

Bread Formulation = CB-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-1	-4.8086	-4.4550	-4.1014
CB-inf-mw-24	-3.0636	-2.7100	-2.3564
CB-inf-mw-48	-1.8386	-1.4850	-1.1314
CB-inf-mw-72	-0.4536	-0.1000	0.2536
CB-inf-mw-96	-0.1686	0.1850	0.5386
CB-X-G-E-conv-1	-5.7086	-5.3550	-5.0014
CB-X-G-E-conv-24	-4.9036	-4.5500	-4.1964
CB-X-G-E-conv-48	-4.0686	-3.7150	-3.3614
CB-X-G-E-conv-72	-2.5336	-2.1800	-1.8264
CB-X-G-E-conv-96	-2.0186	-1.6650	-1.3114
CB-X-G-E-inf-mw-1	-5.4686	-5.1150	-4.7614
CB-X-G-E-inf-mw-24	-4.4086	-4.0550	-3.7014
CB-X-G-E-inf-mw-48	-3.2386	-2.8850	-2.5314
CB-X-G-E-inf-mw-72	-2.1336	-1.7800	-1.4264
CB-X-G-E-inf-mw-96	-1.7086	-1.3550	-1.0014
RB-conv-1	-3.3436	-2.9900	-2.6364
RB-conv-24	-1.2236	-0.8700	-0.5164
RB-conv-48	0.6064	0.9600	1.3136
RB-conv-72	1.6464	2.0000	2.3536

RB-cov-96	1.9564	2.3100	2.6636
RB-inf-mw-1	-2.9486	-2.5950	-2.2414
RB-inf-mw-24	-0.8286	-0.4750	-0.1214
RB-inf-mw-48	0.6814	1.0350	1.3886
RB-inf-mw-72	2.2964	2.6500	3.0036
RB-inf-mw-96	2.4614	2.8150	3.1686
RB-X-G-E-conv-1	-5.5836	-5.2300	-4.8764
RB-X-G-E-conv-24	-4.5036	-4.1500	-3.7964
RB-X-G-E-conv-48	-3.3186	-2.9650	-2.6114
RB-X-G-E-conv-72	-1.5386	-1.1850	-0.8314
RB-X-G-E-conv-96	-1.0386	-0.6850	-0.3314
RB-X-G-E-inf-mw-1	-5.2036	-4.8500	-4.4964
RB-X-G-E-inf-mw-24	-3.7536	-3.4000	-3.0464
RB-X-G-E-inf-mw-48	-2.6036	-2.2500	-1.8964
RB-X-G-E-inf-mw-72	-1.0586	-0.7050	-0.3514
RB-X-G-E-inf-mw-96	-0.6586	-0.3050	0.0486

Bread Formulation = CB-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-24	1.3914	1.7450	2.0986
CB-inf-mw-48	2.6164	2.9700	3.3236
CB-inf-mw-72	4.0014	4.3550	4.7086
CB-inf-mw-96	4.2864	4.6400	4.9936
CB-X-G-E-conv-1	-1.2536	-0.9000	-0.5464
CB-X-G-E-conv-24	-0.4486	-0.0950	0.2586

CB-X-G-E-conv-48	0.3864	0.7400	1.0936
CB-X-G-E-conv-72	1.9214	2.2750	2.6286
CB-X-G-E-conv-96	2.4364	2.7900	3.1436
CB-X-G-E-inf-mw-1	-1.0136	-0.6600	-0.3064
CB-X-G-E-inf-mw-24	0.0464	0.4000	0.7536
CB-X-G-E-inf-mw-48	1.2164	1.5700	1.9236
CB-X-G-E-inf-mw-72	2.3214	2.6750	3.0286
CB-X-G-E-inf-mw-96	2.7464	3.1000	3.4536
RB-conv-1	1.1114	1.4650	1.8186
RB-conv-24	3.2314	3.5850	3.9386
RB-conv-48	5.0614	5.4150	5.7686
RB-conv-72	6.1014	6.4550	6.8086
RB-cov-96	6.4114	6.7650	7.1186
RB-inf-mw-1	1.5064	1.8600	2.2136
RB-inf-mw-24	3.6264	3.9800	4.3336
RB-inf-mw-48	5.1364	5.4900	5.8436
RB-inf-mw-72	6.7514	7.1050	7.4586
RB-inf-mw-96	6.9164	7.2700	7.6236
RB-X-G-E-conv-1	-1.1286	-0.7750	-0.4214
RB-X-G-E-conv-24	-0.0486	0.3050	0.6586
RB-X-G-E-conv-48	1.1364	1.4900	1.8436
RB-X-G-E-conv-72	2.9164	3.2700	3.6236
RB-X-G-E-conv-96	3.4164	3.7700	4.1236
RB-X-G-E-inf-mw-1	-0.7486	-0.3950	-0.0414
RB-X-G-E-inf-mw-24	0.7014	1.0550	1.4086

RB-X-G-E-inf-mw-48	1.8514	2.2050	2.5586
RB-X-G-E-inf-mw-72	3.3964	3.7500	4.1036
RB-X-G-E-inf-mw-96	3.7964	4.1500	4.5036

Bread Formulation = CB-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-48	0.8714	1.2250	1.5786
CB-inf-mw-72	2.2564	2.6100	2.9636
CB-inf-mw-96	2.5414	2.8950	3.2486
CB-X-G-E-conv-1	-2.9986	-2.6450	-2.2914
CB-X-G-E-conv-24	-2.1936	-1.8400	-1.4864
CB-X-G-E-conv-48	-1.3586	-1.0050	-0.6514
CB-X-G-E-conv-72	0.1764	0.5300	0.8836
CB-X-G-E-conv-96	0.6914	1.0450	1.3986
CB-X-G-E-inf-mw-1	-2.7586	-2.4050	-2.0514
CB-X-G-E-inf-mw-24	-1.6986	-1.3450	-0.9914
CB-X-G-E-inf-mw-48	-0.5286	-0.1750	0.1786
CB-X-G-E-inf-mw-72	0.5764	0.9300	1.2836
CB-X-G-E-inf-mw-96	1.0014	1.3550	1.7086
RB-conv-1	-0.6336	-0.2800	0.0736
RB-conv-24	1.4864	1.8400	2.1936
RB-conv-48	3.3164	3.6700	4.0236
RB-conv-72	4.3564	4.7100	5.0636
RB-cov-96	4.6664	5.0200	5.3736
RB-inf-mw-1	-0.2386	0.1150	0.4686

RB-inf-mw-24	1.8814	2.2350	2.5886
RB-inf-mw-48	3.3914	3.7450	4.0986
RB-inf-mw-72	5.0064	5.3600	5.7136
RB-inf-mw-96	5.1714	5.5250	5.8786
RB-X-G-E-conv-1	-2.8736	-2.5200	-2.1664
RB-X-G-E-conv-24	-1.7936	-1.4400	-1.0864
RB-X-G-E-conv-48	-0.6086	-0.2550	0.0986
RB-X-G-E-conv-72	1.1714	1.5250	1.8786
RB-X-G-E-conv-96	1.6714	2.0250	2.3786
RB-X-G-E-inf-mw-1	-2.4936	-2.1400	-1.7864
RB-X-G-E-inf-mw-24	-1.0436	-0.6900	-0.3364
RB-X-G-E-inf-mw-48	0.1064	0.4600	0.8136
RB-X-G-E-inf-mw-72	1.6514	2.0050	2.3586
RB-X-G-E-inf-mw-96	2.0514	2.4050	2.7586

Bread Formulation = CB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-72	1.0314	1.3815	1.7386
CB-inf-mw-96	1.3164	1.6700	2.0236
CB-X-G-E-conv-1	-4.2236	-3.8700	-3.5164
CB-X-G-E-conv-24	-3.4186	-3.0650	-2.7114
CB-X-G-E-conv-48	-2.5836	-2.2300	-1.8764
CB-X-G-E-conv-72	-1.0486	-0.6950	-0.3414
CB-X-G-E-conv-96	-0.5336	-0.1800	0.1736
CB-X-G-E-inf-mw-1	-3.9836	-3.6300	-3.2764

CB-X-G-E-inf-mw-24	-2.9236	-2.5700	-2.2164
CB-X-G-E-inf-mw-48	-1.7536	-1.4000	-1.0464
CB-X-G-E-inf-mw-72	-0.6486	-0.2950	0.0586
CB-X-G-E-inf-mw-96	-0.2236	0.1300	0.4836
RB-conv-1	-1.8586	-1.5050	-1.1514
RB-conv-24	0.2614	0.6150	0.9686
RB-conv-48	2.0914	2.4450	2.7986
RB-conv-72	3.1314	3.4850	3.8386
RB-cov-96	3.1314	3.4850	4.1486
RB-inf-mw-1	-1.4636	-1.1100	-0.7564
RB-inf-mw-24	0.6564	1.0100	1.3636
RB-inf-mw-48	2.1664	2.5200	2.8736
RB-inf-mw-72	3.7814	4.1350	4.4886
RB-inf-mw-96	3.9464	4.3000	4.6536
RB-X-G-E-conv-1	-4.0986	-3.7450	-3.3914
RB-X-G-E-conv-24	-3.0186	-2.6650	-2.3114
RB-X-G-E-conv-48	-1.8336	-1.4800	-1.1264
RB-X-G-E-conv-72	-0.0536	0.3000	0.6536
RB-X-G-E-conv-96	0.4464	0.8000	1.1536
RB-X-G-E-inf-mw-1	-3.7186	-3.3650	-3.0114
RB-X-G-E-inf-mw-24	-2.2686	-1.9150	-1.5614
RB-X-G-E-inf-mw-48	-1.1186	-0.7650	-0.4114
RB-X-G-E-inf-mw-72	0.4264	0.7800	1.1336
RB-X-G-E-inf-mw-96	0.8264	1.1800	1.5336

Bread Formulation = CB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-96	-0.0686	0.2850	0.6386
CB-X-G-E-conv-1	-5.6086	-5.2550	-4.9014
CB-X-G-E-conv-24	-4.8036	-4.4500	-4.0964
CB-X-G-E-conv-48	-3.9686	-3.6150	-3.2614
CB-X-G-E-conv-72	-2.4336	-2.0800	-1.7264
CB-X-G-E-conv-96	-1.9186	-1.5650	-1.2114
CB-X-G-E-inf-mw-1	-5.3686	-5.0150	-4.6614
CB-X-G-E-inf-mw-24	-4.3086	-3.9550	-3.6014
CB-X-G-E-inf-mw-48	-3.1386	-2.7850	-2.4314
CB-X-G-E-inf-mw-72	-2.0336	-1.6800	-1.3264
CB-X-G-E-inf-mw-96	-1.6086	-1.2550	-0.9014
RB-conv-1	-3.2436	-2.8900	-2.5364
RB-conv-24	-1.1236	-0.7700	-0.4164
RB-conv-48	0.7064	1.0600	1.4136
RB-conv-72	1.7464	2.1000	2.4536
RB-cov-96	2.0564	2.4100	2.7636
RB-inf-mw-1	-2.8486	-2.4950	-2.1414
RB-inf-mw-24	-0.7286	-0.3750	-0.0214
RB-inf-mw-48	0.7814	1.1350	1.4886
RB-inf-mw-72	2.3964	2.7500	3.1036
RB-inf-mw-96	2.5614	2.9150	3.2686
RB-X-G-E-conv-1	-5.4836	-5.1300	-4.7764

RB-X-G-E-conv-24	-4.4036	-4.0500	-3.6964
RB-X-G-E-conv-48	-3.2186	-2.8650	-2.5114
RB-X-G-E-conv-72	-1.4386	-1.0850	-0.7314
RB-X-G-E-conv-96	-0.9386	-0.5850	-0.2314
RB-X-G-E-inf-mw-1	-5.1036	-4.7500	-4.3964
RB-X-G-E-inf-mw-24	-3.6536	-3.3000	-2.9464
RB-X-G-E-inf-mw-48	-2.5036	-2.1500	-1.7964
RB-X-G-E-inf-mw-72	-0.9586	-0.6050	-0.2514
RB-X-G-E-inf-mw-96	-0.5586	-0.2050	0.1486

Bread Formulation = CB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-1	-5.8936	-5.5400	-5.1864
CB-X-G-E-conv-24	-5.0886	-4.7350	-4.3814
CB-X-G-E-conv-48	-4.2536	-3.9000	-3.5464
CB-X-G-E-conv-72	-2.7186	-2.3650	-2.0114
CB-X-G-E-conv-96	-2.2036	-1.8500	-1.4964
CB-X-G-E-inf-mw-1	-5.6536	-5.3000	-4.9464
CB-X-G-E-inf-mw-24	-4.5936	-4.2400	-3.8864
CB-X-G-E-inf-mw-48	-3.4236	-3.0700	-2.7164
CB-X-G-E-inf-mw-72	-2.3186	-1.9650	-1.6114
CB-X-G-E-inf-mw-96	-1.8936	-1.5400	-1.1864
RB-conv-1	-3.5286	-3.1750	-2.8214
RB-conv-24	-1.4086	-1.0550	-0.7014
RB-conv-48	0.4214	0.7750	1.1286

RB-conv-72	1.4614	1.8150	2.1686
RB-cov-96	1.7714	2.1250	2.4786
RB-inf-mw-1	-3.1336	-2.7800	-2.4264
RB-inf-mw-24	-1.0136	-0.6600	-0.3064
RB-inf-mw-48	0.4964	0.8500	Oca.36
RB-inf-mw-72	2.1114	2.4650	2.8186
RB-inf-mw-96	2.2764	2.6300	2.9836
RB-X-G-E-conv-1	-5.7686	-5.4150	-5.0614
RB-X-G-E-conv-24	-4.6886	-4.3350	-3.9814
RB-X-G-E-conv-48	-3.5036	-3.1500	-2.7964
RB-X-G-E-conv-72	-1.7236	-1.3700	-1.0164
RB-X-G-E-conv-96	-1.2236	-0.8700	-0.5164
RB-X-G-E-inf-mw-1	-5.3886	-5.0350	-4.6814
RB-X-G-E-inf-mw-24	-3.9386	-3.5850	-3.2314
RB-X-G-E-inf-mw-48	-2.7886	-2.4350	-2.0814
RB-X-G-E-inf-mw-72	-1.2436	-0.8900	-0.5364
RB-X-G-E-inf-mw-96	-0.8436	-0.4900	-0.1364

Bread Formulation = CB-X-G-E-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-24	0.4514	0.8050	1.1586
CB-X-G-E-conv-48	1.2864	1.6400	1.9936
CB-X-G-E-conv-72	2.8214	3.1750	3.5286
CB-X-G-E-conv-96	3.3364	3.6900	4.0436
CB-X-G-E-inf-mw-1	-0.1136	0.2400	0.5936

CB-X-G-E-inf-mw-24	0.9464	1.3000	1.6536
CB-X-G-E-inf-mw-48	2.1164	2.4700	2.8236
CB-X-G-E-inf-mw-72	3.2214	3.5750	3.9286
CB-X-G-E-inf-mw-96	3.6464	4.0000	4.3536
RB-conv-1	2.0114	2.3650	2.7186
RB-conv-24	4.1314	4.4850	4.8386
RB-conv-48	5.9614	6.3150	6.6686
RB-conv-72	7.0014	7.3550	7.7086
RB-cov-96	7.3114	7.6650	8.0186
RB-inf-mw-1	2.4064	2.7600	3.1136
RB-inf-mw-24	4.5264	4.8800	5.2336
RB-inf-mw-48	6.0364	6.3900	6.7436
RB-inf-mw-72	7.6514	8.0050	8.3586
RB-inf-mw-96	7.8164	8.1700	8.5236
RB-X-G-E-conv-1	-0.2286	0.1250	0.4786
RB-X-G-E-conv-24	0.8514	1.2050	1.5586
RB-X-G-E-conv-48	2.0364	2.3900	2.7436
RB-X-G-E-conv-72	3.8164	4.1700	4.5236
RB-X-G-E-conv-96	4.3164	4.6700	5.0236
RB-X-G-E-inf-mw-1	0.1514	0.5050	0.8586
RB-X-G-E-inf-mw-24	1.6014	1.9550	2.3086
RB-X-G-E-inf-mw-48	2.7514	3.1050	3.4586
RB-X-G-E-inf-mw-72	4.2964	4.6500	5.0036
RB-X-G-E-inf-mw-96	4.6964	5.0500	5.4036

Bread Formulation = CB-X-G-E-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-48	0.4814	0.8350	1.1886
CB-X-G-E-conv-72	2.0164	2.3700	2.7236
CB-X-G-E-conv-96	2.5314	2.8850	3.2386
CB-X-G-E-inf-mw-1	-0.9186	-0.5650	-0.2114
CB-X-G-E-inf-mw-24	0.1414	0.4950	0.8486
CB-X-G-E-inf-mw-48	1.3114	1.6650	2.0186
CB-X-G-E-inf-mw-72	2.4164	2.7700	3.1236
CB-X-G-E-inf-mw-96	2.8414	3.1950	3.5486
RB-conv-1	1.2064	1.5600	1.9136
RB-conv-24	3.3264	3.6800	4.0336
RB-conv-48	5.1564	5.5100	5.8636
RB-conv-72	6.1964	6.5500	6.9036
RB-cov-96	6.5064	6.8600	7.2136
RB-inf-mw-1	1.6014	1.9550	2.3086
RB-inf-mw-24	3.7214	4.0750	4.4286
RB-inf-mw-48	5.2314	5.5850	5.9386
RB-inf-mw-72	6.8464	7.2000	7.5536
RB-inf-mw-96	7.0114	7.3650	7.7186
RB-X-G-E-conv-1	-1.0336	-0.6800	-0.3264
RB-X-G-E-conv-24	0.0464	0.4000	0.7536
RB-X-G-E-conv-48	1.2314	1.5850	1.9386
RB-X-G-E-conv-72	3.0114	3.3650	3.7186
RB-X-G-E-conv-96	3.5114	3.8650	4.2186

RB-X-G-E-inf-mw-1	-0.6536	-0.3000	0.0536
RB-X-G-E-inf-mw-24	0.7964	1.1500	1.5036
RB-X-G-E-inf-mw-48	1.9464	2.3000	2.6536
RB-X-G-E-inf-mw-72	3.4914	3.8450	4.1986
RB-X-G-E-inf-mw-96	3.8914	4.2450	4.5986

Bread Formulation = CB-X-G-E-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-72	1.1814	1.5350	1.8886
CB-X-G-E-conv-96	1.6964	2.0500	2.4036
CB-X-G-E-inf-mw-1	-1.7536	-1.4000	-1.0464
CB-X-G-E-inf-mw-24	-0.6936	-0.3400	0.0136
CB-X-G-E-inf-mw-48	0.4764	0.8300	1.1836
CB-X-G-E-inf-mw-72	1.5814	1.9350	2.2886
CB-X-G-E-inf-mw-96	2.0064	2.3600	2.7136
RB-conv-1	0.3714	0.7250	1.0786
RB-conv-24	2.4914	2.8450	3.1986
RB-conv-48	4.3214	4.6750	5.0286
RB-conv-72	5.3614	5.7150	6.0686
RB-cov-96	5.6714	6.0250	6.3786
RB-inf-mw-1	0.7664	1.1200	1.4736
RB-inf-mw-24	2.8864	3.2400	3.5936
RB-inf-mw-48	4.3964	4.7500	5.1036
RB-inf-mw-72	6.0114	6.3650	6.7186
RB-inf-mw-96	6.1764	6.5300	6.8836

RB-X-G-E-conv-1	-1.8686	-1.5150	-1.1614
RB-X-G-E-conv-24	-0.7886	-0.4350	-0.0814
RB-X-G-E-conv-48	0.3964	0.7500	1.1036
RB-X-G-E-conv-72	2.1764	2.5300	2.8836
RB-X-G-E-conv-96	2.6764	3.0300	3.3836
RB-X-G-E-inf-mw-1	-1.4886	-1.1350	-0.7814
RB-X-G-E-inf-mw-24	-0.0386	0.3150	0.6686
RB-X-G-E-inf-mw-48	1.1114	1.4650	1.8186
RB-X-G-E-inf-mw-72	2.6564	3.0100	3.3636
RB-X-G-E-inf-mw-96	3.0564	3.4100	3.7636

Bread Formulation = CB-X-G-E-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-96	0.1614	0.5150	0.8686
CB-X-G-E-inf-mw-1	-3.2886	-2.9350	-2.5814
CB-X-G-E-inf-mw-24	-2.2286	-1.8750	-1.5214
CB-X-G-E-inf-mw-48	-1.0586	-0.7050	-0.3514
CB-X-G-E-inf-mw-72	0.0464	0.4000	0.7536
CB-X-G-E-inf-mw-96	0.4714	0.8250	1.1786
RB-conv-1	-1.1636	-0.8100	-0.4564
RB-conv-24	0.9564	1.3100	1.6636
RB-conv-48	2.7864	3.1400	3.4936
RB-conv-72	3.8264	4.1800	4.5336
RB-cov-96	4.1364	4.4900	4.8436
RB-inf-mw-1	-0.7686	-0.4150	-0.0614

RB-inf-mw-24	1.3514	1.7050	2.0586
RB-inf-mw-48	2.8614	3.2150	3.5686
RB-inf-mw-72	4.4764	4.8300	5.1836
RB-inf-mw-96	4.6414	4.9950	5.3486
RB-X-G-E-conv-1	-3.4036	-3.0500	-2.6964
RB-X-G-E-conv-24	-2.3236	-1.9700	-1.6164
RB-X-G-E-conv-48	-1.1386	-0.7850	-0.4314
RB-X-G-E-conv-72	0.6414	0.9950	1.3486
RB-X-G-E-conv-96	1.1414	1.4950	1.8486
RB-X-G-E-inf-mw-1	-3.0236	-2.6700	-2.3164
RB-X-G-E-inf-mw-24	-1.5736	-1.2200	-0.8664
RB-X-G-E-inf-mw-48	-0.4236	-0.0700	0.2836
RB-X-G-E-inf-mw-72	1.1214	1.4750	1.8286
RB-X-G-E-inf-mw-96	1.5214	1.8750	2.2286

Bread Formulation = CB-X-G-E-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-1	-3.8036	-3.4500	-3.0964
CB-X-G-E-inf-mw-24	-2.7436	-2.3900	-2.0364
CB-X-G-E-inf-mw-48	-1.5736	-1.2200	-0.8664
CB-X-G-E-inf-mw-72	-0.4686	-0.1150	0.2386
CB-X-G-E-inf-mw-96	-0.0436	0.3100	0.6636
RB-conv-1	-1.6786	-1.3250	-0.9714
RB-conv-24	0.4414	0.7950	1.1486
RB-conv-48	2.2714	2.6250	2.9786

RB-conv-72	3.3114	3.6650	4.0186
RB-cov-96	3.6214	3.9750	4.3286
RB-inf-mw-1	-1.2836	-0.9300	-0.5764
RB-inf-mw-24	0.8364	1.1900	1.5436
RB-inf-mw-48	2.3464	2.7000	3.0536
RB-inf-mw-72	3.9614	4.3150	4.6686
RB-inf-mw-96	4.1264	4.4800	4.8336
RB-X-G-E-conv-1	-3.9186	-3.5650	-3.2114
RB-X-G-E-conv-24	-2.8386	-2.4850	-2.1314
RB-X-G-E-conv-48	-1.6536	-1.3000	-0.9464
RB-X-G-E-conv-72	0.1264	0.4800	0.8336
RB-X-G-E-conv-96	0.6264	0.9800	1.3336
RB-X-G-E-inf-mw-1	-3.5386	-3.1850	-2.8314
RB-X-G-E-inf-mw-24	-2.0886	-1.7350	-1.3814
RB-X-G-E-inf-mw-48	-0.9386	-0.5850	-0.2314
RB-X-G-E-inf-mw-72	0.6064	0.9600	1.3136
RB-X-G-E-inf-mw-96	1.0064	1.3600	1.7136

Bread Formulation = CB-X-G-E-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-24	0.7064	1.0600	1.4136
CB-X-G-E-inf-mw-48	1.8764	2.2300	2.5836
CB-X-G-E-inf-mw-72	2.9814	3.3350	3.6886
CB-X-G-E-inf-mw-96	3.4064	3.7600	4.1136
RB-conv-1	1.7714	2.1250	2.4786

RB-conv-24	3.8914	4.2450	4.5986
RB-conv-48	5.7214	6.0750	6.4286
RB-conv-72	6.7614	7.1150	7.4686
RB-cov-96	7.0714	7.4250	7.7786
RB-inf-mw-1	2.1664	2.5200	2.8736
RB-inf-mw-24	4.2864	4.6400	4.9936
RB-inf-mw-48	5.7964	6.1500	6.5036
RB-inf-mw-72	7.4114	7.7650	8.1186
RB-inf-mw-96	7.5764	7.9300	8.2836
RB-X-G-E-conv-1	-0.4686	-0.1150	0.2386
RB-X-G-E-conv-24	0.6114	0.9650	1.3186
RB-X-G-E-conv-48	1.7964	2.1500	2.5036
RB-X-G-E-conv-72	3.5764	3.9300	4.2836
RB-X-G-E-conv-96	4.0764	4.4300	4.7836
RB-X-G-E-inf-mw-1	-0.0886	0.2650	0.6186
RB-X-G-E-inf-mw-24	1.3614	1.7150	2.0686
RB-X-G-E-inf-mw-48	2.5114	2.8650	3.2186
RB-X-G-E-inf-mw-72	4.0564	4.4100	4.7636
RB-X-G-E-inf-mw-96	4.4564	4.8100	5.1636

Bread Formulation = CB-X-G-E-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-48	0.8164	1.1700	1.5236
CB-X-G-E-inf-mw-72	1.9214	2.2750	2.6286
CB-X-G-E-inf-mw-96	2.3464	2.7000	3.0536

RB-conv-1	0.7114	1.0650	1.4186
RB-conv-24	2.8314	3.1850	3.5386
RB-conv-48	4.6614	5.0150	5.3686
RB-conv-72	5.7014	6.0550	6.4086
RB-cov-96	6.0114	6.3650	6.7186
RB-inf-mw-1	1.1064	1.4600	1.8136
RB-inf-mw-24	3.2264	3.5800	3.9336
RB-inf-mw-48	4.7364	5.0900	5.4436
RB-inf-mw-72	6.3514	6.7050	7.0586
RB-inf-mw-96	6.5164	6.8700	7.2236
RB-X-G-E-conv-1	-1.5286	-1.1750	-0.8214
RB-X-G-E-conv-24	-0.4486	-0.0950	0.2586
RB-X-G-E-conv-48	0.7364	1.0900	1.4436
RB-X-G-E-conv-72	2.5164	2.8700	3.2236
RB-X-G-E-conv-96	3.0164	3.3700	3.7236
RB-X-G-E-inf-mw-1	-1.1486	-0.7950	-0.4414
RB-X-G-E-inf-mw-24	0.3014	0.6550	1.0086
RB-X-G-E-inf-mw-48	1.4514	1.8050	2.1586
RB-X-G-E-inf-mw-72	2.9964	3.3500	3.7036
RB-X-G-E-inf-mw-96	3.3964	3.7500	4.1036

Bread Formulation = CB-X-G-E-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-72	0.7514	1.1050	1.4586
CB-X-G-E-inf-mw-96	1.1764	1.5300	1.8836

RB-conv-1	-0.4586	-0.1050	0.2486
RB-conv-24	1.6614	2.0150	2.3686
RB-conv-48	3.4914	3.8450	4.1986
RB-conv-72	4.5314	4.8850	5.2386
RB-cov-96	4.8414	5.1950	5.5486
RB-inf-mw-1	-0.0636	0.2900	0.6436
RB-inf-mw-24	2.0564	2.4100	2.7636
RB-inf-mw-48	3.5664	3.9200	4.2736
RB-inf-mw-72	5.1814	5.5350	5.8886
RB-inf-mw-96	5.3464	5.7000	6.0536
RB-X-G-E-conv-1	-2.6986	-2.3450	-1.9914
RB-X-G-E-conv-24	-1.6186	-1.2650	-0.9114
RB-X-G-E-conv-48	-0.4336	-0.0800	0.2736
RB-X-G-E-conv-72	1.3464	1.7000	2.0536
RB-X-G-E-conv-96	1.8464	2.2000	2.5536
RB-X-G-E-inf-mw-1	-2.3186	-1.9650	-1.6114
RB-X-G-E-inf-mw-24	-0.8686	-0.5150	-0.1614
RB-X-G-E-inf-mw-48	0.2814	0.6350	0.9886
RB-X-G-E-inf-mw-72	1.8264	2.1800	2.5336
RB-X-G-E-inf-mw-96	2.2264	2.5800	2.9336

Bread Formulation = CB-X-G-E-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-96	0.0714	0.4250	0.7786
RB-conv-1	-1.5636	-1.2100	-0.8564

RB-conv-24	0.5564	0.9100	1.2636
RB-conv-48	2.3864	2.7400	3.0936
RB-conv-72	3.4264	3.7800	4.1336
RB-cov-96	3.7364	4.0900	4.4436
RB-inf-mw-1	-1.1686	-0.8150	-0.4614
RB-inf-mw-24	0.9514	1.3050	1.6586
RB-inf-mw-48	2.4614	2.8150	3.1686
RB-inf-mw-72	4.0764	4.4300	4.7836
RB-inf-mw-96	4.2414	4.5950	4.9486
RB-X-G-E-conv-1	-3.8036	-3.4500	-3.0964
RB-X-G-E-conv-24	-2.7236	-2.3700	-2.0164
RB-X-G-E-conv-48	-1.5386	-1.1850	-0.8314
RB-X-G-E-conv-72	0.2414	0.5950	0.9486
RB-X-G-E-conv-96	0.7414	1.0950	1.4486
RB-X-G-E-inf-mw-1	-3.4236	-3.0700	-2.7164
RB-X-G-E-inf-mw-24	-1.9736	-1.6200	-1.2664
RB-X-G-E-inf-mw-48	-0.8236	-0.4700	-0.1164
RB-X-G-E-inf-mw-72	0.7214	1.0750	1.4286
RB-X-G-E-inf-mw-96	1.1214	1.4750	1.8286

Bread Formulation = CB-X-G-E-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-1	-1.9886	-1.6350	-1.2814
RB-conv-24	0.1314	0.4850	0.8386
RB-conv-48	1.9614	2.3150	2.6686

RB-conv-72	3.0014	3.3550	3.7086
RB-cov-96	3.3114	3.6650	4.0186
RB-inf-mw-1	-1.5936	-1.2400	-0.8864
RB-inf-mw-24	0.5264	0.8800	1.2336
RB-inf-mw-48	2.0364	2.3900	2.7436
RB-inf-mw-72	3.6514	4.0050	4.3586
RB-inf-mw-96	3.8164	4.1700	4.5236
RB-X-G-E-conv-1	-4.2286	-3.8750	-3.5214
RB-X-G-E-conv-24	-3.1486	-2.7950	-2.4414
RB-X-G-E-conv-48	-1.9636	-1.6100	-1.2564
RB-X-G-E-conv-72	-0.1836	0.1700	0.5236
RB-X-G-E-conv-96	0.3164	0.6700	1.0236
RB-X-G-E-inf-mw-1	-3.8486	-3.4950	-3.1414
RB-X-G-E-inf-mw-24	-2.3986	-2.0450	-1.6914
RB-X-G-E-inf-mw-48	-1.2486	-0.8950	-0.5414
RB-X-G-E-inf-mw-72	0.2964	0.6500	1.0036
RB-X-G-E-inf-mw-96	0.6964	1.0500	1.4036

Bread Formulation = RB-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-24	1.7664	2.1200	2.4736
RB-conv-48	3.5964	3.9500	4.3036
RB-conv-72	4.6364	4.9900	5.3436
RB-cov-96	4.9464	5.3000	5.6536
RB-inf-mw-1	0.0414	0.3950	0.7486

RB-inf-mw-24	2.1614	2.5150	2.8686
RB-inf-mw-48	3.6714	4.0250	4.3786
RB-inf-mw-72	5.2864	5.6400	5.9936
RB-inf-mw-96	5.4514	5.8050	6.1586
RB-X-G-E-conv-1	-2.5936	-2.2400	-1.8864
RB-X-G-E-conv-24	-1.5136	-1.1600	-0.8064
RB-X-G-E-conv-48	-0.3286	0.0250	0.3786
RB-X-G-E-conv-72	1.4514	1.8050	2.1586
RB-X-G-E-conv-96	1.9514	2.3050	2.6586
RB-X-G-E-inf-mw-1	-2.2136	-1.8600	-1.5064
RB-X-G-E-inf-mw-24	-0.7636	-0.4100	-0.0564
RB-X-G-E-inf-mw-48	0.3864	0.7400	1.0936
RB-X-G-E-inf-mw-72	1.9314	2.2850	2.6386
RB-X-G-E-inf-mw-96	2.3314	2.6850	3.0386

Bread Formulation = RB-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-48	1.4764	1.8300	2.1836
RB-conv-72	2.5164	2.8700	3.2236
RB-cov-96	2.8264	3.1800	3.5336
RB-inf-mw-1	-2.0786	-1.7250	-1.3714
RB-inf-mw-24	0.0414	0.3950	0.7486
RB-inf-mw-48	1.5514	1.9050	2.2586
RB-inf-mw-72	3.1664	3.5200	3.8736
RB-inf-mw-96	3.3314	3.6850	4.0386
RB-X-G-E-conv-1	-4.7136	-4.3600	-4.0064
RB-X-G-E-conv-24	-3.6336	-3.2800	-2.9264
RB-X-G-E-conv-48	-2.4486	-2.0950	-1.7414
RB-X-G-E-conv-72	-0.6686	-0.3150	0.0386
RB-X-G-E-conv-96	-0.1686	0.1850	0.5386
RB-X-G-E-inf-mw-1	-4.3336	-3.9800	-3.6264
RB-X-G-E-inf-mw-24	-2.8836	-2.5300	-2.1764
RB-X-G-E-inf-mw-48	-1.7336	-1.3800	-1.0264
RB-X-G-E-inf-mw-72	-0.1886	0.1650	0.5186
RB-X-G-E-inf-mw-96	0.2114	0.5650	0.9186

Bread Formulation = RB-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-72	0.6864	1.0400	1.3936
RB-cov-96	0.9964	1.3500	1.7036

RB-inf-mw-1	-3.9086	-3.5550	-3.2014
RB-inf-mw-24	-1.7886	-1.4350	-1.0814
RB-inf-mw-48	-0.2786	0.0750	0.4286
RB-inf-mw-72	1.3364	1.6900	2.0436
RB-inf-mw-96	1.5014	1.8550	2.2086
RB-X-G-E-conv-1	-6.5436	-6.1900	-5.8364
RB-X-G-E-conv-24	-5.4636	-5.1100	-4.7564
RB-X-G-E-conv-48	-4.2786	-3.9250	-3.5714
RB-X-G-E-conv-72	-2.4986	-2.1450	-1.7914
RB-X-G-E-conv-96	-1.9986	-1.6450	-1.2914
RB-X-G-E-inf-mw-1	-6.1636	-5.8100	-5.4564
RB-X-G-E-inf-mw-24	-4.7136	-4.3600	-4.0064
RB-X-G-E-inf-mw-48	-3.5636	-3.2100	-2.8564
RB-X-G-E-inf-mw-72	-2.0186	-1.6650	-1.3114
RB-X-G-E-inf-mw-96	-1.6186	-1.2650	-0.9114

Bread Formulation = RB-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-cov-96	-0.0436	0.3100	0.6636
RB-inf-mw-1	-4.9486	-4.5950	-4.2414
RB-inf-mw-24	-2.8286	-2.4750	-2.1214
RB-inf-mw-48	-1.3186	-0.9650	-0.6114
RB-inf-mw-72	0.2964	0.6500	1.0036
RB-inf-mw-96	0.4614	0.8150	1.1686
RB-X-G-E-conv-1	-7.5836	-7.2300	-6.8764

RB-X-G-E-conv-24	-6.5036	-6.1500	-5.7964
RB-X-G-E-conv-48	-5.3186	-4.9650	-4.6114
RB-X-G-E-conv-72	-3.5386	-3.1850	-2.8314
RB-X-G-E-conv-96	-3.0386	-2.6850	-2.3314
RB-X-G-E-inf-mw-1	-7.2036	-6.8500	-6.4964
RB-X-G-E-inf-mw-24	-5.7536	-5.4000	-5.0464
RB-X-G-E-inf-mw-48	-4.6036	-4.2500	-3.8964
RB-X-G-E-inf-mw-72	-3.0586	-2.7050	-2.3514
RB-X-G-E-inf-mw-96	-2.6586	-2.3050	-1.9514

Bread Formulation = RB-cov-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-1	-5.2586	-4.9050	-4.5514
RB-inf-mw-24	-3.1386	-2.7850	-2.4314
RB-inf-mw-48	-1.6286	-1.2750	-0.9214
RB-inf-mw-72	-0.0136	0.3400	0.6936
RB-inf-mw-96	0.1514	0.5050	0.8586
RB-X-G-E-conv-1	-7.8936	-7.5400	-7.1864
RB-X-G-E-conv-24	-6.8136	-6.4600	-6.1064
RB-X-G-E-conv-48	-5.6286	-5.2750	-4.9214
RB-X-G-E-conv-72	-3.8486	-3.4950	-3.1414
RB-X-G-E-conv-96	-3.3486	-2.9950	-2.6414
RB-X-G-E-inf-mw-1	-7.5136	-7.1600	-6.8064
RB-X-G-E-inf-mw-24	-6.0636	-5.7100	-5.3564
RB-X-G-E-inf-mw-48	-4.9136	-4.5600	-4.2064

RB-X-G-E-inf-mw-72	-3.3686	-3.0150	-2.6614
RB-X-G-E-inf-mw-96	-2.9686	-2.6150	-2.2614

Bread Formulation = RB-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-24	1.7664	2.1200	2.4736
RB-inf-mw-48	3.2764	3.6300	3.9836
RB-inf-mw-72	4.8914	5.2450	5.5986
RB-inf-mw-96	5.0564	5.4100	5.7636
RB-X-G-E-conv-1	-2.9886	-2.6350	-2.2814
RB-X-G-E-conv-24	-1.9086	-1.5550	-1.2014
RB-X-G-E-conv-48	-0.7236	-0.3700	-0.0164
RB-X-G-E-conv-72	1.0564	1.4100	1.7636
RB-X-G-E-conv-96	1.5564	1.9100	2.2636
RB-X-G-E-inf-mw-1	-2.6086	-2.2550	-1.9014
RB-X-G-E-inf-mw-24	-1.1586	-0.8050	-0.4514
RB-X-G-E-inf-mw-48	-0.0086	0.3450	0.6986
RB-X-G-E-inf-mw-72	1.5364	1.8900	2.2436
RB-X-G-E-inf-mw-96	1.9364	2.2900	2.6436

Bread Formulation = RB-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-48	1.1564	1.5100	1.8636
RB-inf-mw-72	2.7714	3.1250	3.4786
RB-inf-mw-96	2.9364	3.2900	3.6436

RB-X-G-E-conv-1	-5.1086	-4.7550	-4.4014
RB-X-G-E-conv-24	-4.0286	-3.6750	-3.3214
RB-X-G-E-conv-48	-2.8436	-2.4900	-2.1364
RB-X-G-E-conv-72	-1.0636	-0.7100	-0.3564
RB-X-G-E-conv-96	-0.5636	-0.2100	0.1436
RB-X-G-E-inf-mw-1	-4.7286	-4.3750	-4.0214
RB-X-G-E-inf-mw-24	-3.2786	-2.9250	-2.5714
RB-X-G-E-inf-mw-48	-2.1286	-1.7750	-1.4214
RB-X-G-E-inf-mw-72	-0.5836	-0.2300	0.1236
RB-X-G-E-inf-mw-96	-0.1836	0.1700	0.5236

Bread Formulation = RB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-72	1.2614	1.6150	1.9686
RB-inf-mw-96	1.4264	1.7800	2.1336
RB-X-G-E-conv-1	-6.6186	-6.2650	-5.9114
RB-X-G-E-conv-24	-5.5386	-5.1850	-4.8314
RB-X-G-E-conv-48	-4.3536	-4.0000	-3.6464
RB-X-G-E-conv-72	-2.5736	-2.2200	-1.8664
RB-X-G-E-conv-96	-2.0736	-1.7200	-1.3664
RB-X-G-E-inf-mw-1	-6.2386	-5.8850	-5.5314
RB-X-G-E-inf-mw-24	-4.7886	-4.4350	-4.0814
RB-X-G-E-inf-mw-48	-3.6386	-3.2850	-2.9314
RB-X-G-E-inf-mw-72	-2.0936	-1.7400	-1.3864
RB-X-G-E-inf-mw-96	-1.6936	-1.3400	-0.9864

Bread Formulation = RB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-96	-0.1886	0.1650	0.5186
RB-X-G-E-conv-1	-8.2336	-7.8800	-7.5264
RB-X-G-E-conv-24	-7.1536	-6.8000	-6.4464
RB-X-G-E-conv-48	-5.9686	-5.6150	-5.2614
RB-X-G-E-conv-72	-4.1886	-3.8350	-3.4814
RB-X-G-E-conv-96	-3.6886	-3.3350	-2.9814
RB-X-G-E-inf-mw-1	-7.8536	-7.5000	-7.1464
RB-X-G-E-inf-mw-24	-6.4036	-6.0500	-5.6964
RB-X-G-E-inf-mw-48	-5.2536	-4.9000	-4.5464
RB-X-G-E-inf-mw-72	-3.7086	-3.3550	-3.0014
RB-X-G-E-inf-mw-96	-3.3086	-2.9550	-2.6014

Bread Formulation = RB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-1	-8.3986	-8.0450	-7.6914
RB-X-G-E-conv-24	-7.3186	-6.9650	-6.6114
RB-X-G-E-conv-48	-6.1336	-5.7800	-5.4264
RB-X-G-E-conv-72	-4.3536	-4.0000	-3.6464
RB-X-G-E-conv-96	-3.8536	-3.5000	-3.1464
RB-X-G-E-inf-mw-1	-8.0186	-7.6650	-7.3114
RB-X-G-E-inf-mw-24	-6.5686	-6.2150	-5.8614
RB-X-G-E-inf-mw-48	-5.4186	-5.0650	-4.7114
RB-X-G-E-inf-mw-72	-3.8736	-3.5200	-3.1664

RB-X-G-E-inf-mw-96	-3.4736	-3.1200	-2.7664

Bread Formulation = RB-X-G-E-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-24	0.7264	1.0800	1.4336
RB-X-G-E-conv-48	1.9114	2.2650	2.6186
RB-X-G-E-conv-72	3.6914	4.0450	4.3986
RB-X-G-E-conv-96	4.1914	4.5450	4.8986
RB-X-G-E-inf-mw-1	0.0264	0.3800	0.7336
RB-X-G-E-inf-mw-24	1.4764	1.8300	2.1836
RB-X-G-E-inf-mw-48	2.6264	2.9800	3.3336
RB-X-G-E-inf-mw-72	4.1714	4.5250	4.8786
RB-X-G-E-inf-mw-96	4.5714	4.9250	5.2786

Bread Formulation = RB-X-G-E-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-48	0.8314	1.1850	1.5386
RB-X-G-E-conv-72	2.6114	2.9650	3.3186
RB-X-G-E-conv-96	3.1114	3.4650	3.8186
RB-X-G-E-inf-mw-1	-1.0536	-0.7000	-0.3464
RB-X-G-E-inf-mw-24	0.3964	0.7500	1.1036
RB-X-G-E-inf-mw-48	1.5464	1.9000	2.2536
RB-X-G-E-inf-mw-72	3.0914	3.4450	3.7986
RB-X-G-E-inf-mw-96	3.4914	3.8450	4.1986

Bread Formulation = RB-X-G-E-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-72	1.4264	1.7800	2.1336
RB-X-G-E-conv-96	1.9264	2.2800	2.6336
RB-X-G-E-inf-mw-1	-2.2386	-1.8850	-1.5314
RB-X-G-E-inf-mw-24	-0.7886	-0.4350	-0.0814
RB-X-G-E-inf-mw-48	0.3614	0.7150	1.0686
RB-X-G-E-inf-mw-72	1.9064	2.2600	2.6136
RB-X-G-E-inf-mw-96	2.3064	2.6600	3.0136

Bread Formulation = RB-X-G-E-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-96	0.1464	0.5	0.8536
RB-X-G-E-inf-mw-1	-4.0186	-3.665	-3.3114
RB-X-G-E-inf-mw-24	-2.5686	-2.215	-1.8614
RB-X-G-E-inf-mw-48	-1.4186	-1.065	-0.7114
RB-X-G-E-inf-mw-72	0.1264	0.48	0.8336
RB-X-G-E-inf-mw-96	0.5264	0.88	1.2336

Bread Formulation = RB-X-G-E-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-1	-4.5186	-4.165	-3.8114
RB-X-G-E-inf-mw-24	-3.0686	-2.715	-2.3614
RB-X-G-E-inf-mw-48	-1.9186	-1.565	-1.2114
RB-X-G-E-inf-mw-72	-0.3736	-0.02	0.3336

RB-X-G-E-inf-mw-96	0.0264	0.38	0.7336

Bread Formulation = RB-X-G-E-inf-mw-1 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-24	1.0964	1.45	1.8036
RB-X-G-E-inf-mw-48	2.2464	2.6	2.9536
RB-X-G-E-inf-mw-72	3.7914	4.145	4.4986
RB-X-G-E-inf-mw-96	4.1914	4.545	4.8986

Bread Formulation = RB-X-G-E-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-48	0.7964	1.15	1.5036
RB-X-G-E-inf-mw-72	2.3414	2.695	3.0486
RB-X-G-E-inf-mw-96	2.7414	3.095	3.4486

Bread Formulation = RB-X-G-E-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-72	1.1914	1.5450	1.8986
RB-X-G-E-inf-mw-96	1.5914	1.9450	2.2986

Bread Formulation = RB-X-G-E-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-96	0.0464	0.4000	0.7536

Table A. 35. General linear model for retrogradation enthaply values of different gluten-free bread formulaions baked in different ovens and stored at different times

Factor	Type	Levels	Values
Bread Formulation	fixed	4	CB, CB-X-G-E, RB, RB-X-G-E
Storage Time	fixed	4	24, 48, 72, 96
Oven type	fixed	2	Con, ınf-mw

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Bread Formulation	3	13.9606	13.9606	4.6535	451.61	0.000
Storage Time	3	7.1139	7.1139	2.3713	230.13	0.000
Oven type	1	1.0474	1.0474	1.0474	101.65	0.000
Error	56	0.5770	0.5770	0.0103		
Total	63	22.6989				

Formulation	N	Mean	Grouping
RB	16	2.8	A
CB	16	2.0	B
RB-X-G-E	16	1.8	C
CB-X-G-E	16	1.5	D

Storage Time	N	Mean	Grouping
96	16	2.4	A
72	16	2.2	B
48	16	2.0	C
24	16	1.5	D

Oven type	N	Mean	Grouping
ınf-mw	32	2.2	A
Conv	32	1.9	B

Table A. 36. One-way ANOVA for retrogradation enthaply values of different gluten-free bread formulaions baked in different ovens and stored at different times

Source	DF	SS	MS	F	P
Bread Formulation	31	22.47310	0.72494	102.72	0.000
Error	32	0.22584	0.00706		
Total	63	22.69895			

Level	N	Mean	StDev
CB-conv-24	2	1.294	0.0707
CB-conv-48	2	1.867	0.0707
CB-conv-72	2	1.981	0.0707
CB-conv-96	2	2.1612	0.0707
CB-inf-mw-24	2	1.3945	0.0219
CB-inf-mw-48	2	2.0455	0.1195
CB-inf-mw-72	2	2.3975	0.0177
CB-inf-mw-96	2	2.5005	0.0983
CB-X-G-E-conv-24	2	1.0475	0.0742
CB-X-G-E-conv-48	2	1.3095	0.0573
CB-X-G-E-conv-72	2	1.593	0.0382
CB-X-G-E-conv-96	2	1.692	0.082
CB-X-G-E-inf-mw-24	2	1.1945	0.0926

CB-X-G-E-inf-mw-48	2	1.634	0.0792
CB-X-G-E-inf-mw-72	2	1.7765	0.0474
CB-X-G-E-inf-mw-96	2	1.8935	0.0375
RB-conv-24	2	2.0935	0.1082
RB-conv-48	2	2.651	0.0707
RB-conv-72	2	2.932	0.0707
RB-cov-96	2	3.071	0.0707
RB-inf-mw-24	2	2.294	0.0792
RB-inf-mw-48	2	2.928	0.0877
RB-inf-mw-72	2	3.075	0.1061
RB-inf-mw-96	2	3.243	0.0665
RB-X-G-E-conv-24	2	1.192	0.0707
RB-X-G-E-conv-48	2	1.584	0.0707
RB-X-G-E-conv-72	2	1.806	0.0707
RB-X-G-E-conv-96	2	2.107	0.0707
RB-X-G-E-inf-mw-24	2	1.4885	0.1011
RB-X-G-E-inf-mw-48	2	2.005	0.1344
RB-X-G-E-inf-mw-72	2	2.171	0.0976
RB-X-G-E-inf-mw-96	2	2.4345	0.1775

Bread Formulation	N	Mean	Grouping
RB-inf-mw-96	2	3.243	A
RB-inf-mw-72	2	3.075	A
RB-cov-96	2	3.071	A
RB-conv-72	2	2.932	A B

RB-inf-mw-48	2	2.928	A B
RB-conv-48	2	2.651	B C
CB-inf-mw-96	2	2.5005	C D
RB-X-G-E-inf-mw-96	2	2.4345	C D E
CB-inf-mw-72	2	2.3975	C D E
RB-inf-mw-24	2	2.294	D E F
RB-X-G-E-inf-mw-72	2	2.171	D E F G
CB-conv-96	2	2.1612	D E F G
RB-X-G-E-conv-96	2	2.107	E F G H
RB-conv-24	2	2.0935	E F G H
CB-inf-mw-48	2	2.0455	F G H
RB-X-G-E-inf-mw-48	2	2.005	F G H I
CB-conv-72	2	1.981	F G H I J
CB-X-G-E-inf-mw-96	2	1.8935	G H I J K
CB-conv-48	2	1.867	G H I J K
RB-X-G-E-conv-72	2	1.806	H I J K L
CB-X-G-E-inf-mw-72	2	1.7765	H I J K L
CB-X-G-E-conv-96	2	1.692	I J K L M
CB-X-G-E-inf-mw-48	2	1.634	J K L M N
CB-X-G-E-conv-72	2	1.593	K L M N
RB-X-G-E-conv-48	2	1.584	K L M N
RB-X-G-E-inf-mw-24	2	1.4885	L M N O
CB-inf-mw-24	2	1.3945	M N O P
CB-X-G-E-conv-48	2	1.3095	N O P
CB-conv-24	2	1.294	N O P

CB-X-G-E-inf-mw-24	2	1.1945	O P
RB-X-G-E-conv-24	2	1.192	O P
CB-X-G-E-conv-24	2	1.0475	P

Bread Formulation = CB-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-48	0.2249	0.5730	0.9211
CB-conv-72	0.3389	0.6870	1.0351
CB-conv-96	0.5191	0.8672	1.2153
CB-inf-mw-24	-0.2476	0.1005	0.4486
CB-inf-mw-48	0.4034	0.7515	1.0996
CB-inf-mw-72	0.7554	1.1035	1.4516
CB-inf-mw-96	0.8584	1.2065	1.5546
CB-X-G-E-conv-24	-0.5946	-0.2465	0.1016
CB-X-G-E-conv-48	-0.3326	0.0155	0.3636
CB-X-G-E-conv-72	-0.0491	0.2990	0.6471
CB-X-G-E-conv-96	0.0499	0.3980	0.7461
CB-X-G-E-inf-mw-24	-0.4476	-0.0995	0.2486
CB-X-G-E-inf-mw-48	-0.0081	0.3400	0.6881
CB-X-G-E-inf-mw-72	0.1344	0.4825	0.8306
CB-X-G-E-inf-mw-96	0.2514	0.5995	0.9476
RB-conv-24	0.4514	0.7995	1.1476
RB-conv-48	1.0089	1.3570	1.7051
RB-conv-72	1.2899	1.6380	1.9861
RB-cov-96	1.4289	1.7770	2.1251

RB-inf-mw-24	0.6519	1.0000	1.3481
RB-inf-mw-48	1.2859	1.6340	1.9821
RB-inf-mw-72	1.4329	1.7810	2.1291
RB-inf-mw-96	1.6009	1.9490	2.2971
RB-X-G-E-conv-24	-0.4501	-0.1020	0.2461
RB-X-G-E-conv-48	-0.0581	0.2900	0.6381
RB-X-G-E-conv-72	0.1639	0.5120	0.8601
RB-X-G-E-conv-96	0.4649	0.8130	1.1611
RB-X-G-E-inf-mw-24	-0.1536	0.1945	0.5426
RB-X-G-E-inf-mw-48	0.3629	0.7110	1.0591
RB-X-G-E-inf-mw-72	0.5289	0.8770	1.2251
RB-X-G-E-inf-mw-96	0.7924	1.1405	1.4886

Bread Formulation = CB-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-72	-0.2341	0.1140	0.4621
CB-conv-96	-0.0539	0.2942	0.6423
CB-inf-mw-24	-0.8206	-0.4725	-0.1244
CB-inf-mw-48	-0.1696	0.1785	0.5266
CB-inf-mw-72	0.1824	0.5305	0.8786
CB-inf-mw-96	0.2854	0.6335	0.9816
CB-X-G-E-conv-24	-1.1676	-0.8195	-0.4714
CB-X-G-E-conv-48	-0.9056	-0.5575	-0.2094
CB-X-G-E-conv-72	-0.6221	-0.2740	0.0741
CB-X-G-E-conv-96	-0.5231	-0.1750	0.1731

CB-X-G-E-inf-mw-24	-1.0206	-0.6725	-0.3244
CB-X-G-E-inf-mw-48	-0.5811	-0.2330	0.1151
CB-X-G-E-inf-mw-72	-0.4386	-0.0905	0.2576
CB-X-G-E-inf-mw-96	-0.3216	0.0265	0.3746
RB-conv-24	-0.1216	0.2265	0.5746
RB-conv-48	0.4359	0.7840	1.1321
RB-conv-72	0.7169	1.0650	1.4131
RB-cov-96	0.8559	1.2040	1.5521
RB-inf-mw-24	0.0789	0.4270	0.7751
RB-inf-mw-48	0.7129	1.0610	1.4091
RB-inf-mw-72	0.8599	1.2080	1.5561
RB-inf-mw-96	1.0279	1.3760	1.7241
RB-X-G-E-conv-24	-1.0231	-0.6750	-0.3269
RB-X-G-E-conv-48	-0.6311	-0.2830	0.0651
RB-X-G-E-conv-72	-0.4091	-0.0610	0.2871
RB-X-G-E-conv-96	-0.1081	0.2400	0.5881
RB-X-G-E-inf-mw-24	-0.7266	-0.3785	-0.0304
RB-X-G-E-inf-mw-48	-0.2101	0.1380	0.4861
RB-X-G-E-inf-mw-72	-0.0441	0.3040	0.6521
RB-X-G-E-inf-mw-96	0.2194	0.5675	0.9156

Bread Formulation = CB-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-96	-0.1679	0.1802	0.5283
CB-inf-mw-24	-0.9346	-0.5865	-0.2384

CB-inf-mw-48	-0.2836	0.0645	0.4126
CB-inf-mw-72	0.0684	0.4165	0.7646
CB-inf-mw-96	0.1714	0.5195	0.8676
CB-X-G-E-conv-24	-1.2816	-0.9335	-0.5854
CB-X-G-E-conv-48	-1.0196	-0.6715	-0.3234
CB-X-G-E-conv-72	-0.7361	-0.3880	-0.0399
CB-X-G-E-conv-96	-0.6371	-0.2890	0.0591
CB-X-G-E-inf-mw-24	-1.1346	-0.7865	-0.4384
CB-X-G-E-inf-mw-48	-0.6951	-0.3470	0.0011
CB-X-G-E-inf-mw-72	-0.5526	-0.2045	0.1436
CB-X-G-E-inf-mw-96	-0.4356	-0.0875	0.2606
RB-conv-24	-0.2356	0.1125	0.4606
RB-conv-48	0.3219	0.6700	1.0181
RB-conv-72	0.6029	0.9510	1.2991
RB-cov-96	0.7419	1.0900	1.4381
RB-inf-mw-24	-0.0351	0.3130	0.6611
RB-inf-mw-48	0.5989	0.9470	1.2951
RB-inf-mw-72	0.7459	1.0940	1.4421
RB-inf-mw-96	0.9139	1.2620	1.6101
RB-X-G-E-conv-24	-1.1371	-0.7890	-0.4409
RB-X-G-E-conv-48	-0.7451	-0.3970	-0.0489
RB-X-G-E-conv-72	-0.5231	-0.1750	0.1731
RB-X-G-E-conv-96	-0.2221	0.1260	0.4741
RB-X-G-E-inf-mw-24	-0.8406	-0.4925	-0.1444
RB-X-G-E-inf-mw-48	-0.3241	0.0240	0.3721

RB-X-G-E-inf-mw-72	-0.1581	0.1900	0.5381
RB-X-G-E-inf-mw-96	0.1054	0.4535	0.8016

Bread Formulation = CB-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-24	-1.1148	-0.7667	-0.4186
CB-inf-mw-48	-0.4638	-0.1157	0.2324
CB-inf-mw-72	-0.1118	0.2363	0.5844
CB-inf-mw-96	-0.0088	0.3393	0.6874
CB-X-G-E-conv-24	-1.4618	-1.1137	-0.7656
CB-X-G-E-conv-48	-1.1998	-0.8517	-0.5036
CB-X-G-E-conv-72	-0.9163	-0.5682	-0.2201
CB-X-G-E-conv-96	-0.8173	-0.4692	-0.1211
CB-X-G-E-inf-mw-24	-1.3148	-0.9667	-0.6186
CB-X-G-E-inf-mw-48	-0.8753	-0.5272	-0.1791
CB-X-G-E-inf-mw-72	-0.7328	-0.3847	-0.0366
CB-X-G-E-inf-mw-96	-0.6158	-0.2677	0.0804
RB-conv-24	-0.4158	-0.0677	0.2804
RB-conv-48	0.1417	0.4898	0.8379
RB-conv-72	0.4227	0.7708	1.1189
RB-cov-96	0.5617	0.9098	1.2579
RB-inf-mw-24	-0.2153	0.1328	0.4809
RB-inf-mw-48	0.4187	0.7668	1.1149
RB-inf-mw-72	0.5657	0.9138	1.2619
RB-inf-mw-96	0.7337	1.0818	1.4299

RB-X-G-E-conv-24	-1.3173	-0.9692	-0.6211
RB-X-G-E-conv-48	-0.9253	-0.5772	-0.2291
RB-X-G-E-conv-72	-0.7033	-0.3552	-0.0071
RB-X-G-E-conv-96	-0.4023	-0.0542	0.2939
RB-X-G-E-inf-mw-24	-1.0208	-0.6727	-0.3246
RB-X-G-E-inf-mw-48	-0.5043	-0.1562	0.1919
RB-X-G-E-inf-mw-72	-0.3383	0.0098	0.3579
RB-X-G-E-inf-mw-96	-0.0748	0.2733	0.6214

Bread Formulation = CB-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-48	0.3029	0.651	0.9991
CB-inf-mw-72	0.6549	1.003	1.3511
CB-inf-mw-96	0.7579	1.106	1.4541
CB-X-G-E-conv-24	-0.6951	-0.347	0.0011
CB-X-G-E-conv-48	-0.4331	-0.085	0.2631
CB-X-G-E-conv-72	-0.1496	0.1985	0.5466
CB-X-G-E-conv-96	-0.0506	0.2975	0.6456
CB-X-G-E-inf-mw-24	-0.5481	-0.2	0.1481
CB-X-G-E-inf-mw-48	-0.1086	0.2395	0.5876
CB-X-G-E-inf-mw-72	0.0339	0.382	0.7301
CB-X-G-E-inf-mw-96	0.1509	0.499	0.8471
RB-conv-24	0.3509	0.699	1.0471
RB-conv-48	0.9084	1.2565	1.6046
RB-conv-72	1.1894	1.5375	1.8856

RB-cov-96	1.3284	1.6765	2.0246
RB-inf-mw-24	0.5514	0.8995	1.2476
RB-inf-mw-48	1.1854	1.5335	1.8816
RB-inf-mw-72	1.3324	1.6805	2.0286
RB-inf-mw-96	1.5004	1.8485	2.1966
RB-X-G-E-conv-24	-0.5506	-0.2025	0.1456
RB-X-G-E-conv-48	-0.1586	0.1895	0.5376
RB-X-G-E-conv-72	0.0634	0.4115	0.7596
RB-X-G-E-conv-96	0.3644	0.7125	1.0606
RB-X-G-E-inf-mw-24	-0.2541	0.094	0.4421
RB-X-G-E-inf-mw-48	0.2624	0.6105	0.9586
RB-X-G-E-inf-mw-72	0.4284	0.7765	1.1246
RB-X-G-E-inf-mw-96	0.6919	1.04	1.3881

Bread Formulation = CB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-72	0.0039	0.352	0.7001
CB-inf-mw-96	0.1069	0.455	0.8031
CB-X-G-E-conv-24	-1.3461	-0.998	-0.6499
CB-X-G-E-conv-48	-1.0841	-0.736	-0.3879
CB-X-G-E-conv-72	-0.8006	-0.4525	-0.1044
CB-X-G-E-conv-96	-0.7016	-0.3535	-0.0054
CB-X-G-E-inf-mw-24	-1.1991	-0.851	-0.5029
CB-X-G-E-inf-mw-48	-0.7596	-0.4115	-0.0634
CB-X-G-E-inf-mw-72	-0.6171	-0.269	0.0791

CB-X-G-E-inf-mw-96	-0.5001	-0.152	0.1961
RB-conv-24	-0.3001	0.048	0.3961
RB-conv-48	0.2574	0.6055	0.9536
RB-conv-72	0.5384	0.8865	1.2346
RB-cov-96	0.6774	1.0255	1.3736
RB-inf-mw-24	-0.0996	0.2485	0.5966
RB-inf-mw-48	0.5344	0.8825	1.2306
RB-inf-mw-72	0.6814	1.0295	1.3776
RB-inf-mw-96	0.8494	1.1975	1.5456
RB-X-G-E-conv-24	-1.2016	-0.8535	-0.5054
RB-X-G-E-conv-48	-0.8096	-0.4615	-0.1134
RB-X-G-E-conv-72	-0.5876	-0.2395	0.1086
RB-X-G-E-conv-96	-0.2866	0.0615	0.4096
RB-X-G-E-inf-mw-24	-0.9051	-0.557	-0.2089
RB-X-G-E-inf-mw-48	-0.3886	-0.0405	0.3076
RB-X-G-E-inf-mw-72	-0.2226	0.1255	0.4736
RB-X-G-E-inf-mw-96	0.0409	0.389	0.7371

Bread Formulation = CB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-96	-0.2451	0.103	0.4511
CB-X-G-E-conv-24	-1.6981	-1.35	-1.0019
CB-X-G-E-conv-48	-1.4361	-1.088	-0.7399
CB-X-G-E-conv-72	-1.1526	-0.8045	-0.4564
CB-X-G-E-conv-96	-1.0536	-0.7055	-0.3574

CB-X-G-E-inf-mw-24	-1.5511	-1.203	-0.8549
CB-X-G-E-inf-mw-48	-1.1116	-0.7635	-0.4154
CB-X-G-E-inf-mw-72	-0.9691	-0.621	-0.2729
CB-X-G-E-inf-mw-96	-0.8521	-0.504	-0.1559
RB-conv-24	-0.6521	-0.304	0.0441
RB-conv-48	-0.0946	0.2535	0.6016
RB-conv-72	0.1864	0.5345	0.8826
RB-cov-96	0.3254	0.6735	1.0216
RB-inf-mw-24	-0.4516	-0.1035	0.2446
RB-inf-mw-48	0.1824	0.5305	0.8786
RB-inf-mw-72	0.3294	0.6775	1.0256
RB-inf-mw-96	0.4974	0.8455	1.1936
RB-X-G-E-conv-24	-1.5536	-1.2055	-0.8574
RB-X-G-E-conv-48	-1.1616	-0.8135	-0.4654
RB-X-G-E-conv-72	-0.9396	-0.5915	-0.2434
RB-X-G-E-conv-96	-0.6386	-0.2905	0.0576
RB-X-G-E-inf-mw-24	-1.2571	-0.909	-0.5609
RB-X-G-E-inf-mw-48	-0.7406	-0.3925	-0.0444
RB-X-G-E-inf-mw-72	-0.5746	-0.2265	0.1216
RB-X-G-E-inf-mw-96	-0.3111	0.037	0.3851

Bread Formulation = CB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-24	-1.8011	-1.453	-1.1049
CB-X-G-E-conv-48	-1.5391	-1.191	-0.8429

CB-X-G-E-conv-72	-1.2556	-0.9075	-0.5594
CB-X-G-E-conv-96	-1.1566	-0.8085	-0.4604
CB-X-G-E-inf-mw-24	-1.6541	-1.306	-0.9579
CB-X-G-E-inf-mw-48	-1.2146	-0.8665	-0.5184
CB-X-G-E-inf-mw-72	-1.0721	-0.724	-0.3759
CB-X-G-E-inf-mw-96	-0.9551	-0.607	-0.2589
RB-conv-24	-0.7551	-0.407	-0.0589
RB-conv-48	-0.1976	0.1505	0.4986
RB-conv-72	0.0834	0.4315	0.7796
RB-cov-96	0.2224	0.5705	0.9186
RB-inf-mw-24	-0.5546	-0.2065	0.1416
RB-inf-mw-48	0.0794	0.4275	0.7756
RB-inf-mw-72	0.2264	0.5745	0.9226
RB-inf-mw-96	0.3944	0.7425	1.0906
RB-X-G-E-conv-24	-1.6566	-1.3085	-0.9604
RB-X-G-E-conv-48	-1.2646	-0.9165	-0.5684
RB-X-G-E-conv-72	-1.0426	-0.6945	-0.3464
RB-X-G-E-conv-96	-0.7416	-0.3935	-0.0454
RB-X-G-E-inf-mw-24	-1.3601	-1.012	-0.6639
RB-X-G-E-inf-mw-48	-0.8436	-0.4955	-0.1474
RB-X-G-E-inf-mw-72	-0.6776	-0.3295	0.0186
RB-X-G-E-inf-mw-96	-0.4141	-0.066	0.2821

Bread Formulation = CB-X-G-E-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-48	-0.0861	0.262	0.6101
CB-X-G-E-conv-72	0.1974	0.5455	0.8936
CB-X-G-E-conv-96	0.2964	0.6445	0.9926
CB-X-G-E-inf-mw-24	-0.2011	0.147	0.4951
CB-X-G-E-inf-mw-48	0.2384	0.5865	0.9346
CB-X-G-E-inf-mw-72	0.3809	0.729	1.0771
CB-X-G-E-inf-mw-96	0.4979	0.846	1.1941
RB-conv-24	0.6979	1.046	1.3941
RB-conv-48	1.2554	1.6035	1.9516
RB-conv-72	1.5364	1.8845	2.2326
RB-cov-96	1.6754	2.0235	2.3716
RB-inf-mw-24	0.8984	1.2465	1.5946
RB-inf-mw-48	1.5324	1.8805	2.2286
RB-inf-mw-72	1.6794	2.0275	2.3756
RB-inf-mw-96	1.8474	2.1955	2.5436
RB-X-G-E-conv-24	-0.2036	0.1445	0.4926
RB-X-G-E-conv-48	0.1884	0.5365	0.8846
RB-X-G-E-conv-72	0.4104	0.7585	1.1066
RB-X-G-E-conv-96	0.7114	1.0595	1.4076
RB-X-G-E-inf-mw-24	0.0929	0.441	0.7891
RB-X-G-E-inf-mw-48	0.6094	0.9575	1.3056
RB-X-G-E-inf-mw-72	0.7754	1.1235	1.4716
RB-X-G-E-inf-mw-96	1.0389	1.387	1.7351

Bread Formulation = CB-X-G-E-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-72	-0.0646	0.2835	0.6316
CB-X-G-E-conv-96	0.0344	0.3825	0.7306
CB-X-G-E-inf-mw-24	-0.4631	-0.115	0.2331
CB-X-G-E-inf-mw-48	-0.0236	0.3245	0.6726
CB-X-G-E-inf-mw-72	0.1189	0.467	0.8151
CB-X-G-E-inf-mw-96	0.2359	0.584	0.9321
RB-conv-24	0.4359	0.784	1.1321
RB-conv-48	0.9934	1.3415	1.6896
RB-conv-72	1.2744	1.6225	1.9706
RB-cov-96	1.4134	1.7615	2.1096
RB-inf-mw-24	0.6364	0.9845	1.3326
RB-inf-mw-48	1.2704	1.6185	1.9666
RB-inf-mw-72	1.4174	1.7655	2.1136
RB-inf-mw-96	1.5854	1.9335	2.2816
RB-X-G-E-conv-24	-0.4656	-0.1175	0.2306
RB-X-G-E-conv-48	-0.0736	0.2745	0.6226
RB-X-G-E-conv-72	0.1484	0.4965	0.8446
RB-X-G-E-conv-96	0.4494	0.7975	1.1456
RB-X-G-E-inf-mw-24	-0.1691	0.179	0.5271
RB-X-G-E-inf-mw-48	0.3474	0.6955	1.0436
RB-X-G-E-inf-mw-72	0.5134	0.8615	1.2096
RB-X-G-E-inf-mw-96	0.7769	1.125	1.4731

Bread Formulation = CB-X-G-E-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-96	-0.2491	0.099	0.4471
CB-X-G-E-inf-mw-24	-0.7466	-0.3985	-0.0504
CB-X-G-E-inf-mw-48	-0.3071	0.041	0.3891
CB-X-G-E-inf-mw-72	-0.1646	0.1835	0.5316
CB-X-G-E-inf-mw-96	-0.0476	0.3005	0.6486
RB-conv-24	0.1524	0.5005	0.8486
RB-conv-48	0.7099	1.058	1.4061
RB-conv-72	0.9909	1.339	1.6871
RB-cov-96	1.1299	1.478	1.8261
RB-inf-mw-24	0.3529	0.701	1.0491
RB-inf-mw-48	0.9869	1.335	1.6831
RB-inf-mw-72	1.1339	1.482	1.8301
RB-inf-mw-96	1.3019	1.65	1.9981
RB-X-G-E-conv-24	-0.7491	-0.401	-0.0529
RB-X-G-E-conv-48	-0.3571	-0.009	0.3391
RB-X-G-E-conv-72	-0.1351	0.213	0.5611
RB-X-G-E-conv-96	0.1659	0.514	0.8621
RB-X-G-E-inf-mw-24	-0.4526	-0.1045	0.2436
RB-X-G-E-inf-mw-48	0.0639	0.412	0.7601
RB-X-G-E-inf-mw-72	0.2299	0.578	0.9261
RB-X-G-E-inf-mw-96	0.4934	0.8415	1.1896

Bread Formulation = CB-X-G-E-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-24	-0.8456	-0.4975	-0.1494
CB-X-G-E-inf-mw-48	-0.4061	-0.058	0.2901
CB-X-G-E-inf-mw-72	-0.2636	0.0845	0.4326
CB-X-G-E-inf-mw-96	-0.1466	0.2015	0.5496
RB-conv-24	0.0534	0.4015	0.7496
RB-conv-48	0.6109	0.959	1.3071
RB-conv-72	0.8919	1.24	1.5881
RB-cov-96	1.0309	1.379	1.7271
RB-inf-mw-24	0.2539	0.602	0.9501
RB-inf-mw-48	0.8879	1.236	1.5841
RB-inf-mw-72	1.0349	1.383	1.7311
RB-inf-mw-96	1.2029	1.551	1.8991
RB-X-G-E-conv-24	-0.8481	-0.5	-0.1519
RB-X-G-E-conv-48	-0.4561	-0.108	0.2401
RB-X-G-E-conv-72	-0.2341	0.114	0.4621
RB-X-G-E-conv-96	0.0669	0.415	0.7631
RB-X-G-E-inf-mw-24	-0.5516	-0.2035	0.1446
RB-X-G-E-inf-mw-48	-0.0351	0.313	0.6611
RB-X-G-E-inf-mw-72	0.1309	0.479	0.8271
RB-X-G-E-inf-mw-96	0.3944	0.7425	1.0906

Bread Formulation = CB-X-G-E-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-48	0.0914	0.4395	0.7876
CB-X-G-E-inf-mw-72	0.2339	0.582	0.9301
CB-X-G-E-inf-mw-96	0.3509	0.699	1.0471
RB-conv-24	0.5509	0.899	1.2471
RB-conv-48	1.1084	1.4565	1.8046
RB-conv-72	1.3894	1.7375	2.0856
RB-cov-96	1.5284	1.8765	2.2246
RB-inf-mw-24	0.7514	1.0995	1.4476
RB-inf-mw-48	1.3854	1.7335	2.0816
RB-inf-mw-72	1.5324	1.8805	2.2286
RB-inf-mw-96	1.7004	2.0485	2.3966
RB-X-G-E-conv-24	-0.3506	-0.0025	0.3456
RB-X-G-E-conv-48	0.0414	0.3895	0.7376
RB-X-G-E-conv-72	0.2634	0.6115	0.9596
RB-X-G-E-conv-96	0.5644	0.9125	1.2606
RB-X-G-E-inf-mw-24	-0.0541	0.294	0.6421
RB-X-G-E-inf-mw-48	0.4624	0.8105	1.1586
RB-X-G-E-inf-mw-72	0.6284	0.9765	1.3246
RB-X-G-E-inf-mw-96	0.8919	1.24	1.5881

Bread Formulation = CB-X-G-E-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-72	-0.2056	0.1425	0.4906

CB-X-G-E-inf-mw-96	-0.0886	0.2595	0.6076
RB-conv-24	0.1114	0.4595	0.8076
RB-conv-48	0.6689	1.017	1.3651
RB-conv-72	0.9499	1.298	1.6461
RB-cov-96	1.0889	1.437	1.7851
RB-inf-mw-24	0.3119	0.66	1.0081
RB-inf-mw-48	0.9459	1.294	1.6421
RB-inf-mw-72	1.0929	1.441	1.7891
RB-inf-mw-96	1.2609	1.609	1.9571
RB-X-G-E-conv-24	-0.7901	-0.442	-0.0939
RB-X-G-E-conv-48	-0.3981	-0.05	0.2981
RB-X-G-E-conv-72	-0.1761	0.172	0.5201
RB-X-G-E-conv-96	0.1249	0.473	0.8211
RB-X-G-E-inf-mw-24	-0.4936	-0.1455	0.2026
RB-X-G-E-inf-mw-48	0.0229	0.371	0.7191
RB-X-G-E-inf-mw-72	0.1889	0.537	0.8851
RB-X-G-E-inf-mw-96	0.4524	0.8005	1.1486

Bread Formulation = CB-X-G-E-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-96	-0.2311	0.117	0.4651
RB-conv-24	-0.0311	0.317	0.6651
RB-conv-48	0.5264	0.8745	1.2226
RB-conv-72	0.8074	1.1555	1.5036
RB-cov-96	0.9464	1.2945	1.6426

RB-inf-mw-24	0.1694	0.5175	0.8656
RB-inf-mw-48	0.8034	1.1515	1.4996
RB-inf-mw-72	0.9504	1.2985	1.6466
RB-inf-mw-96	1.1184	1.4665	1.8146
RB-X-G-E-conv-24	-0.9326	-0.5845	-0.2364
RB-X-G-E-conv-48	-0.5406	-0.1925	0.1556
RB-X-G-E-conv-72	-0.3186	0.0295	0.3776
RB-X-G-E-conv-96	-0.0176	0.3305	0.6786
RB-X-G-E-inf-mw-24	-0.6361	-0.288	0.0601
RB-X-G-E-inf-mw-48	-0.1196	0.2285	0.5766
RB-X-G-E-inf-mw-72	0.0464	0.3945	0.7426
RB-X-G-E-inf-mw-96	0.3099	0.658	1.0061

Bread Formulation = CB-X-G-E-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-24	-0.1481	0.2000	0.5481
RB-conv-48	0.4094	0.7575	1.1056
RB-conv-72	0.6904	1.0385	1.3866
RB-cov-96	0.8294	1.1775	1.5256
RB-inf-mw-24	0.0524	0.4005	0.7486
RB-inf-mw-48	0.6864	1.0345	1.3826
RB-inf-mw-72	0.8334	1.1815	1.5296
RB-inf-mw-96	1.0014	1.3495	1.6976
RB-X-G-E-conv-24	-1.0496	-0.7015	-0.3534
RB-X-G-E-conv-48	-0.6576	-0.3095	0.0386

RB-X-G-E-conv-72	-0.4356	-0.0875	0.2606
RB-X-G-E-conv-96	-0.1346	0.2135	0.5616
RB-X-G-E-inf-mw-24	-0.7531	-0.4050	-0.0569
RB-X-G-E-inf-mw-48	-0.2366	0.1115	0.4596
RB-X-G-E-inf-mw-72	-0.0706	0.2775	0.6256
RB-X-G-E-inf-mw-96	0.1929	0.5410	0.8891

Bread Formulation = RB-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-48	0.2094	0.5575	0.9056
RB-conv-72	0.4904	0.8385	1.1866
RB-cov-96	0.6294	0.9775	1.3256
RB-inf-mw-24	-0.1476	0.2005	0.5486
RB-inf-mw-48	0.4864	0.8345	1.1826
RB-inf-mw-72	0.6334	0.9815	1.3296
RB-inf-mw-96	0.8014	1.1495	1.4976
RB-X-G-E-conv-24	-1.2496	-0.9015	-0.5534
RB-X-G-E-conv-48	-0.8576	-0.5095	-0.1614
RB-X-G-E-conv-72	-0.6356	-0.2875	0.0606
RB-X-G-E-conv-96	-0.3346	0.0135	0.3616
RB-X-G-E-inf-mw-24	-0.9531	-0.6050	-0.2569
RB-X-G-E-inf-mw-48	-0.4366	-0.0885	0.2596
RB-X-G-E-inf-mw-72	-0.2706	0.0775	0.4256
RB-X-G-E-inf-mw-96	-0.0071	0.3410	0.6891

Bread Formulation = RB-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-72	-0.0671	0.2810	0.6291
RB-cov-96	0.0719	0.4200	0.7681
RB-inf-mw-24	-0.7051	-0.3570	-0.0089
RB-inf-mw-48	-0.0711	0.2770	0.6251
RB-inf-mw-72	0.0759	0.4240	0.7721
RB-inf-mw-96	0.2439	0.5920	0.9401
RB-X-G-E-conv-24	-1.8071	-1.4590	-1.1109
RB-X-G-E-conv-48	-1.4151	-1.0670	-0.7189
RB-X-G-E-conv-72	-1.1931	-0.8450	-0.4969
RB-X-G-E-conv-96	-0.8921	-0.5440	-0.1959
RB-X-G-E-inf-mw-24	-1.5106	-1.1625	-0.8144
RB-X-G-E-inf-mw-48	-0.9941	-0.6460	-0.2979
RB-X-G-E-inf-mw-72	-0.8281	-0.4800	-0.1319
RB-X-G-E-inf-mw-96	-0.5646	-0.2165	0.1316

Bread Formulation = RB-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-cov-96	-0.2091	0.1390	0.4871
RB-inf-mw-24	-0.9861	-0.6380	-0.2899
RB-inf-mw-48	-0.3521	-0.0040	0.3441
RB-inf-mw-72	-0.2051	0.1430	0.4911
RB-inf-mw-96	-0.0371	0.3110	0.6591
RB-X-G-E-conv-24	-2.0881	-1.7400	-1.3919

RB-X-G-E-conv-48	-1.6961	-1.3480	-0.9999
RB-X-G-E-conv-72	-1.4741	-1.1260	-0.7779
RB-X-G-E-conv-96	-1.1731	-0.8250	-0.4769
RB-X-G-E-inf-mw-24	-1.7916	-1.4435	-1.0954
RB-X-G-E-inf-mw-48	-1.2751	-0.9270	-0.5789
RB-X-G-E-inf-mw-72	-1.1091	-0.7610	-0.4129
RB-X-G-E-inf-mw-96	-0.8456	-0.4975	-0.1494

Bread Formulation = RB-cov-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-24	-1.1251	-0.7770	-0.4289
RB-inf-mw-48	-0.4911	-0.1430	0.2051
RB-inf-mw-72	-0.3441	0.0040	0.3521
RB-inf-mw-96	-0.1761	0.1720	0.5201
RB-X-G-E-conv-24	-2.2271	-1.8790	-1.5309
RB-X-G-E-conv-48	-1.8351	-1.4870	-1.1389
RB-X-G-E-conv-72	-1.6131	-1.2650	-0.9169
RB-X-G-E-conv-96	-1.3121	-0.9640	-0.6159
RB-X-G-E-inf-mw-24	-1.9306	-1.5825	-1.2344
RB-X-G-E-inf-mw-48	-1.4141	-1.0660	-0.7179
RB-X-G-E-inf-mw-72	-1.2481	-0.9000	-0.5519
RB-X-G-E-inf-mw-96	-0.9846	-0.6365	-0.2884

Bread Formulation = RB-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-48	0.2859	0.6340	0.9821
RB-inf-mw-72	0.4329	0.7810	1.1291
RB-inf-mw-96	0.6009	0.9490	1.2971
RB-X-G-E-conv-24	-1.4501	-1.1020	-0.7539
RB-X-G-E-conv-48	-1.0581	-0.7100	-0.3619
RB-X-G-E-conv-72	-0.8361	-0.4880	-0.1399
RB-X-G-E-conv-96	-0.5351	-0.1870	0.1611
RB-X-G-E-inf-mw-24	-1.1536	-0.8055	-0.4574
RB-X-G-E-inf-mw-48	-0.6371	-0.2890	0.0591
RB-X-G-E-inf-mw-72	-0.4711	-0.1230	0.2251
RB-X-G-E-inf-mw-96	-0.2076	0.1405	0.4886

Bread Formulation = RB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-72	-0.2011	0.1470	0.4951
RB-inf-mw-96	-0.0331	0.3150	0.6631
RB-X-G-E-conv-24	-2.0841	-1.7360	-1.3879
RB-X-G-E-conv-48	-1.6921	-1.3440	-0.9959
RB-X-G-E-conv-72	-1.4701	-1.1220	-0.7739
RB-X-G-E-conv-96	-1.1691	-0.8210	-0.4729
RB-X-G-E-inf-mw-24	-1.7876	-1.4395	-1.0914
RB-X-G-E-inf-mw-48	-1.2711	-0.9230	-0.5749
RB-X-G-E-inf-mw-72	-1.1051	-0.7570	-0.4089

RB-X-G-E-inf-mw-96	-0.8416	-0.4935	-0.1454

Bread Formulation = RB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-96	-0.1801	0.1680	0.5161
RB-X-G-E-conv-24	-2.2311	-1.8830	-1.5349
RB-X-G-E-conv-48	-1.8391	-1.4910	-1.1429
RB-X-G-E-conv-72	-1.6171	-1.2690	-0.9209
RB-X-G-E-conv-96	-1.3161	-0.9680	-0.6199
RB-X-G-E-inf-mw-24	-1.9346	-1.5865	-1.2384
RB-X-G-E-inf-mw-48	-1.4181	-1.0700	-0.7219
RB-X-G-E-inf-mw-72	-1.2521	-0.9040	-0.5559
RB-X-G-E-inf-mw-96	-0.9886	-0.6405	-0.2924

Bread Formulation = RB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-24	-2.3991	-2.0510	-1.7029
RB-X-G-E-conv-48	-2.0071	-1.6590	-1.3109
RB-X-G-E-conv-72	-1.7851	-1.4370	-1.0889
RB-X-G-E-conv-96	-1.4841	-1.1360	-0.7879
RB-X-G-E-inf-mw-24	-2.1026	-1.7545	-1.4064
RB-X-G-E-inf-mw-48	-1.5861	-1.2380	-0.8899
RB-X-G-E-inf-mw-72	-1.4201	-1.0720	-0.7239
RB-X-G-E-inf-mw-96	-1.1566	-0.8085	-0.4604

Bread Formulation = RB-X-G-E-conv-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-48	0.0439	0.3920	0.7401
RB-X-G-E-conv-72	0.2659	0.6140	0.9621
RB-X-G-E-conv-96	0.5669	0.9150	12.631
RB-X-G-E-inf-mw-24	-0.0516	0.2965	0.6446
RB-X-G-E-inf-mw-48	0.4649	0.8130	1.1611
RB-X-G-E-inf-mw-72	0.6309	0.9790	1.3271
RB-X-G-E-inf-mw-96	0.8944	1.2425	1.5906

Bread Formulation = RB-X-G-E-conv-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-72	-0.1261	0.2220	0.5701
RB-X-G-E-conv-96	0.1749	0.5230	0.8711
RB-X-G-E-inf-mw-24	-0.4436	-0.0955	0.2526
RB-X-G-E-inf-mw-48	0.0729	0.4210	0.7691
RB-X-G-E-inf-mw-72	0.2389	0.5870	0.9351
RB-X-G-E-inf-mw-96	0.5024	0.8505	1.1986

Bread Formulation = RB-X-G-E-conv-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-96	-0.0471	0.3010	0.6491
RB-X-G-E-inf-mw-24	-0.6656	-0.3175	0.0306
RB-X-G-E-inf-mw-48	-0.1491	0.1990	0.5471
RB-X-G-E-inf-mw-72	0.0169	0.3650	0.7131

RB-X-G-E-inf-mw-96	0.2804	0.6285	0.9766

Bread Formulation = RB-X-G-E-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-24	-0.9666	-0.6185	-0.2704
RB-X-G-E-inf-mw-48	-0.4501	-0.1020	0.2461
RB-X-G-E-inf-mw-72	-0.2841	0.0640	0.4121
RB-X-G-E-inf-mw-96	-0.0206	0.3275	0.6756

Bread Formulation = RB-X-G-E-inf-mw-24 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-48	0.1684	0.5165	0.8646
RB-X-G-E-inf-mw-72	0.3344	0.6825	1.0306
RB-X-G-E-inf-mw-96	0.5979	0.9460	1.2941

Bread Formulation = RB-X-G-E-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-72	-0.1821	0.1660	0.5141
RB-X-G-E-inf-mw-96	0.0814	0.4295	0.7776

Bread Formulation = RB-X-G-E-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-96	-0.0846	0.2635	0.6116

Table A. 37. General linear model for TMC grades values of different gluten-free bread formulaions baked in different ovens and stored at different times

Factor	Type	Levels	Values
Bread Formulation	fixed	4	CB, CB-X-G-E, RB, RB-X-G-E
Storage Time	fixed	5	1, 24, 48, 7, 96
Oven type	fixed	2	Convtional, infrared-microwave combination oven

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Bread Formulation	3	1.0412	1.0412	0.3471	2.86	0.003
Storage Time	4	0.4596	0.4596	0.1149	0.95	0.004
Oven type	1	0.2523	0.2523	0.2523	2.08	0.154
Error	71	8.6248	8.6248	0.1215		
Total	79	10.3778				

Formulation	N	Mean	Grouping
CB-X-G-E	20	0.2	A
CB	20	0.2	BC
RB-X-G-E	20	0.2	BC
RB	20	0.5	D

Storage Time	N	Mean	Grouping
96	16	0.4	CD
24	16	0.2	B

72	16	0.2	C
48	16	0.3	BC
1	16	0.2	A

Oven type	N	Mean	Grouping
ınf-mw	40	0.3	A
Conv	40	0.2	A

Table A. 38. One-way ANOVA for TMC values of different gluten-free bread formulaions baked in different ovens and stored at different times

Source	DF	SS	MS	F	P
Bread Formulation	39	5.255	0.135	1.05	0.037
Error	40	5.123	0.128		
Total	79	10.378			

Level	N	Mean	StDev
CB-conv-1	2	0.2105	0.0035
CB-conv-24	2	0.2135	0.0049
CB-conv-48	2	0.2355	0.0049
CB-conv-72	2	0.2505	0.0064
CB-conv-96	2	0.2550	0.0057
CB-inf-mw-1	2	0.2030	0.0042
CB-inf-mw-24	2	0.2090	0.0057
CB-inf-mw-48	2	0.2325	0.0035

CB-inf-mw-72	2	0.2465	0.0035
CB-inf-mw-96	2	0.2540	0.0028
CB-X-G-E-conv-1	2	0.1935	0.0049
CB-X-G-E-conv-24	2	0.1965	0.0035
CB-X-G-E-conv-48	2	0.2075	0.0049
CB-X-G-E-conv-72	2	0.2300	0.0014
CB-X-G-E-conv-96	2	0.2365	0.0021
CB-X-G-E-inf-mw-1	2	0.1885	0.0021
CB-X-G-E-inf-mw-24	2	0.1920	0.0085
CB-X-G-E-inf-mw-48	2	0.2115	0.0035
CB-X-G-E-inf-mw-72	2	0.2280	0.0042
CB-X-G-E-inf-mw-96	2	0.2335	0.0078
RB-conv-1	2	0.2415	0.0021
RB-conv-24	2	0.2525	0.0021
RB-conv-48	2	0.2560	0.0028
RB-conv-72	2	0.2670	0.0028
RB-cov-96	2	0.2785	0.0035
RB-inf-mw-1	2	0.2495	0.0049
RB-inf-mw-24	2	1.2560	1.4142
RB-inf-mw-48	2	0.2605	0.0007
RB-inf-mw-72	2	0.2675	0.0021
RB-inf-mw-96	2	1.5305	1.7671
RB-X-G-E-conv-1	2	0.2025	0.0035
RB-X-G-E-conv-24	2	0.2075	0.0035
RB-X-G-E-conv-48	2	0.2240	0.0085

RB-X-G-E-conv-72	2	0.2440	0.0042
RB-X-G-E-conv-96	2	0.2490	0.0057
RB-X-G-E-inf-mw-1	2	0.2035	0.0064
RB-X-G-E-inf-mw-24	2	0.2145	0.0064
RB-X-G-E-inf-mw-48	2	0.2280	0.0028
RB-X-G-E-inf-mw-72	2	0.2410	0.0042
RB-X-G-E-inf-mw-96	2	0.2485	0.0035

Bread Formulation	N	Mean	Grouping
RB-inf-mw-96	2	1.5305	A
RB-inf-mw-24	2	1.2560	A
RB-cov-96	2	0.2785	A
RB-inf-mw-72	2	0.2675	AB
RB-conv-72	2	0.2670	AB
RB-inf-mw-48	2	0.2605	BC
RB-conv-48	2	0.2560	BC
CB-conv-96	2	0.2550	CD
CB-inf-mw-96	2	0.2540	CD
RB-conv-24	2	0.2525	CDE
CB-conv-72	2	0.2505	CDE
RB-inf-mw-1	2	0.2495	DEF
RB-X-G-E-conv-96	2	0.2490	DEFG
RB-X-G-E-inf-mw-96	2	0.2485	DEFG
CB-inf-mw-72	2	0.2465	E F G H

RB-X-G-E-conv-72	2	0.2440	E F G H
RB-conv-1	2	0.2415	F G H I
RB-X-G-E-inf-mw-72	2	0.2410	F G H I
CB-X-G-E-conv-96	2	0.2365	F G H I J
CB-conv-48	2	0.2355	F G H I J
CB-X-G-E-inf-mw-96	2	0.2335	G H I J K
CB-inf-mw-48	2	0.2325	G H I J K
CB-X-G-E-conv-72	2	0.2300	H I J K L
RB-X-G-E-inf-mw-48	2	0.2280	H I J K L
CB-X-G-E-inf-mw-72	2	0.2280	H I J K L
RB-X-G-E-conv-48	2	0.2240	H I J K L
RB-X-G-E-inf-mw-24	2	0.2145	I J K L M
CB-conv-24	2	0.2135	I J K L M
CB-X-G-E-inf-mw-48	2	0.2115	K L M N
CB-conv-1	2	0.2105	L M N O
CB-inf-mw-24	2	0.2090	M N O P
RB-X-G-E-conv-24	2	0.2075	M N O P
CB-X-G-E-conv-48	2	0.2075	M N O P
RB-X-G-E-inf-mw-1	2	0.2035	N O P
CB-inf-mw-1	2	0.2030	N O P
RB-X-G-E-conv-1	2	0.2025	N O P
CB-X-G-E-conv-24	2	0.1965	O P
CB-X-G-E-conv-1	2	0.1935	P
CB-X-G-E-inf-mw-24	2	0.1920	P
CB-X-G-E-inf-mw-1	2	0.1885	P

Bread Formulation = RB-inf-mw-96 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-24	-1.5002	0.0030	1.5062
RB-cov-96	-1.4782	0.0250	1.5282
RB-inf-mw-72	-1.4632	0.0400	1.5432
RB-conv-72	-1.4587	0.0445	1.5477
RB-inf-mw-48	-1.5107	-0.0075	-1.4957
RB-conv-48	-1.5047	-0.0015	-1.5017
CB-conv-96	-1.4812	-0.0220	-1.5252
CB-inf-mw-96	-1.4672	-0.0360	-1.5392
RB-conv-24	-1.4597	-0.0435	-1.5467
CB-conv-72	-1.5202	-0.0170	-1.4862
RB-inf-mw-1	-1.5172	-0.0140	-1.4892
RB-X-G-E-conv-96	-1.5062	-0.0030	-1.5002
RB-X-G-E-inf-mw-96	-1.4837	-0.0195	-1.5227
CB-inf-mw-72	-1.4772	-0.0260	-1.5292
RB-X-G-E-conv-72	-1.5252	-0.0220	-1.4812
RB-conv-1	-1.5217	-0.0185	-1.4847
RB-X-G-E-inf-mw-72	-1.5022	-0.0010	-1.5042
CB-X-G-E-conv-96	-1.4857	-0.0175	-1.5207
CB-conv-48	-1.4802	-0.0230	-1.5262
CB-X-G-E-inf-mw-96	-1.4722	-0.0310	-1.5342
CB-inf-mw-48	-1.4612	-0.0420	-1.5452
CB-X-G-E-conv-72	-1.4577	-0.0455	-1.5487
RB-X-G-E-inf-mw-48	-1.4467	-0.0565	-1.5597

CB-X-G-E-inf-mw-72	-1.4352	-0.0680	-1.5712
RB-X-G-E-conv-48	-1.4642	-0.0390	-1.5422
RB-X-G-E-inf-mw-24	-0.4577	-1.0455	-2.5487
CB-conv-24	-1.4532	-0.0500	-1.5532
CB-X-G-E-inf-mw-48	-1.4462	-0.0570	-1.5602
CB-conv-1	-0.1832	-1.3200	-2.8232
CB-inf-mw-24	-1.5112	-0.0080	-1.4952
RB-X-G-E-conv-24	-1.5062	-0.0030	-1.5002
CB-X-G-E-conv-48	-1.4897	-0.0135	-1.5167
RB-X-G-E-inf-mw-1	-1.4697	-0.0335	-1.5367
CB-inf-mw-1	-1.4647	-0.0385	-1.5417
RB-X-G-E-conv-1	-1.5102	-0.0070	-1.4962
CB-X-G-E-conv-24	-1.4992	-0.0040	-1.5072
CB-X-G-E-conv-1	-1.4857	-0.0175	-1.5207
CB-X-G-E-inf-mw-24	-1.4727	-0.0305	-1.5337
CB-X-G-E-inf-mw-1	-1.4652	-0.0380	-1.5412

Bread Formulation = RB-inf-mw-24subtracted from:

Bread Formulation	Lower	Center	Upper
RB-cov-96	-1.4812	0.0220	1.5252
RB-inf-mw-72	-1.4662	0.0370	1.5402
RB-conv-72	-1.4617	0.0415	1.5447
RB-inf-mw-48	-1.5137	-0.0105	1.4927
RB-conv-48	-1.5077	-0.0045	-1.4987
CB-conv-96	-1.4842	-0.0190	-1.5222

CB-inf-mw-96	-1.4702	-0.0330	-1.5362
RB-conv-24	-1.4627	-0.0405	-1.5437
CB-conv-72	-1.5232	-0.0200	-1.4832
RB-inf-mw-1	-1.5202	-0.0170	-1.4862
RB-X-G-E-conv-96	-1.5092	-0.0060	-1.4972
RB-X-G-E-inf-mw-96	-1.4867	-0.0165	-1.5197
CB-inf-mw-72	-1.4802	-0.0230	-1.5262
RB-X-G-E-conv-72	-1.5282	-0.0250	-1.4782
RB-conv-1	-1.5247	-0.0215	-1.4817
RB-X-G-E-inf-mw-72	-1.5052	-0.0020	-1.5012
CB-X-G-E-conv-96	-1.4887	-0.0145	-1.5177
CB-conv-48	-1.4832	-0.0200	-1.5232
CB-X-G-E-inf-mw-96	-1.4752	-0.0280	-1.5312
CB-inf-mw-48	-1.4642	-0.0390	-1.5422
CB-X-G-E-conv-72	-1.4607	-0.0425	-1.5457
RB-X-G-E-inf-mw-48	-1.4497	-0.0535	-1.5567
CB-X-G-E-inf-mw-72	-1.4382	-0.0650	-1.5682
RB-X-G-E-conv-48	-1.4672	-0.0360	-1.5392
RB-X-G-E-inf-mw-24	-0.4607	-1.0425	-2.5457
CB-conv-24	-1.4562	-0.0470	-1.5502
CB-X-G-E-inf-mw-48	-1.4492	-0.0540	-1.5572
CB-conv-1	-0.1862	-1.3170	-2.8202
CB-inf-mw-24	-1.5142	-0.0110	-1.4922
RB-X-G-E-conv-24	-1.5092	-0.0060	-1.4972
CB-X-G-E-conv-48	-1.4927	-0.0105	-1.5137

RB-X-G-E-inf-mw-1	-1.4727	-0.0305	-1.5337
CB-inf-mw-1	-1.4677	-0.0355	-1.5387
RB-X-G-E-conv-1	-1.5132	-0.0100	-1.4932
CB-X-G-E-conv-24	-1.5022	-0.0010	-1.5042
CB-X-G-E-conv-1	-1.4887	-0.0145	-1.5177
CB-X-G-E-inf-mw-24	-1.4757	-0.0275	-1.5307
CB-X-G-E-inf-mw-1	-1.4682	-0.0350	-1.5382

Bread Formulation = RB-cov-96subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-72	-1.4882	0.0150	1.5182
RB-conv-72	-1.4837	0.0195	1.5227
RB-inf-mw-48	-1.5357	-0.0325	-1.4707
RB-conv-48	-1.5297	-0.0265	-1.4767
CB-conv-96	-1.5062	-0.0030	-1.5002
CB-inf-mw-96	-1.4922	-0.0110	-1.5142
RB-conv-24	-1.4847	-0.0185	-1.5217
CB-conv-72	-1.5452	-0.0420	-1.4612
RB-inf-mw-1	-1.5422	-0.0390	-1.4642
RB-X-G-E-conv-96	-1.5312	-0.0280	-1.4752
RB-X-G-E-inf-mw-96	-1.5087	-0.0055	-1.4977
CB-inf-mw-72	-1.5022	-0.0010	-1.5042
RB-X-G-E-conv-72	-1.5502	-0.0470	-1.4562
RB-conv-1	-1.5467	-0.0435	-1.4597
RB-X-G-E-inf-mw-72	-1.5272	-0.0240	-1.4792

CB-X-G-E-conv-96	-1.5107	-0.0075	-1.4957
CB-conv-48	-1.5052	-0.0020	-1.5012
CB-X-G-E-inf-mw-96	-1.4972	-0.0060	-1.5092
CB-inf-mw-48	-1.4862	-0.0170	-1.5202
CB-X-G-E-conv-72	-1.4827	-0.0205	-1.5237
RB-X-G-E-inf-mw-48	-1.4717	-0.0315	-1.5347
CB-X-G-E-inf-mw-72	-1.4602	-0.0430	-1.5462
RB-X-G-E-conv-48	-1.4892	-0.0140	-1.5172
RB-X-G-E-inf-mw-24	-0.4827	-1.0205	-2.5237
CB-conv-24	-1.4782	-0.0250	-1.5282
CB-X-G-E-inf-mw-48	-1.4712	-0.0320	-1.5352
CB-conv-1	-0.2082	-1.2950	-2.7982
CB-inf-mw-24	-1.5362	-0.0330	-1.4702
RB-X-G-E-conv-24	-1.5312	-0.0280	-1.4752
CB-X-G-E-conv-48	-1.5147	-0.0115	-1.4917
RB-X-G-E-inf-mw-1	-1.4947	-0.0085	-1.5117
CB-inf-mw-1	-1.4897	-0.0135	-1.5167
RB-X-G-E-conv-1	-1.5352	-0.0320	-1.4712
CB-X-G-E-conv-24	-1.5242	-0.0210	-1.4822
CB-X-G-E-conv-1	-1.5107	-0.0075	-1.4957
CB-X-G-E-inf-mw-24	-1.4977	-0.0055	-1.5087
CB-X-G-E-inf-mw-1	-1.4902	-0.0130	-1.5162

Bread Formulation = RB-inf-mw-72 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-72	-1.4987	0.0045	1.5077
RB-inf-mw-48	-1.5507	-0.0475	1.4557
RB-conv-48	-1.5447	-0.0415	1.4617
CB-conv-96	-1.5212	-0.0180	-1.4852
CB-inf-mw-96	-1.5072	-0.0040	-1.4992
RB-conv-24	-1.4997	-0.0035	-1.5067
CB-conv-72	-1.5602	-0.0570	-1.4462
RB-inf-mw-1	-1.5572	-0.0540	-1.4492
RB-X-G-E-conv-96	-1.5462	-0.0430	-1.4602
RB-X-G-E-inf-mw-96	-1.5237	-0.0205	-1.4827
CB-inf-mw-72	-1.5172	-0.0140	-1.4892
RB-X-G-E-conv-72	-1.5652	-0.0620	-1.4412
RB-conv-1	-1.5617	-0.0585	-1.4447
RB-X-G-E-inf-mw-72	-1.5422	-0.0390	-1.4642
CB-X-G-E-conv-96	-1.5257	-0.0225	-1.4807
CB-conv-48	-1.5202	-0.0170	-1.4862
CB-X-G-E-inf-mw-96	-1.5122	-0.0090	-1.4942
CB-inf-mw-48	-1.5012	-0.0020	-1.5052
CB-X-G-E-conv-72	-1.4977	-0.0055	-1.5087
RB-X-G-E-inf-mw-48	-1.4867	-0.0165	-1.5197
CB-X-G-E-inf-mw-72	-1.4752	-0.0280	-1.5312
RB-X-G-E-conv-48	-1.5042	-0.0010	-1.5022
RB-X-G-E-inf-mw-24	-0.4977	-1.0055	-2.5087

CB-conv-24	-1.4932	-0.0100	-1.5132
CB-X-G-E-inf-mw-48	-1.4862	-0.0170	-1.5202
CB-conv-1	-0.2232	-1.2800	-2.7832
CB-inf-mw-24	-1.5512	-0.0480	-1.4552
RB-X-G-E-conv-24	-1.5462	-0.0430	-1.4602
CB-X-G-E-conv-48	-1.5297	-0.0265	-1.4767
RB-X-G-E-inf-mw-1	-1.5097	-0.0065	-1.4967
CB-inf-mw-1	-1.5047	-0.0015	-1.5017
RB-X-G-E-conv-1	-1.5502	-0.0470	-1.4562
CB-X-G-E-conv-24	-1.5392	-0.0360	-1.4672
CB-X-G-E-conv-1	-1.5257	-0.0225	-1.4807
CB-X-G-E-inf-mw-24	-1.5127	-0.0095	-1.4937
CB-X-G-E-inf-mw-1	-1.5052	-0.0020	-1.5012

Bread Formulation = RB-conv-72subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-48	-1.5552	-0.0520	1.4512
RB-conv-48	-1.5492	-0.0460	1.4572
CB-conv-96	-1.5257	-0.0225	-1.4807
CB-inf-mw-96	-1.5117	-0.0085	-1.4947
RB-conv-24	-1.5042	-0.0010	-1.5022
CB-conv-72	-1.5647	-0.0615	-1.4417
RB-inf-mw-1	-1.5617	-0.0585	-1.4447
RB-X-G-E-conv-96	-1.5507	-0.0475	-1.4557
RB-X-G-E-inf-mw-96	-1.5282	-0.0250	-1.4782

CB-inf-mw-72	-1.5217	-0.0185	-1.4847
RB-X-G-E-conv-72	-1.5697	-0.0665	-1.4367
RB-conv-1	-1.5662	-0.0630	-1.4402
RB-X-G-E-inf-mw-72	-1.5467	-0.0435	-1.4597
CB-X-G-E-conv-96	-1.5302	-0.0270	-1.4762
CB-conv-48	-1.5247	-0.0215	-1.4817
CB-X-G-E-inf-mw-96	-1.5167	-0.0135	-1.4897
CB-inf-mw-48	-1.5057	-0.0025	-1.5007
CB-X-G-E-conv-72	-1.5022	-0.0010	-1.5042
RB-X-G-E-inf-mw-48	-1.4912	-0.0120	-1.5152
CB-X-G-E-inf-mw-72	-1.4797	-0.0235	-1.5267
RB-X-G-E-conv-48	-1.5087	-0.0055	-1.4977
RB-X-G-E-inf-mw-24	-0.5022	-1.0010	-2.5042
CB-conv-24	-1.4977	-0.0055	-1.5087
CB-X-G-E-inf-mw-48	-1.4907	-0.0125	-1.5157
CB-conv-1	-0.2277	-1.2755	-2.7787
CB-inf-mw-24	-1.5557	-0.0525	-1.4507
RB-X-G-E-conv-24	-1.5507	-0.0475	-1.4557
CB-X-G-E-conv-48	-1.5342	-0.0310	-1.4722
RB-X-G-E-inf-mw-1	-1.5142	-0.0110	-1.4922
CB-inf-mw-1	-1.5092	-0.0060	-1.4972
RB-X-G-E-conv-1	-1.5547	-0.0515	-1.4517
CB-X-G-E-conv-24	-1.5437	-0.0405	-1.4627
CB-X-G-E-conv-1	-1.5302	-0.0270	-1.4762
CB-X-G-E-inf-mw-24	-1.5172	-0.0140	-1.4892

CB-X-G-E-inf-mw-1	-1.5097	-0.0065	-1.4967

Bread Formulation = RB-inf-mw-48 subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-48	-1.4972	0.0060	1.5092
CB-conv-96	-1.4737	0.0295	1.5327
CB-inf-mw-96	-1.4597	0.0435	1.5467
RB-conv-24	-1.4522	0.0510	1.5542
CB-conv-72	-1.5127	-0.0095	1.4937
RB-inf-mw-1	-1.5097	-0.0065	-1.4967
RB-X-G-E-conv-96	-1.4987	-0.0045	-1.5077
RB-X-G-E-inf-mw-96	-1.4762	-0.0270	-1.5302
CB-inf-mw-72	-1.4697	-0.0335	-1.5367
RB-X-G-E-conv-72	-1.5177	-0.0145	-1.4887
RB-conv-1	-1.5142	-0.0110	-1.4922
RB-X-G-E-inf-mw-72	-1.4947	-0.0085	-1.5117
CB-X-G-E-conv-96	-1.4782	-0.0250	-1.5282
CB-conv-48	-1.4727	-0.0305	-1.5337
CB-X-G-E-inf-mw-96	-1.4647	-0.0385	-1.5417
CB-inf-mw-48	-1.4537	0.0495	-1.5527
CB-X-G-E-conv-72	-1.4502	-0.0530	-1.5562
RB-X-G-E-inf-mw-48	-1.4392	-0.0640	-1.5672
CB-X-G-E-inf-mw-72	-1.4277	0.0755	-1.5787
RB-X-G-E-conv-48	-1.4567	-0.0465	-1.5497
RB-X-G-E-inf-mw-24	-0.4502	-1.0530	-2.5562

CB-conv-24	-1.4457	-0.0575	-1.5607
CB-X-G-E-inf-mw-48	-1.4387	-0.0645	-1.5677
CB-conv-1	-0.1757	-1.3275	-2.8307
CB-inf-mw-24	-1.5037	-0.0005	-1.5027
RB-X-G-E-conv-24	-1.4987	-0.0045	-1.5077
CB-X-G-E-conv-48	-1.4822	-0.0210	-1.5242
RB-X-G-E-inf-mw-1	-1.4622	-0.0410	-1.5442
CB-inf-mw-1	-1.4572	-0.0460	-1.5492
RB-X-G-E-conv-1	-1.5027	-0.0005	-1.5037
CB-X-G-E-conv-24	-1.4917	-0.0115	-1.5147
CB-X-G-E-conv-1	-1.4782	-0.0250	-1.5282
CB-X-G-E-inf-mw-24	-1.4652	-0.0380	-1.5412
CB-X-G-E-inf-mw-1	-1.4577	-0.0455	-1.5487

Bread Formulation = RB-conv-48subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-96	-1.4797	0.0235	1.5267
CB-inf-mw-96	-1.4657	0.0375	1.5407
RB-conv-24	-1.4582	0.0450	1.5482
CB-conv-72	-1.5187	-0.0155	1.4877
RB-inf-mw-1	-1.5157	-0.0125	-1.4907
RB-X-G-E-conv-96	-1.5047	-0.0015	-1.5017
RB-X-G-E-inf-mw-96	-1.4822	-0.0210	-1.5242
CB-inf-mw-72	-1.4757	-0.0275	-1.5307
RB-X-G-E-conv-72	-1.5237	-0.0205	-1.4827

RB-conv-1	-1.5202	-0.0170	-1.4862
RB-X-G-E-inf-mw-72	-1.5007	-0.0025	-1.5057
CB-X-G-E-conv-96	-1.4842	-0.0190	-1.5222
CB-conv-48	-1.4787	-0.0245	-1.5277
CB-X-G-E-inf-mw-96	-1.4707	-0.0325	-1.5357
CB-inf-mw-48	-1.4597	-0.0435	-1.5467
CB-X-G-E-conv-72	-1.4562	-0.0470	-1.5502
RB-X-G-E-inf-mw-48	-1.4452	-0.0580	-1.5612
CB-X-G-E-inf-mw-72	-1.4337	-0.0695	-1.5727
RB-X-G-E-conv-48	-1.4627	-0.0405	-1.5437
RB-X-G-E-inf-mw-24	-0.4562	-1.0470	-2.5502
CB-conv-24	-1.4517	-0.0515	-1.5547
CB-X-G-E-inf-mw-48	-1.4447	-0.0585	-1.5617
CB-conv-1	-0.1817	-1.3215	-2.8247
CB-inf-mw-24	-1.5097	-0.0065	-1.4967
RB-X-G-E-conv-24	-1.5047	-0.0015	-1.5017
CB-X-G-E-conv-48	-1.4882	-0.0150	-1.5182
RB-X-G-E-inf-mw-1	-1.4682	-0.0350	-1.5382
CB-inf-mw-1	-1.4632	-0.0400	-1.5432
RB-X-G-E-conv-1	-1.5087	-0.0055	-1.4977
CB-X-G-E-conv-24	-1.4977	-0.0055	-1.5087
CB-X-G-E-conv-1	-1.4842	-0.0190	-1.5222
CB-X-G-E-inf-mw-24	-1.4712	-0.0320	-1.5352
CB-X-G-E-inf-mw-1	-1.4637	-0.0395	-1.5427

Bread Formulation = CB-conv-96 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-96	-1.4892	0.0140	1.5172
RB-conv-24	-1.4817	0.0215	1.5247
CB-conv-72	-1.5422	-0.0390	1.4642
RB-inf-mw-1	-1.5392	-0.0360	-1.4672
RB-X-G-E-conv-96	-1.5282	-0.0250	-1.4782
RB-X-G-E-inf-mw-96	-1.5057	-0.0025	-1.5007
CB-inf-mw-72	-1.4992	-0.0040	-1.5072
RB-X-G-E-conv-72	-1.5472	-0.0440	-1.4592
RB-conv-1	-1.5437	-0.0405	-1.4627
RB-X-G-E-inf-mw-72	-1.5242	-0.0210	-1.4822
CB-X-G-E-conv-96	-1.5077	-0.0045	-1.4987
CB-conv-48	-1.5022	-0.0010	-1.5042
CB-X-G-E-inf-mw-96	-1.4942	-0.0090	-1.5122
CB-inf-mw-48	-1.4832	-0.0200	-1.5232
CB-X-G-E-conv-72	-1.4797	-0.0235	-1.5267
RB-X-G-E-inf-mw-48	-1.4687	-0.0345	-1.5377
CB-X-G-E-inf-mw-72	-1.4572	-0.0460	-1.5492
RB-X-G-E-conv-48	-1.4862	-0.0170	-1.5202
RB-X-G-E-inf-mw-24	-0.4797	-1.0235	-2.5267
CB-conv-24	-1.4752	-0.0280	-1.5312
CB-X-G-E-inf-mw-48	-1.4682	-0.0350	-1.5382
CB-conv-1	-0.2052	-1.2980	-2.8012
CB-inf-mw-24	-1.5332	-0.0300	-1.4732

RB-X-G-E-conv-24	-1.5282	-0.0250	-1.4782
CB-X-G-E-conv-48	-1.5117	-0.0085	-1.4947
RB-X-G-E-inf-mw-1	-1.4917	-0.0115	-1.5147
CB-inf-mw-1	-1.4867	-0.0165	-1.5197
RB-X-G-E-conv-1	-1.5322	-0.0290	-1.4742
CB-X-G-E-conv-24	-1.5212	-0.0180	-1.4852
CB-X-G-E-conv-1	-1.5077	-0.0045	-1.4987
CB-X-G-E-inf-mw-24	-1.4947	0.0085	1.5117
CB-X-G-E-inf-mw-1	-1.4872	0.0160	1.5192

Bread Formulation = CB-inf-mw-96subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-24	-1.4957	0.0075	1.5107
CB-conv-72	-1.5562	-0.0530	1.4502
RB-inf-mw-1	-1.5532	-0.0500	-1.4532
RB-X-G-E-conv-96	-1.5422	-0.0390	-1.4642
RB-X-G-E-inf-mw-96	-1.5197	-0.0165	-1.4867
CB-inf-mw-72	-1.5132	-0.0100	-1.4932
RB-X-G-E-conv-72	-1.5612	-0.0580	-1.4452
RB-conv-1	-1.5577	-0.0545	-1.4487
RB-X-G-E-inf-mw-72	-1.5382	-0.0350	-1.4682
CB-X-G-E-conv-96	-1.5217	-0.0185	-1.4847
CB-conv-48	-1.5162	-0.0130	-1.4902
CB-X-G-E-inf-mw-96	-1.5082	-0.0050	-1.4982
CB-inf-mw-48	-1.4972	-0.0060	-1.5092

CB-X-G-E-conv-72	-1.4937	-0.0095	-1.5127
RB-X-G-E-inf-mw-48	-1.4827	-0.0205	-1.5237
CB-X-G-E-inf-mw-72	-1.4712	-0.0320	-1.5352
RB-X-G-E-conv-48	-1.5002	-0.0030	-1.5062
RB-X-G-E-inf-mw-24	-0.4937	-1.0095	-2.5127
CB-conv-24	-1.4892	-0.0140	-1.5172
CB-X-G-E-inf-mw-48	-1.4822	-0.0210	-1.5242
CB-conv-1	-0.2192	-1.2840	-2.7872
CB-inf-mw-24	-1.5472	-0.0440	-1.4592
RB-X-G-E-conv-24	-1.5422	-0.0390	-1.4642
CB-X-G-E-conv-48	-1.5257	-0.0225	-1.4807
RB-X-G-E-inf-mw-1	-1.5057	-0.0025	-1.5007
CB-inf-mw-1	-1.5007	-0.0025	-1.5057
RB-X-G-E-conv-1	-1.5462	-0.0430	-1.4602
CB-X-G-E-conv-24	-1.5352	-0.0320	-1.4712
CB-X-G-E-conv-1	-1.5217	-0.0185	-1.4847
CB-X-G-E-inf-mw-24	-1.5087	-0.0055	-1.4977
CB-X-G-E-inf-mw-1	-1.5012	-0.0020	-1.5052

Bread Formulation = RB-conv-24subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-72	-1.5637	-0.0605	1.4427
RB-inf-mw-1	-1.5607	-0.0575	1.4457
RB-X-G-E-conv-96	-1.5497	-0.0465	1.4567
RB-X-G-E-inf-mw-96	-1.5272	-0.0240	1.4792

CB-inf-mw-72	-1.5207	-0.0175	1.4857
RB-X-G-E-conv-72	-1.5687	-0.0655	1.4377
RB-conv-1	-1.5652	-0.0620	-1.4412
RB-X-G-E-inf-mw-72	-1.5457	-0.0425	-1.4607
CB-X-G-E-conv-96	-1.5292	-0.0260	-1.4772
CB-conv-48	-1.5237	-0.0205	-1.4827
CB-X-G-E-inf-mw-96	-1.5157	-0.0125	-1.4907
CB-inf-mw-48	-1.5047	-0.0015	-1.5017
CB-X-G-E-conv-72	-1.5012	-0.0020	-1.5052
RB-X-G-E-inf-mw-48	-1.4902	-0.0130	-1.5162
CB-X-G-E-inf-mw-72	-1.4787	-0.0245	-1.5277
RB-X-G-E-conv-48	-1.5077	-0.0045	-1.4987
RB-X-G-E-inf-mw-24	-0.5012	-1.0020	-2.5052
CB-conv-24	-1.4967	-0.0065	-1.5097
CB-X-G-E-inf-mw-48	-1.4897	-0.0135	-1.5167
CB-conv-1	-0.2267	-1.2765	-2.7797
CB-inf-mw-24	-1.5547	-0.0515	-1.4517
RB-X-G-E-conv-24	-1.5497	-0.0465	-1.4567
CB-X-G-E-conv-48	-1.5332	-0.0300	-1.4732
RB-X-G-E-inf-mw-1	-1.5132	-0.0100	-1.4932
CB-inf-mw-1	-1.5082	-0.0050	-1.4982
RB-X-G-E-conv-1	-1.5537	-0.0505	-1.4527
CB-X-G-E-conv-24	-1.5427	-0.0395	-1.4637
CB-X-G-E-conv-1	-1.5292	-0.0260	-1.4772
CB-X-G-E-inf-mw-24	-1.5162	-0.0130	-1.4902

CB-X-G-E-inf-mw-1	-1.5087	-0.0055	-1.4977

Bread Formulation = CB-conv-72subtracted from:

Bread Formulation	Lower	Center	Upper
RB-inf-mw-1	-1.5002	0.0030	1.5062
RB-X-G-E-conv-96	-1.4892	0.0140	1.5172
RB-X-G-E-inf-mw-96	-1.4667	0.0365	1.5397
CB-inf-mw-72	-1.4602	0.0430	1.5462
RB-X-G-E-conv-72	-1.5082	-0.0050	1.4982
RB-conv-1	-1.5047	-0.0015	-1.5017
RB-X-G-E-inf-mw-72	-1.4852	-0.0180	-1.5212
CB-X-G-E-conv-96	-1.4687	-0.0345	-1.5377
CB-conv-48	-1.4632	-0.0400	-1.5432
CB-X-G-E-inf-mw-96	-1.4552	-0.0480	-1.5512
CB-inf-mw-48	-1.4442	-0.0590	-1.5622
CB-X-G-E-conv-72	-1.4407	-0.0625	-1.5657
RB-X-G-E-inf-mw-48	-1.4297	-0.0735	-1.5767
CB-X-G-E-inf-mw-72	-1.4182	-0.0850	-1.5882
RB-X-G-E-conv-48	-1.4472	-0.0560	-1.5592
RB-X-G-E-inf-mw-24	-0.4407	-1.0625	-2.5657
CB-conv-24	-1.4362	-0.0670	-1.5702
CB-X-G-E-inf-mw-48	-1.4292	-0.0740	-1.5772
CB-conv-1	-0.1662	-1.3370	-2.8402
CB-inf-mw-24	-1.4942	-0.0090	-1.5122
RB-X-G-E-conv-24	-1.4892	-0.0140	-1.5172

CB-X-G-E-conv-48	-1.4727	-0.0305	-1.5337
RB-X-G-E-inf-mw-1	-1.4527	-0.0505	-1.5537
CB-inf-mw-1	-1.4477	-0.0555	-1.5587
RB-X-G-E-conv-1	-1.4932	-0.0100	-1.5132
CB-X-G-E-conv-24	-1.4822	-0.0210	-1.5242
CB-X-G-E-conv-1	-1.4687	-0.0345	-1.5377
CB-X-G-E-inf-mw-24	-1.4557	-0.0475	-1.5507
CB-X-G-E-inf-mw-1	-1.4482	-0.0550	-1.5582

Bread Formulation = RB-inf-mw-1subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-96	-1.4922	0.0110	1.5142
RB-X-G-E-inf-mw-96	-1.4697	0.0335	1.5367
CB-inf-mw-72	-1.4632	0.0400	1.5432
RB-X-G-E-conv-72	-1.5112	-0.0080	1.4952
RB-conv-1	-1.5077	-0.0045	1.4987
RB-X-G-E-inf-mw-72	-1.4882	0.0150	1.5182
CB-X-G-E-conv-96	-1.4717	0.0315	1.5347
CB-conv-48	-1.4662	0.0370	1.5402
CB-X-G-E-inf-mw-96	-1.4582	-0.0450	-1.5482
CB-inf-mw-48	-1.4472	-0.0560	-1.5592
CB-X-G-E-conv-72	-1.4437	-0.0595	-1.5627
RB-X-G-E-inf-mw-48	-1.4327	-0.0705	-1.5737
CB-X-G-E-inf-mw-72	-1.4212	-0.0820	-1.5852
RB-X-G-E-conv-48	-1.4502	-0.0530	-1.5562

RB-X-G-E-inf-mw-24	-0.4437	-1.0595	-2.5627
CB-conv-24	-1.4392	-0.0640	-1.5672
CB-X-G-E-inf-mw-48	-1.4322	-0.0710	-1.5742
CB-conv-1	-0.1692	-1.3340	-2.8372
CB-inf-mw-24	-1.4972	-0.0060	-1.5092
RB-X-G-E-conv-24	-1.4922	-0.0110	-1.5142
CB-X-G-E-conv-48	-1.4757	-0.0275	-1.5307
RB-X-G-E-inf-mw-1	-1.4557	-0.0475	-1.5507
CB-inf-mw-1	-1.4507	-0.0525	-1.5557
RB-X-G-E-conv-1	-1.4962	-0.0070	-1.5102
CB-X-G-E-conv-24	-1.4852	-0.0180	-1.5212
CB-X-G-E-conv-1	-1.4717	-0.0315	-1.5347
CB-X-G-E-inf-mw-24	-1.4587	-0.0445	-1.5477
CB-X-G-E-inf-mw-1	-1.4512	-0.0520	-1.5552

Bread Formulation = RB-X-G-E-conv-96subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-96	-1.4807	0.0225	1.5257
CB-inf-mw-72	-1.4742	0.0290	1.5322
RB-X-G-E-conv-72	-1.5222	-0.0190	1.4842
RB-conv-1	-1.5187	-0.0155	1.4877
RB-X-G-E-inf-mw-72	-1.4992	0.0040	1.5072
CB-X-G-E-conv-96	-1.4827	0.0205	1.5237
CB-conv-48	-1.4772	0.0260	1.5292
CB-X-G-E-inf-mw-96	-1.4692	0.0340	1.5372

CB-inf-mw-48	-1.4582	0.0450	1.5482
CB-X-G-E-conv-72	-1.4547	-0.0485	-1.5517
RB-X-G-E-inf-mw-48	-1.4437	-0.0595	-1.5627
CB-X-G-E-inf-mw-72	-1.4322	-0.0710	-1.5742
RB-X-G-E-conv-48	-1.4612	-0.0420	-1.5452
RB-X-G-E-inf-mw-24	-0.4547	-1.0485	-2.5517
CB-conv-24	-1.4502	-0.0530	-1.5562
CB-X-G-E-inf-mw-48	-1.4432	-0.0600	-1.5632
CB-conv-1	-0.1802	-1.3230	-2.8262
CB-inf-mw-24	-1.5082	-0.0050	-1.4982
RB-X-G-E-conv-24	-1.5032	-0.0000	-1.5032
CB-X-G-E-conv-48	-1.4867	-0.0165	-1.5197
RB-X-G-E-inf-mw-1	-1.4667	-0.0365	-1.5397
CB-inf-mw-1	-1.4617	-0.0415	-1.5447
RB-X-G-E-conv-1	-1.5072	-0.0040	-1.4992
CB-X-G-E-conv-24	-1.4962	-0.0070	-1.5102
CB-X-G-E-conv-1	-1.4827	-0.0205	-1.5237
CB-X-G-E-inf-mw-24	-1.4697	-0.0335	-1.5367
CB-X-G-E-inf-mw-1	-1.4622	-0.0410	-1.5442

Bread Formulation = RB-X-G-E-inf-mw-96subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-72	-.14967	0.0065	1.5097
RB-X-G-E-conv-72	-1.5447	-0.0415	1.4617
RB-conv-1	-1.5412	-0.0380	1.4652

RB-X-G-E-inf-mw-72	-1.5217	-0.0185	1.4847
CB-X-G-E-conv-96	-1.5052	-0.0020	1.5012
CB-conv-48	-1.4997	0.0035	1.5067
CB-X-G-E-inf-mw-96	-1.4917	0.0115	1.5147
CB-inf-mw-48	-1.4807	0.0225	1.5257
CB-X-G-E-conv-72	-1.4772	-0.0260	-1.5292
RB-X-G-E-inf-mw-48	-1.4662	-0.0370	-1.5402
CB-X-G-E-inf-mw-72	-1.4547	-0.0485	-1.5517
RB-X-G-E-conv-48	-1.4837	-0.0195	-1.5227
RB-X-G-E-inf-mw-24	-0.4772	-1.0260	-2.5292
CB-conv-24	-1.4727	-0.0305	-1.5337
CB-X-G-E-inf-mw-48	-1.4657	-0.0375	-1.5407
CB-conv-1	-0.2027	-1.3005	-2.8037
CB-inf-mw-24	-1.5307	-0.0275	-1.4757
RB-X-G-E-conv-24	-1.5257	-0.0225	-1.4807
CB-X-G-E-conv-48	-1.5092	-0.0060	-1.4972
RB-X-G-E-inf-mw-1	-1.4892	-0.0140	-1.5172
CB-inf-mw-1	-1.4842	-0.0190	-1.5222
RB-X-G-E-conv-1	-1.5297	-0.0265	-1.4767
CB-X-G-E-conv-24	-1.5187	-0.0155	-1.4877
CB-X-G-E-conv-1	-1.5052	-0.0020	-1.5012
CB-X-G-E-inf-mw-24	-1.4922	-0.0110	-1.5142
CB-X-G-E-inf-mw-1	-1.4847	-0.0185	-1.5217

Bread Formulation = CB-inf-mw-72subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-72	-1.5512	-0.0480	1.4552
RB-conv-1	-1.5477	-0.0445	1.4587
RB-X-G-E-inf-mw-72	-1.5282	-0.0250	1.4782
CB-X-G-E-conv-96	-1.5117	-0.0085	1.4947
CB-conv-48	-1.5062	-0.0030	1.5002
CB-X-G-E-inf-mw-96	-1.4982	0.0050	1.5082
CB-inf-mw-48	-1.4872	0.0160	1.5192
CB-X-G-E-conv-72	-1.4837	0.0195	1.5227
RB-X-G-E-inf-mw-48	-1.4727	0.0305	1.5337
CB-X-G-E-inf-mw-72	-1.4612	0.0420	1.5452
RB-X-G-E-conv-48	-1.4902	0.0130	1.5162
RB-X-G-E-inf-mw-24	-0.4837	-1.0195	-2.5227
CB-conv-24	-1.4792	-0.0240	-1.5272
CB-X-G-E-inf-mw-48	-1.4722	-0.0310	-1.5342
CB-conv-1	-0.2092	-1.2940	-2.7972
CB-inf-mw-24	-1.5372	-0.0340	-1.4692
RB-X-G-E-conv-24	-1.5322	-0.0290	-1.4742
CB-X-G-E-conv-48	-1.5157	-0.0125	-1.4907
RB-X-G-E-inf-mw-1	-1.4957	-0.0075	-1.5107
CB-inf-mw-1	-1.4907	-0.0125	-1.5157
RB-X-G-E-conv-1	-1.5362	-0.0330	-1.4702
CB-X-G-E-conv-24	-1.5252	-0.0220	-1.4812
CB-X-G-E-conv-1	-1.5117	-0.0085	-1.4947
CB-X-G-E-inf-mw-24	-1.4987	-0.0045	-1.5077

CB-X-G-E-inf-mw-1	-1.4912	-0.0120	-1.5152

Bread Formulation = RB-X-G-E-conv-72subtracted from:

Bread Formulation	Lower	Center	Upper
RB-conv-1	-1.4997	0.0035	1.5067
RB-X-G-E-inf-mw-72	-1.4802	0.0230	1.5262
CB-X-G-E-conv-96	-1.4637	0.0395	1.5427
CB-conv-48	-1.4582	0.0450	1.5482
CB-X-G-E-inf-mw-96	-1.4502	0.0530	1.5562
CB-inf-mw-48	-1.4392	0.0640	1.5672
CB-X-G-E-conv-72	-1.4357	0.0675	1.5707
RB-X-G-E-inf-mw-48	-1.4247	0.0785	1.5817
CB-X-G-E-inf-mw-72	-1.4132	0.0900	1.5932
RB-X-G-E-conv-48	-1.4422	0.0610	1.5642
RB-X-G-E-inf-mw-24	-0.4357	-1.0675	-2.5707
CB-conv-24	-1.4312	-0.0720	-1.5752
CB-X-G-E-inf-mw-48	-1.4242	-0.0790	-1.5822
CB-conv-1	-0.1612	-1.3420	-2.8452
CB-inf-mw-24	-1.4892	-0.0140	-1.5172
RB-X-G-E-conv-24	-1.4842	-0.0190	-1.5222
CB-X-G-E-conv-48	-1.4677	-0.0355	-1.5387
RB-X-G-E-inf-mw-1	-1.4477	-0.0555	-1.5587
CB-inf-mw-1	-1.4427	-0.0605	-1.5637
RB-X-G-E-conv-1	-1.4882	-0.0150	-1.5182
CB-X-G-E-conv-24	-1.4772	-0.0260	-1.5292

CB-X-G-E-conv-1	-1.4637	-0.0395	-1.5427
CB-X-G-E-inf-mw-24	-1.4507	-0.0525	-1.5557
CB-X-G-E-inf-mw-1	-1.4432	-0.0600	-1.5632

Bread Formulation = RB-conv-1subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-72	-1.4837	0.0195	1.5227
CB-X-G-E-conv-96	-1.4672	0.0360	1.5392
CB-conv-48	-1.4617	0.0415	1.5447
CB-X-G-E-inf-mw-96	-1.4537	0.0495	1.5527
CB-inf-mw-48	-1.4427	0.0605	1.5637
CB-X-G-E-conv-72	-1.4392	0.0640	1.5672
RB-X-G-E-inf-mw-48	-1.4282	0.0750	1.5782
CB-X-G-E-inf-mw-72	-1.4167	0.0865	1.5897
RB-X-G-E-conv-48	-1.4457	0.0575	1.5607
RB-X-G-E-inf-mw-24	-0.4392	1.0640	2.5672
CB-conv-24	-1.4347	0.0685	1.5717
CB-X-G-E-inf-mw-48	-1.4277	-0.0755	-1.5787
CB-conv-1	-0.1647	-1.3385	-2.8417
CB-inf-mw-24	-1.4927	-0.0105	-1.5137
RB-X-G-E-conv-24	-1.4877	-0.0155	-1.5187
CB-X-G-E-conv-48	-1.4712	-0.0320	-1.5352
RB-X-G-E-inf-mw-1	-1.4512	-0.0520	-1.5552
CB-inf-mw-1	-1.4462	-0.0570	-1.5602
RB-X-G-E-conv-1	-1.4917	-0.0115	-1.5147

CB-X-G-E-conv-24	-1.4807	-0.0225	-1.5257
CB-X-G-E-conv-1	-1.4672	-0.0360	-1.5392
CB-X-G-E-inf-mw-24	-1.4542	-0.0490	-1.5522
CB-X-G-E-inf-mw-1	-1.4467	-0.0565	-1.5597

Bread Formulation = RB-X-G-E-inf-mw-72subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-96	-1.4867	0.0165	1.5197
CB-conv-48	-1.4812	0.0220	1.5252
CB-X-G-E-inf-mw-96	-1.4732	0.0300	1.5332
CB-inf-mw-48	-1.4622	0.0410	1.5442
CB-X-G-E-conv-72	-1.4587	0.0445	1.5477
RB-X-G-E-inf-mw-48	-1.4477	0.0555	1.5587
CB-X-G-E-inf-mw-72	-1.4362	0.0670	1.5702
RB-X-G-E-conv-48	-1.4652	0.0380	1.5412
RB-X-G-E-inf-mw-24	-0.4587	1.0445	2.5477
CB-conv-24	-1.4542	0.0490	1.5522
CB-X-G-E-inf-mw-48	-1.4472	-0.0560	-1.5592
CB-conv-1	-0.1842	-1.3190	-2.8222
CB-inf-mw-24	-1.5122	-0.0090	-1.4942
RB-X-G-E-conv-24	-1.5072	-0.0040	-1.4992
CB-X-G-E-conv-48	-1.4907	-0.0125	-1.5157
RB-X-G-E-inf-mw-1	-1.4707	-0.0325	-1.5357
CB-inf-mw-1	-1.4657	-0.0375	-1.5407
RB-X-G-E-conv-1	-1.5112	-0.0080	-1.4952

CB-X-G-E-conv-24	-1.5002	-0.0030	-1.5062
CB-X-G-E-conv-1	-1.4867	-0.0165	-1.5197
CB-X-G-E-inf-mw-24	-1.4737	-0.0295	-1.5327
CB-X-G-E-inf-mw-1	-1.4662	-0.0370	-1.5402

Bread Formulation = CB-X-G-E-conv-96subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-48	-1.4977	0.0055	1.5087
CB-X-G-E-inf-mw-96	-1.4897	0.0135	1.5167
CB-inf-mw-48	-1.4787	0.0245	1.5277
CB-X-G-E-conv-72	-1.4752	0.0280	1.5312
RB-X-G-E-inf-mw-48	-1.4642	0.0390	1.5422
CB-X-G-E-inf-mw-72	-1.4527	0.0505	1.5537
RB-X-G-E-conv-48	-1.4817	0.0215	1.5247
RB-X-G-E-inf-mw-24	-0.4752	1.0280	2.5312
CB-conv-24	-1.4707	0.0325	1.5357
CB-X-G-E-inf-mw-48	-1.4637	-0.0395	-1.5427
CB-conv-1	-0.2007	-1.3025	-2.8057
CB-inf-mw-24	-1.5287	-0.0255	-1.4777
RB-X-G-E-conv-24	-1.5237	-0.0205	-1.4827
CB-X-G-E-conv-48	-1.5072	-0.0040	-1.4992
RB-X-G-E-inf-mw-1	-1.4872	-0.0160	-1.5192
CB-inf-mw-1	-1.4822	-0.0210	-1.5242
RB-X-G-E-conv-1	-1.5277	-0.0245	-1.4787
CB-X-G-E-conv-24	-1.5167	-0.0135	-1.4897
CB-X-G-E-conv-1	-1.5032	-0.0000	-1.5032

CB-X-G-E-inf-mw-24	-1.4902	-0.0130	-1.5162
CB-X-G-E-inf-mw-1	-1.4827	-0.0205	-1.5237

Bread Formulation = CB-conv-48subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-96	-1.4952	0.0080	1.5112
CB-inf-mw-48	-1.4842	0.0190	1.5222
CB-X-G-E-conv-72	-1.4807	0.0225	1.5257
RB-X-G-E-inf-mw-48	-1.4697	0.0335	1.5367
CB-X-G-E-inf-mw-72	-1.4582	0.0450	1.5482
RB-X-G-E-conv-48	-1.4872	0.0160	1.5192
RB-X-G-E-inf-mw-24	-0.4807	1.0225	2.5257
CB-conv-24	-1.4762	0.0270	1.5302
CB-X-G-E-inf-mw-48	-1.4692	-0.0340	-1.5372
CB-conv-1	-0.2062	-1.2970	-2.8002
CB-inf-mw-24	-1.5342	-0.0310	-1.4722
RB-X-G-E-conv-24	-1.5292	-0.0260	-1.4772
CB-X-G-E-conv-48	-1.5127	-0.0095	-1.4937
RB-X-G-E-inf-mw-1	-1.4927	-0.0105	-1.5137
CB-inf-mw-1	-1.4877	-0.0155	-1.5187
RB-X-G-E-conv-1	-1.5332	-0.0300	-1.4732
CB-X-G-E-conv-24	-1.5222	-0.0190	-1.4842
CB-X-G-E-conv-1	-1.5087	-0.0055	-1.4977
CB-X-G-E-inf-mw-24	-1.4957	-0.0075	-1.5107
CB-X-G-E-inf-mw-1	-1.4882	-0.0150	-1.5182

Bread Formulation = CB-X-G-E-inf-mw-96subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-48	-1.4922	0.0110	1.5142
CB-X-G-E-conv-72	-1.4887	0.0145	1.5177
RB-X-G-E-inf-mw-48	-1.4777	0.0255	1.5287
CB-X-G-E-inf-mw-72	-1.4662	0.0370	1.5402
RB-X-G-E-conv-48	-1.4952	0.0080	1.5112
RB-X-G-E-inf-mw-24	-0.4887	1.0145	2.5177
CB-conv-24	-1.4842	0.0190	1.5222
CB-X-G-E-inf-mw-48	-1.4772	0.0260	1.5292
CB-conv-1	-0.2142	-1.2890	-2.7922
CB-inf-mw-24	-1.5422	-0.0390	-1.4642
RB-X-G-E-conv-24	-1.5372	-0.0340	-1.4692
CB-X-G-E-conv-48	-1.5207	-0.0175	-1.4857
RB-X-G-E-inf-mw-1	-1.5007	-0.0025	-1.5057
CB-inf-mw-1	-1.4957	-0.0075	-1.5107
RB-X-G-E-conv-1	-1.5412	-0.0380	-1.4652
CB-X-G-E-conv-24	-1.5302	-0.0270	-1.4762
CB-X-G-E-conv-1	-1.5167	-0.0135	-1.4897
CB-X-G-E-inf-mw-24	-1.5037	-0.0005	-1.5027
CB-X-G-E-inf-mw-1	-1.4962	-0.0070	-1.5102

Bread Formulation = CB-inf-mw-48subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-72	-1.4997	0.0035	1.5067

RB-X-G-E-inf-mw-48	-1.4887	0.0145	1.5177
CB-X-G-E-inf-mw-72	-1.4772	0.0260	1.5292
RB-X-G-E-conv-48	-1.5062	-0.0030	1.5002
RB-X-G-E-inf-mw-24	-0.4997	10.035	2.5067
CB-conv-24	-1.4952	0.0080	1.5112
CB-X-G-E-inf-mw-48	-1.4882	0.0150	1.5182
CB-conv-1	-0.2252	-1.2780	-2.7812
CB-inf-mw-24	-1.5532	-0.0500	-1.4532
RB-X-G-E-conv-24	-1.5482	-0.0450	-1.4582
CB-X-G-E-conv-48	-1.5317	-0.0285	-1.4747
RB-X-G-E-inf-mw-1	-1.5117	-0.0085	-1.4947
CB-inf-mw-1	-1.5067	-0.0035	-1.4997
RB-X-G-E-conv-1	-1.5522	-0.0490	-1.4542
CB-X-G-E-conv-24	-1.5412	-0.0380	-1.4652
CB-X-G-E-conv-1	-1.5277	-0.0245	-1.4787
CB-X-G-E-inf-mw-24	-1.5147	-0.0115	-1.4917
CB-X-G-E-inf-mw-1	-1.5072	-0.0040	-1.4992

Bread Formulation = CB-X-G-E-conv-72subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-48	-1.4922	0.0110	1.5142
CB-X-G-E-inf-mw-72	-1.4807	0.0225	1.5257
RB-X-G-E-conv-48	-1.5097	-0.0065	1.4967
RB-X-G-E-inf-mw-24	-0.5032	1.0000	2.5032
CB-conv-24	-1.4987	0.0045	1.5077

CB-X-G-E-inf-mw-48	-1.4917	0.0115	1.5147
CB-conv-1	-0.2287	1.2745	2.7777
CB-inf-mw-24	-1.5567	-0.0535	-1.4497
RB-X-G-E-conv-24	-1.5517	-0.0485	-1.4547
CB-X-G-E-conv-48	-1.5352	-0.0320	-1.4712
RB-X-G-E-inf-mw-1	-1.5152	-0.0120	-1.4912
CB-inf-mw-1	-1.5102	-0.0070	-1.4962
RB-X-G-E-conv-1	-1.5557	-0.0525	-1.4507
CB-X-G-E-conv-24	-1.5447	-0.0415	-1.4617
CB-X-G-E-conv-1	-1.5312	-0.0280	-1.4752
CB-X-G-E-inf-mw-24	-1.5182	-0.0150	-1.4882
CB-X-G-E-inf-mw-1	-1.5107	-0.0075	-1.4957

Bread Formulation = RB-X-G-E-inf-mw-48subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-72	-1.4917	0.0115	1.5147
RB-X-G-E-conv-48	-1.5207	-0.0175	1.4857
RB-X-G-E-inf-mw-24	-0.5142	0.9890	2.4922
CB-conv-24	-1.5097	-0.0065	1.4967
CB-X-G-E-inf-mw-48	-1.5027	0.0005	1.5037
CB-conv-1	-0.2397	1.2635	2.7667
CB-inf-mw-24	-1.5677	-0.0645	-1.4387
RB-X-G-E-conv-24	-1.5627	-0.0595	-1.4437
CB-X-G-E-conv-48	-1.5462	-0.0430	-1.4602
RB-X-G-E-inf-mw-1	-1.5262	-0.0230	-1.4802

CB-inf-mw-1	-1.5212	-0.0180	-1.4852
RB-X-G-E-conv-1	-1.5667	-0.0635	-1.4397
CB-X-G-E-conv-24	-1.5557	-0.0525	-1.4507
CB-X-G-E-conv-1	-1.5422	-0.0390	-1.4642
CB-X-G-E-inf-mw-24	-1.5292	-0.0260	-1.4772
CB-X-G-E-inf-mw-1	-1.5217	-0.0185	-1.4847

Bread Formulation = CB-X-G-E-inf-mw-72subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-48	-1.5322	-0.0290	1.4742
RB-X-G-E-inf-mw-24	-0.5257	0.9775	2.4807
CB-conv-24	-1.5212	-0.0180	1.4852
CB-X-G-E-inf-mw-48	-1.5142	-0.0110	1.4922
CB-conv-1	-0.2512	1.2520	2.7552
CB-inf-mw-24	-1.5792	-0.0760	1.4272
RB-X-G-E-conv-24	-1.5742	-0.0710	-1.4322
CB-X-G-E-conv-48	-1.5577	-0.0545	-1.4487
RB-X-G-E-inf-mw-1	-1.5377	-0.0345	-1.4687
CB-inf-mw-1	-1.5327	-0.0295	-1.4737
RB-X-G-E-conv-1	-1.5782	-0.0750	-1.4282
CB-X-G-E-conv-24	-1.5672	-0.0640	-1.4392
CB-X-G-E-conv-1	-1.5537	-0.0505	-1.4527
CB-X-G-E-inf-mw-24	-1.5407	-0.0375	-1.4657
CB-X-G-E-inf-mw-1	-1.5332	-0.0300	-1.4732

Bread Formulation = RB-X-G-E-conv-48subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-24	-0.4967	1.0065	2.5097
CB-conv-24	-1.4922	0.0110	1.5142
CB-X-G-E-inf-mw-48	-1.4852	0.0180	1.5212
CB-conv-1	-0.2222	1.2810	2.7842
CB-inf-mw-24	-1.5502	-0.0470	-1.4562
RB-X-G-E-conv-24	-1.5452	-0.0420	-1.4612
CB-X-G-E-conv-48	-1.5287	-0.0255	-1.4777
RB-X-G-E-inf-mw-1	-1.5087	-0.0055	-1.4977
CB-inf-mw-1	-1.5037	-0.0005	-1.5027
RB-X-G-E-conv-1	-1.5492	-0.0460	-1.4572
CB-X-G-E-conv-24	-1.5382	-0.0350	-1.4682
CB-X-G-E-conv-1	-1.5247	-0.0215	-1.4817
CB-X-G-E-inf-mw-24	-1.5117	-0.0085	-1.4947
CB-X-G-E-inf-mw-1	-1.5042	-0.0010	-1.5022

Bread Formulation = RB-X-G-E-inf-mw-24subtracted from:

Bread Formulation	Lower	Center	Upper
CB-conv-24	-2.4987	-0.9955	0.5077
CB-X-G-E-inf-mw-48	-2.4917	-0.9885	0.5147
CB-conv-1	-1.2287	0.2745	1.7777
CB-inf-mw-24	-2.5567	-1.0535	0.4497
RB-X-G-E-conv-24	-2.5517	-1.0485	0.4547
CB-X-G-E-conv-48	-2.5352	-1.0320	0.4712

RB-X-G-E-inf-mw-1	-2.5152	-1.0120	-0.4912
CB-inf-mw-1	-2.5102	-1.0070	-0.4962
RB-X-G-E-conv-1	-2.5557	-1.0525	-0.4507
CB-X-G-E-conv-24	-2.5447	-1.0415	-0.4617
CB-X-G-E-conv-1	-2.5312	-1.0280	-0.4752
CB-X-G-E-inf-mw-24	-2.5182	-1.0150	-0.4882
CB-X-G-E-inf-mw-1	-2.5107	-1.0075	-0.4957

Bread Formulation = CB-conv-24subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-48	-1.4962	0.0070	1.5102
CB-conv-1	-0.2332	1.2700	2.7732
CB-inf-mw-24	-1.5612	-0.0580	1.4452
RB-X-G-E-conv-24	-1.5562	-0.0530	1.4502
CB-X-G-E-conv-48	-1.5397	-0.0365	1.4667
RB-X-G-E-inf-mw-1	-1.5197	-0.0165	-1.4867
CB-inf-mw-1	-1.5147	-0.0115	-1.4917
RB-X-G-E-conv-1	-1.5602	-0.0570	-1.4462
CB-X-G-E-conv-24	-1.5492	-0.0460	-1.4572
CB-X-G-E-conv-1	-1.5357	-0.0325	-1.4707
CB-X-G-E-inf-mw-24	-1.5227	-0.0195	-1.4837
CB-X-G-E-inf-mw-1	-1.5152	-0.0120	-1.4912

Bread Formulation = CB-X-G-E-inf-mw-48subtracted from:

Bread Formulation	Lower	Center	Upper

CB-conv-1	-0.2402	1.2630	2.7662
CB-inf-mw-24	-1.5682	-0.0650	1.4382
RB-X-G-E-conv-24	-1.5632	-0.0600	1.4432
CB-X-G-E-conv-48	-1.5467	-0.0435	1.4597
RB-X-G-E-inf-mw-1	-1.5267	-0.0235	1.4797
CB-inf-mw-1	-1.5217	-0.0185	1.4847
RB-X-G-E-conv-1	-1.5672	-0.0640	1.4392
CB-X-G-E-conv-24	-1.5562	-0.0530	-1.4502
CB-X-G-E-conv-1	-1.5427	-0.0395	-1.4637
CB-X-G-E-inf-mw-24	-1.5297	-0.0265	-1.4767
CB-X-G-E-inf-mw-1	-1.5222	-0.0190	-1.4842

Bread Formulation = CB-conv-1 subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-24	-2.8312	-1.3280	0.1752
RB-X-G-E-conv-24	-2.8262	-1.3230	0.1802
CB-X-G-E-conv-48	-2.8097	-1.3065	0.1967
RB-X-G-E-inf-mw-1	-2.7897	-1.2865	0.2167
CB-inf-mw-1	-2.7847	-1.2815	0.2217
RB-X-G-E-conv-1	-2.8302	-1.3270	0.1762
CB-X-G-E-conv-24	-2.8192	-1.3160	0.1872
CB-X-G-E-conv-1	-2.8057	-1.3025	-0.2007
CB-X-G-E-inf-mw-24	-2.7927	-1.2895	-0.2137
CB-X-G-E-inf-mw-1	-2.7852	-1.2820	-0.2212

Bread Formulation = CB-inf-mw-24subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-24	-1.4982	0.0050	1.5082
CB-X-G-E-conv-48	-1.4817	0.0215	1.5247
RB-X-G-E-inf-mw-1	-1.4617	0.0415	1.5447
CB-inf-mw-1	-1.4567	0.0465	1.5497
RB-X-G-E-conv-1	-1.5022	0.0010	1.5042
CB-X-G-E-conv-24	-1.4912	0.0120	1.5152
CB-X-G-E-conv-1	-1.4777	0.0255	1.5287
CB-X-G-E-inf-mw-24	-1.4647	0.0385	1.5417
CB-X-G-E-inf-mw-1	-1.4572	0.0460	1.5492

Bread Formulation = RB-X-G-E-conv-24subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-48	-1.4867	0.0165	1.5197
RB-X-G-E-inf-mw-1	-1.4667	0.0365	1.5397
CB-inf-mw-1	-1.4617	0.0415	1.5447
RB-X-G-E-conv-1	-1.5072	-0.0040	1.4992
CB-X-G-E-conv-24	-1.4962	0.0070	1.5102
CB-X-G-E-conv-1	-1.4827	0.0205	1.5237
CB-X-G-E-inf-mw-24	-1.4697	0.0335	1.5367
CB-X-G-E-inf-mw-1	-1.4622	0.0410	1.5442

Bread Formulation = CB-X-G-E-conv-48subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-inf-mw-1	-1.4832	0.0200	1.5232

CB-inf-mw-1	-1.4782	0.0250	1.5282
RB-X-G-E-conv-1	-1.5237	-0.0205	1.4827
CB-X-G-E-conv-24	-1.5127	-0.0095	1.4937
CB-X-G-E-conv-1	-1.4992	0.0040	1.5072
CB-X-G-E-inf-mw-24	-1.4862	0.0170	1.5202
CB-X-G-E-inf-mw-1	-1.4787	0.0245	1.5277

Bread Formulation = RB-X-G-E-inf-mw-1subtracted from:

Bread Formulation	Lower	Center	Upper
CB-inf-mw-1	-1.4982	0.0050	1.5082
RB-X-G-E-conv-1	-1.5437	-0.0405	1.4627
CB-X-G-E-conv-24	-1.5327	-0.0295	1.4737
CB-X-G-E-conv-1	-1.5192	-0.0160	1.4872
CB-X-G-E-inf-mw-24	-1.5062	-0.0030	1.5002
CB-X-G-E-inf-mw-1	-1.4987	0.0045	1.5077

Bread Formulation = CB-inf-mw-1subtracted from:

Bread Formulation	Lower	Center	Upper
RB-X-G-E-conv-1	-1.5487	-0.0455	1.4577
CB-X-G-E-conv-24	-1.5377	-0.0345	1.4687
CB-X-G-E-conv-1	-1.5242	-0.0210	1.4822
CB-X-G-E-inf-mw-24	-1.5112	-0.0080	1.4952
CB-X-G-E-inf-mw-1	-1.5037	-0.0005	1.5027

Bread Formulation = RB-X-G-E-conv-1subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-24	-1.4922	0.0110	1.5142
CB-X-G-E-conv-1	-1.4787	0.0245	1.5277
CB-X-G-E-inf-mw-24	-1.4657	0.0375	1.5407
CB-X-G-E-inf-mw-1	-1.4582	0.0450	1.5482

Bread Formulation = CB-X-G-E-conv-24subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-conv-1	-1.4897	0.0135	1.5167
CB-X-G-E-inf-mw-24	-1.4767	0.0265	1.5297
CB-X-G-E-inf-mw-1	-1.4692	0.0340	1.5372

Bread Formulation = CB-X-G-E-conv-1subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-24	-1.4902	0.0130	1.5162
CB-X-G-E-inf-mw-1	-1.4827	0.0205	1.5237

Bread Formulation = CB-X-G-E-inf-mw-24subtracted from:

Bread Formulation	Lower	Center	Upper
CB-X-G-E-inf-mw-1	-1.4957	0.0075	1.5107

APPENDIX B

DSC THERMOGRAPHS

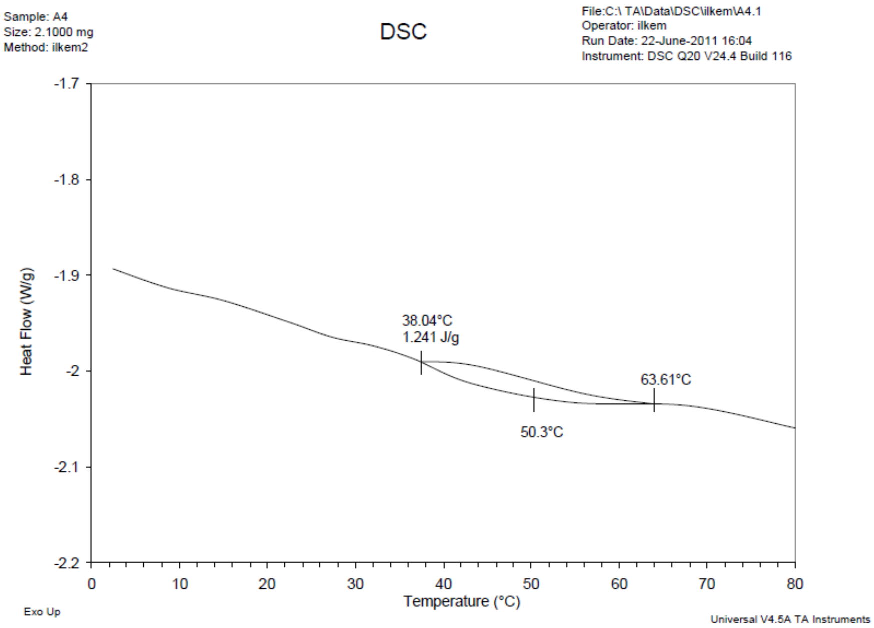

Fig B.1 DSC thermograph of chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture baked in infrared-microwave combination oven and stored for 24 h.

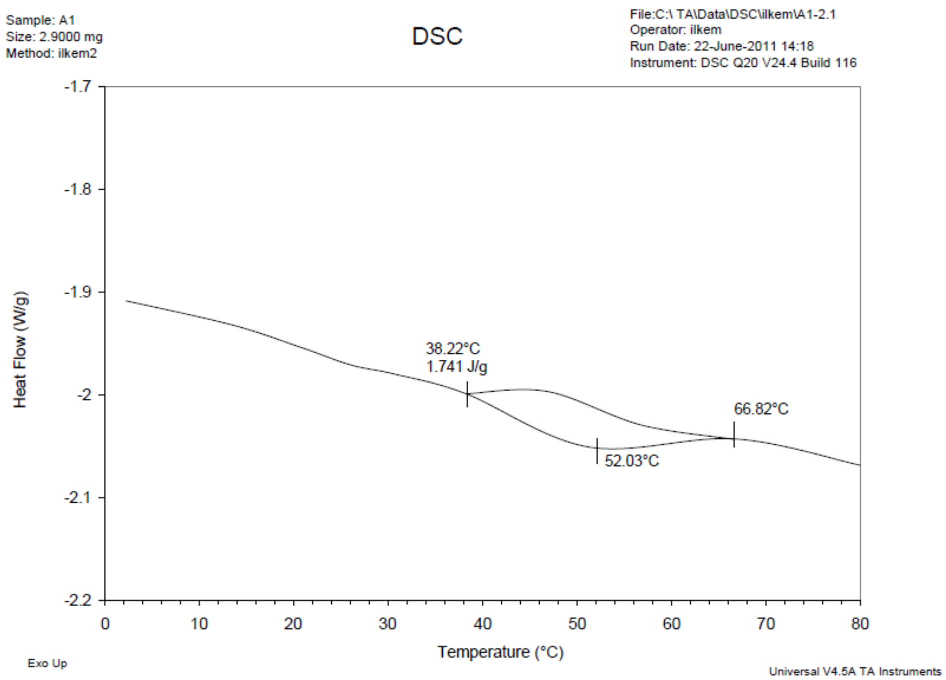

Fig. B2. DSC thermograph of chestnut-rice bread containing xanthan-guar gum blend-DATEM mixture baked in infrared-microwave combination oven and stored for 96 h.

CURRICULUM VITAE

İlkem Demirkesen Mert was born in Nevşehir on March 29, 1982. She was graduated from Food Engineering Department of Ankara University in 2005. She worked as a research assistant in Food Engineering Department of Middle East Technical University for eight years (September 2005-June 2013). She continued the research at Purdue University, USA between august 2011-august 2012. She has been working in Republic of Turkey Ministry of Food, Agriculture and Livestock, since May 2013.

Her publications are listed below:

A. Full Paper Published In International Journals

Demirkesen, I., Kelkar, S., Campanella O. H., Sumnu, G., Sahin, S.**,** Okos, M. Characterization of structure of gluten-free breads by using X-ray microtomography: Relationship between microstructure and quality characteristics. Food Hydrocolloids, in review.

Demirkesen, I., Campanella O. H., Sumnu, G., Sahin, S., Hamaker, B. A study on staling characteristics of gluten free breads prepared with chestnut and rice flours. Food and Bioprocess Technology. DOI:10.1007/s11947-013-1099-3.

Demirkesen, I., Sumnu, G., Sahin, S. Image analysis of gluten-free breads prepared with chestnut and rice flour and baked in different ovens. Food and Bioprocess Technology, DOI:10.1007/s11947-012-0850-5.

Demirkesen, I., Sumnu, G., Sahin, S, Eroğlu, M. M. Quality of gluten-free bread formulations baked in different ovens. Food and Bioprocess Technology, DOI: 10.1007/s11947-011-0712-6.

Demirkesen, I., Sumnu, G., Sahin, S., Uysal., N., 2011. Optimization of formulations and infrared-microwave combination baking conditions of chestnut-rice breads. International Journal of Food Science and Technology, 46, 1809–1815.

Demirkesen, I., Mert, B., Sumnu, G., Sahin, S., 2010. Utilization of chestnut flour in gluten-free bread formulations. Journal of Food Engineering, 101, 329-336.

Demirkesen, I., Mert, B., Sumnu, G., Sahin, S., 2010. Rheological properties of gluten-free bread formulations. Journal of Food Engineering, 96, 295–303.

B. Conference Papers (National)

Demirkesen, I., Sumnu, G., Sahin, S. Farklı fırınlarda pişirilen kestane ve pirinç unu içeren glütensiz ekmeklerin görüntü analiz yöntemi ile incelenmesi, 11. Türkiye Gıda Kongresi, poster sunumu, Ekim 10-12, 2012, Hatay, Türkiye

Demirkesen, I., Mert, B., Sumnu, G., Sahin, S. Glutensiz ekmek hamurlarının reolojik özellikleri, 6. Gıda Kongresi, sözlü bildiri, Aralık, 6-8, 2009, Antalya, Türkiye.

B. Conference Papers (International)

Demirkesen, I., Campanella O. H., Sumnu, G., Sahin, S.**,** Hamaker, B. Effects of chestnut flour on staling characteristics of gluten-free breads. International conference on food engineering and biotechnology (ICFEB), poster presentation, May 19-20, 2013, Copenhagen, Denmark.

Demirkesen, I., Kelkar, S., Campanella O. H., Sumnu, G., Sahin, S.**,** Okos, M. Characterization of structure of gluten-free breads by using X-ray microtomography. Euro FoodChem XVII, oral presentation, May, 07-10, 2013, Istanbul, Turkey.

Demirkesen, I., Sumnu, G., Sahin, S. Image analysis of gluten free breads prepared with chestnut and rice flour and baked in infrared-microwave combination oven. 11 th International Food Hydrocolloids Conference (IFHC), poster presentation, May 14-18, 2012, Whistler Center for Carbohydrate Research, Purdue University, USA.

Demirkesen, I., Sumnu, G., Sahin, S. Utilization of chestnut flour in gluten-free cakes. 6th International CIGR Technical Symposium, poster presentation, April 18-20, 2011, Nantes, France.

Demirkesen, I., Sumnu, G., Sahin, S. Development of gluten-free bread formulations using chestnut and rice flour combinations. International Food Technology (IFT), poster presentation, July 17-20, 2010, Chicago, USA.

Demirkesen, I., Mert, B., Sumnu, G., Sahin. Rheological properties of gluten-free bread formulations using chestnut and rice flour combinations. Second International Symposium onGluten-free cereal products and beverages, poster presentation, June 8-11, 2010, Tampere, Finland.

Demirkesen, I., Sumnu, G., Sahin, S. Development of gluten-free rice breads to be baked in infrared-microwave oven. 43rd Annual International Microwave Power Symposium (IMPI), poster presentation, July 8-10, 2009, Washington DC, USA.

PROJECT WORK

Middle East Technical University, Department of Food Engineering, Research Topic: "Optimization of gluten-free bread formulations to be baked in infrared-microwave combination oven", Researcher, BAP-08-11- DPT.2002K 120510, 2007-2011.

HONORS-AWARDS-SCHOLARSHIPS

Project award, at the first place of Bas Döndüren Fikirler, Yıldız Holding, 2013. Project Title: Sürekli Kızılötesi-Mikrodalga Fırınların Tasarım ve Uygulaması.

Scholarship from YOK (The Council of Higher Education), August 2011-August 2012, Visiting Scholar at Department of Agricultural and Biological Engineering, Purdue University, West Lafayette, Indiana, USA.

Scholarship from TUBITAK (The Scientific and Technological Research Council of Turkey) for PhD education, 2006-2010.

Dean's High Honor Lists, 8 semesters, 2001-2005.

Graduation from B.Sc. at the first place of Food Enginnering Department and second place of Faculty of Engineering, 2005 (GPA 3.86/4.00)