UTILIZATION OF INULIN AS FAT REPLACER IN CAKE AND MAYONNAISE

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ABSTRACT

UTILIZATION OF INULIN AS FAT REPLACER IN CAKE AND MAYONNAISE

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The objective of this study was to analyze microfluidized and non-microfluidized inulin and their effects on rheology, texture, quality, staling of cake and rheology of mayonnaise as fat replacer. In the first part of the study, the effects of microfluidized and non-microfluidized inulin emulsion on rheological properties of cake batter and mayonnaise were evaluated. Inulin emulsions with concentrations of 15%, 22.5% and 30% (w/w) were used to replace 25%, 50%, 75% of oil in cake samples.

In mayonnaise samples, inulin emulsions with concentrations of 15%, 22.5% and 30% were used to replace 12.5%, 25% and 37.5% of oil. The significant effect of different inulin percentages were determined by ANOVA statistical program. The highest shear stress, elastic modulus and viscous modulus was obtained for 30% microfluidized inulin with 75% oil replacement of cake samples and 30% microfluidized inulin with 37.5% oil replacement of mayonnaise sample.

In the second part of the study, textural properties (hardness, adhesiveness and cohesiveness), physical properties (color and weight loss) and staling of baked cake samples (hardness, adhesiveness and cohesiveness) after 2 and 4 days of storage were evaluated. Samples prepared with 30% microfluidized inulin emulsion and 75% of oil replacement.

Keywords: Inulin, Cake baking, Mayonnaise, Rheology, Texture

ÖZ

KEK VE MAYONEZ YAĞ IKAMESI OLARAK INULIN KULLANIMI

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Yüksek Lisans, Gıda Mühendisliği Bölümü

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Bu çalışmanın amacı; mikroakışkanlaştırılmış ve mikroakışkanlaştırılmış olmayan inülini, onun kekin reolojisi, yapısı, bayatlaması, kurutulması ve yağ yerine kullanılan mayonezin reolojisi üzerindeki etkilerini analiz etmektir. Çalışmanın ilk aşamasında, mikroakışkanlaştırılmış ve mikroakışkanlaştırılmış olmayan inülin emülsiyonunun kek yağı ve mayonezin reolojik özellikleri üzerindeki etkileri ölçülmüştür. %15, %22,5 ve %30'luk İnülin emülsiyonları, kek örneklerindeki %25, %50 ve %75'lik yağ yerine kullanılmıştır. Mayonez örneklerinde %15, %22,5 ve %30'luk inülin emülsiyonları %12.5, %25 ve %37.5'luk yağ yerine kullanılmıştır. inülin yüzdelerinin anlamlı etkisi ANOVA istatistik testi ile belirlenmiştir. En yüksek kayma gerilmesi, elastikiyet modülü ve akışkanlık modülü; kek örneklerinde, %75'lik yağ yerine %30'luk mikroakışkanlaştırılmış inülin ve %37.5'luk yağ yerine %30'luk mikroakışkanlaştırılmış inulin mayonez örnekleri için elde edilmiştir. Ikinci aşamasında, yapısal özellikler (sertlik, adhezyonluk ve kohezyonluk), fiziksel (renk ve ağırlık kaybı) ve pişirilmiş kek örneklerinin bayatlama özelliği (sertlik, adhezyonluk ve kohezyonluk) ölçülmüştür. %75'lik yağ yerine %30'luk mikroakışkanlaştırılmış inülin emülsiyonu ile hazırlanmış örneklerde, en yuksek sertlik ve adhezyonluk ve en düşük kohezyonluk elde edilmiştir

Anahtar kelimeler: Inulin, Kek pişirme, Mayonez, Reoloji ve Tekstür

To My Beloved Family

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MF	Microfluidized
MFI	Microfluidized Inulin
NON-MFI	non-microfluidized inulin
IN	inulin

CHAPTER 1

INTRODUCTION

1.1 Inulin

Inulin is considered as a heterogeneous blend of fructose polymers act in nature as plant storage carbohydrates (Akalin et al., 2008). Inulin is formed with some fructose as subunits connected by the bondβ（1→2） which terminal is the unit of glucose. The degree of polymerization is from 2 to 60, generally, the average degree is 10.

Formula: C6nH10n+2O5n+1

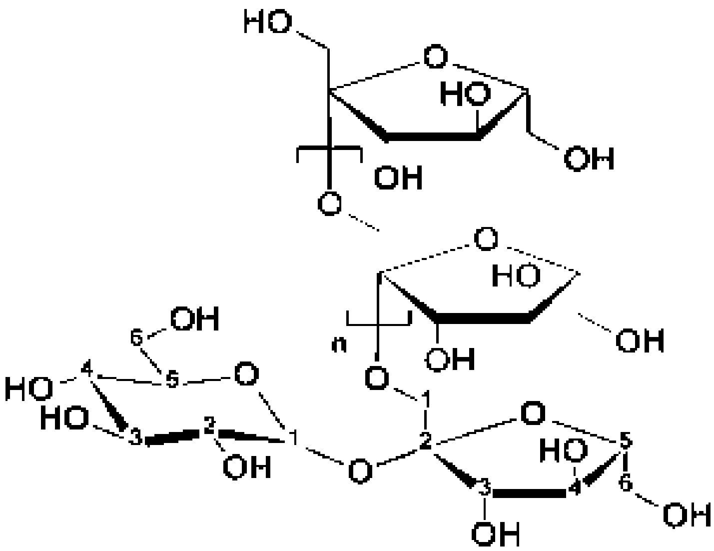

Figure 1.1 Inulin

They are a group of natural polysaccharides produced by many types of plants, industrially most often extracted from chicory. Inulin belongs to a class of dietary fibers known as fructans which is used by some plants as a means of storing energy and is typically found in roots or rhizomes. Most plants that synthesize and store inulin do not store other forms of carbohydrate such as starches. Common sources of this starchy substance are fruits, vegetables, and herbs, including wheat, onions, bananas, leeks, artichokes, and asparagus.

Table 1.1 Inulin content of few food sources

Source	Inulin (g/100g)
Raw onion bulb (Allium cepa)	1.1–7.5
Jerusalem artichoke tuber (Helianthus tuberosus)	16.0–20.0
Chicory root (Cichorium intybus)	35.7–47.6
Asparagus raw (Asparagus officinalis)	2.0–3.0
Garlic (Allium sativum)	9.0–16.0
Wheat (flour baked) (Titicum sp.)	1.0–3.8
Barley (raw cereal)-(Hordeum vulgare)	0.5–1.0

Source: Tungland

Inulin has so many sources among which chicory root is mostly used by industry. Inulin is stored as reserve carbohydrate in the fleshy taproot of chicory, which is equal to 15–20% inulin; thus, it can be considered as concentrated source of inulin. Inulin is officially recognized as a natural food ingredient in all European Union and has a self-affirmed Generally Recognized as Safe (GRAS) status in United States (Nair et al., 2010).

1.1.1 Health Concern

Inulin has a reduced caloric value due to not being digested in the upper gastrointestinal tract. β (2,1) bonds are also effective for being low calorie which link the fructose molecules (Nair et al., 2010). It goes to the bowels where bacteria are able to use it to grow. Inulin stimulates the growth of intestinal bifidobacteria and at the same time it does not rise serum glucose or stimulate insulin secretion. These bacteria are associated with improving bowel function and general health (Niness, 1999).

In a study conducted by Kaur and coworkers (2002), significant reduction of the triglyceride content of blood and liver was observed when inulin was included into the diet of saturated fat fed rats. According to another study carried out by Trautwein and coworkers, a significant reduction in plasma total cholesterol by 29% was noticed. It is obvious that inulin has great influence on lipid metabolism.

Inulin enhances mineral bioavailability probably due to its osmostic effect that transfers water into large intestine (Niness, 1999). According to Delzenne et al. (2004), in the growing rats fed diets with chicory fructans, a significant increase for about 60% in calcium and magnesium absorption as well as iron and zinc balance was observed. Along with these health concerns, inulin could reduce glucose intake which led to postprandial hyperglycemia reduction according to the study conducted by Kim and Shin.(1989) Thus, it is suggested that food containing inulin can be healthy for diabetics.

Inulin decreases the body's ability to make certain kinds of fats; thereby it plays functional roles and possesses nutritional properties, which can be used to formulate innovative healthy foods for today’s consumer.

1.1.2 Functions

Inulin is increasingly used in processed foods because it has unusually adaptable characteristics. Food grade inulin has clean flavor which can improve the mouth feel, stability and acceptability of low fat foods (Nines, 1999). Oligofructose has a sweet and pleasant flavor which is highly soluble. Its flavor ranges from bland to subtly sweet (approx. 10% sweetness of sugar/sucrose).

It improves the flavor and sweetness of low calorie foods and texture of fat-reduced foods without creating any deleterious organoleptic effects. Therefore it can be used to replace sugar, fat, and flour. This is advantageous because inulin contains 25-35% of the food energy of carbohydrates (starch, sugar). In food formulations, inulin may significantly improve organoleptic characteristics.

Inulin can enhance emulsion and foam stability which can function as a great fat and carbohydrate replacer when used under the form of a gel in water. It does not compromise on taste and texture of the final product while contribute in enhancing nutritional properties as it is provided from chicory roots as a fat replacer. Inulin has been confirmed as a dietary fiber for food labeling by legal authorities according to these reasons (Australia New Zealand Food Authority):

1. It is plant extract, comprised of poly- and oligo-saccharides;
2. It is not digested by the enzymes of the human small intestine;
3. It is completely fermented in the large intestine;
4. It mildly increases stool mass, and can ease constipation; and
5. It can be reliably determined by an AOAC method of analysis.

So many studies and researches has been done about inulin and its functionality in different food products such as cheese, yogurt, dressing, bread, milk and dark chocolate.

According to a study about the effect of the addition of different fibers on wheat dough performance and bread quality (Rossel et al., 2002), it was shown that inulin enhances rheological properties of wheat dough without promoting negative effects on overall acceptability of the final product. It has been reported in the study of Hayaloglu et al, (2005) that the yogurt containing 1% of inulin was similar in quality characteristics to control yogurt made with whole milk. Low fat salad dressing has been always in great demand of consumer. Adding inulin by 2 to 20 percent of weight was required to make low calorie salad dressing along with 0.8 percent of weight by xanthan (James, 1998). A desired quality of bread can also be achieved by using inulin since it can accelerate the formation of the bread crust and the maillard reaction. It even led to breads with an overall quality similar to that of non-enriched breads, but baked for a shorter time. Chocolate is considered as one of the most popular products among consumers. According to the study of Mohammadifar et al. (2012) in chocolate samples an inulin.-tagatose ratio of 25%-75% and 100% tagatose can be the best sucrose substitutes without any deleterious changes in organoleptic properties of the product. Regarding the studies that have been done through food industry, inulin is considered as a functional food ingredient that is eligible for enhanced function claims.

1.2 Fat replacer

Fat replacers are substitutes of fat in foods that gives texture and mouth feel similar to original fat in food products. Their main function is reducing calorie content of food. Fat replacers are categorized in three groups of carbohydrate-based, protein-based, or fat-based. Tables 1.2, 1.3 and 1.4 show some common fat replacers used in food industry.

Carbohydrate-based fat replacers such as processed starches imitate fat by binding water and providing lubricity and a pleasing mouth feel sensation (Bath, Shelke, & Hoseney, 1992; Nonaka, 1997). According to the study conducted by Inglett, Warner, & Newman (1994), 50% replacement of fat by soluble β-glucan and amylodextrins derived from oat flour resulted in cookies not significantly different from the full-fat ones, but at higher replacement levels moistness and overall quality were decreased. Fat substitution was carried out by pectin-, gum-, or oat-based fat mimetic in biscuits which led to tenderness increase (Conforti, Charles, & Dunkan, 1996).

Table 1.2 Carbohydrate-based fat replacers. Derived from Calorie Control Council, U.S. American Council on Science and Health (1997).

Carbohydrate-based fat replacers	Foods
Inulin	Yogurt, cheese, frozen desserts, baked goods, icings, fillings, whipped cream, dairy products, fiber supplements, processed meats
Maltodextrins	Dairy products, salad dressings, spreads, sauces, frostings, fillings, processed meat, frozen desserts, extruded products
Dextrins	Salad dressings, puddings, spreads, dairy-type products, frozen desserts
Gums	Bakery products, frozen desserts, sauces, soups, meats, pie fillings, yogurts, meats
Fiber	Frozen reduced fat bakery products
Polydextrose	Baked goods, chewing gums, confections, salad dressings, frozen dairy desserts, gelatins, puddings
carrageenan	Low fat deserts, cheeses, ground beef, hot dogs
Z-Trim	Baked goods, brownies, cheese, ice cream

Table 1.3 Protein-based fat replacers. Derived from Calorie Control Council, U.S. American Council on Science and Health (1997).

Protein-based fat replacers	Foods
Microparticulated Protein (simplesse)	Dairy products (ice cream, butter, sour cream, cheese, yogurt), salad dressing, margarine- and mayonnaise-type products, baked goods, coffee creamer, soups, sauces
Modified Whey Protein	Milk/dairy products (cheese, yogurt, sour cream, ice cream), baked goods, frostings, salad dressing,

Table 1.4 Fat-based fat replacers. Derived from Calorie Control Council, U.S. American Council on Science and Health (1997).

Fat-based fat replacers	Foods
Salatrim	Confections, baked goods, dairy
Emulsifiers	Cake mixes, cookies, icing, dairy products
Glycerol	baking, frying
Olestra	Salty snacks and crackers

Fat replacers are also used in meat products, sauces and soups. Meat products with reduced fat amount can be obtained with creamier and juicier taste and consistent stability due to water immobilization by use of fat replacers. In baked products, inulin as fat replacer creates proper binding characteristics in cereal bars, cookies and cakes (Franck, 2002).

Substituting 100% of the oil in cake formula with the fat replacer causes volume decrease, the crumb becomes less tender and the structure becomes uneven. It was proposed to add emulsifier to the formula in order to decrease the amount of fat by increasing interfacial tension in baked products. Fat containing mono- and diglycerides led to formulation of high-ratio cakes with good volume and texture properties (Matz 1960). Choosing the proper fat replacer for the specific food product depends on its multifunctional role in food matrix which determines the chemical, physical and sensory properties of the food. The more fat amount reduced in the product, the more important the type of chosen fat replacer would be. The fact that there are so many fat replacers being invented shows that this area is among the most powerful growth field in food industry (Roller and Jones, 1996).

Microparticulation was one of the first technological methods used for producing proper fat replacer such as simplesse. It is a protein-based fat replacer first introduced by NutraSweet Company which is based on whey protein concentrate (Singer et al., 1988). Microparticulation process contributes to mimic the actual fat droplets in an oil-in-water emulsion which results in improvement of fat replacer functions (Roller and Jones, 1996).

High fat food intake results in increased blood lipids and cardiovascular diseases. This risk can be reduced along with lowering fat consumption by using fat replacers in food production. Food industry can reduces diabetes, obesity and other health hazards by formulating fat replacer with lower calorie and better textural properties for the specified food product.

1.3 Cake and Cake Batter

Cake is baked product relished by consumers and available worldwide which is served as dessert in various forms at different occasions (Schirmer et al. 2012). Originally it is a small mass of dough baked by turning on a spit; in present usage a dessert made of flour, sugar, eggs, seasonings, usually some leavening and liquid besides the eggs, and shortening. The early method of making sweet cake was by adding other ingredients to a portion of bread dough (Isabel, 2013).

besides the eggs, and shortening. The early method of making sweet cake was by adding other ingredients to a portion of bread dough (Isabel, 2013).

Based on the recipe cakes can be divided in several categories such as high ratio or low ratio cakes. Layer cakes and egg foam cakes are included in the first classification and pound cakes in the latter which are considered as common cake types in bakery industry (Delcour & Hoseney, 2010). Modern cakes are generally raised with baking powder, baking soda, or beaten eggs. By adding other ingredients other than the main ones which are water, flour, sugar, milk, egg, salt and fat, cake types can vary in a wide range.

Table 1.5 List of types of cakes. Derived from Kayaki et al. (2001)

Name	origin	Main ingredients
Ice cream cake	United kingdom	Ice cream
Angel food cake	United kingdim	Sponge cake, cream
Apple cake	Germany	Apple, caramel icing
Banofee pie	United kingdom	Bananas, toffee, biscuits
Bibingka	Philippines	Coconut milk and rice flour
Hot milk cake	United states	Milk and mocha
King cake	France	Sugar, cinnamon, milk, and butter

Cake batter is the result of mixing of dry ingredients throughout liquid phase with specific whipping rate and time. The dry ingredients, such as sugar, flour, salt and baking powder are incorporated into the liquid phase but the fat or oil phase remains dispersed in lakes or clumps throughout the continuous or liquid phase and does not become part of the liquid phase (Painter, 1981). This process leads to oil in water emulsion which rheological properties may vary by changing proportion of the ingredients. Thus, cake batters are oil-in-water emulsions with four bulk phases considered as aqueous, fat, gas, and solid starch granules. The physical and rheological properties of the batters for cake baking have a significant role in determining the characteristics of the final cakes. Among the physical properties of interest, viscosity appears to be particularly important, because it undergoes considerable changes during the baking process (Shelke et al., 1990). Mixing method can also affect batter properties. It can be classified as single or multi stage mixing. Uniform batter can be achieved through single stage mixing while air bubbles are incorporated in batter by the latter (Conforti, 2006).

Rheological properties of batter are highly determined by the ingredients such as volume and texture. Shortening and sugar contributes increasing volume and hardness respectively whereas aqueous phase viscosity is increased due to flour addition (Shepherd & Yoell, 1976). Chemical reactions occurred by mixing process includes production of carbon dioxide and air bubbles due to leaving agents and water vapor rises during baking which results to final product expansion. Temperature plays an important role in cake batter and cake baking stages. Temperature distribution in the product which is generally higher at surface, bottom and center respectively, could affect moisture migration. Moisture moves by thermal gradient regardless of the concentration gradient from the hotter to the colder part which can affect textural properties of the product (Marcotte et al., 2000). It is obvious that discussing the ingredients is as necessary as baking stages and the ingredients can change final products properties.

1.3.1 Ingredient’s Role in Cake Baking and mayonnaise

Ingredients chosen for the cake formula affect rheological, textural and sensory properties of the final product. It is important to analyze the function of all the ingredients used in the bakery product in order to obtain the desired firmness, moistness, cohesiveness and shelf life which is required by the consumer.

1.3.1.1 Shortening

Shortening is defined as edible fat which tenderizes baked goods and keep them softer after baking through being insoluble in water and therefore limiting cohesion of gluten during mixing process. Gluten strands would form a tough meshwork structure in the absence of fat. Shortening is a mixture of triglycerides having widely different melting points. Shortening also acts as a foaming/whipping agent in the aeration process of batters to achieve the required volume of the baked products. In addition to modifying the mouth feel or texture, they often add flavour of their own and tend to round off harsh notes in some of the spice flavours. Emulsifiers may be used along with shortenings which can be listed as lecithin, mono- and diglycerides of fatty acids, propylene glycol mono- and diesters of fatty acids, diacetyl tartaric acid esters of mono- and diglycerides of fatty acids. These emulsifiers have important role in tenderization, anti-staling, lubrication, and aeration of batter (Bodor et al., 1994). According to Shahidi, (2005) Emulsified shortenings results in producing moister, higher volume along with extended shelf life cakes and finer texture. Higher volume is achieved through retaining leaving gas in the cake. Beside tenderizing and moisturizing the cake, fats can delay gelatinization by delaying the transport of water into the starch granule due to the formation of complexes between the lipid and amylose during baking process (Elliasson, 1985). Dough expands more easily when shortening is included in the formula and at the same time, shortening prevents stickeness, and reduces the amount of dusting flour which is necessary during mixing process. Shortening used for cakes should cream readily to facilitate incorporation of air into the batter (Shahidi, 2005).

Fats used in cake baking create three major rheological properties such as consistency, plasticity and texture. Air is dispersed into the solid phase as sugar is mixed with shortening. Other ingredients such as flour, water or any other liquid can be added to the formula during mixing process. In this two stage process, air is trapped in shortening but in one stage batter making process, all the ingredients are mixed at the beginning. In this case air bubbles are trapped in water phase (Shahidi, 2005).

Solid fat content (SFC) is an important parameter in oil industry. It is referred to the percentage of solids in fat at specified temperatures. Solid fat content can influence appearance, flavor release, melt rate, shelf life and stability of fat based food mostly bakery products (Lida, 2002). Measurement of this parameter is carried out by nuclear magnetic resonance (NMR) technique. Gribnau (1997) studied solid content measurement by low-resolution NMR (LR-NMR). The advantages of this technique over classical methods such as dilatometry that measures the expansion of a fat as it is heated were higher speed, more convenience and lower cost per measurement. It is important to determine melting point of the shortening at different temperatures. Shortenings must have a defined melting point to make sure that chocolate melts properly in mouth or spread is used for sandwiches without their consistency changed over different environments.

Table 1.6 Solid fat content (SFC) in different temperatures

	Solid fat content (SFC) in %, according to IUPAC 2.150a			
Temperature	20 ^{0}C	25 ^{0}C	30% ^{0}C	35% ^{0}C
Oil product	55	36	16	3

Table 1.6 shows the solid fat content of the oil invented by Bach and Juul (2006), which is considered as low-lauric and low-trans fat composition along with fast solidification rate. As it is seen in the table 1.6, the difference between SFC at 2O^{0}C and SFC at 35^{0}C is greater than 35%. In IUPAC method, samples are not heated, in fact measurements are taken after cooling the sample at 0^{0}C for 30 minutes but in AOCS (American oil chemists' society) fat is cooled at 0^{0}C for 15 minutes, then heated at 26.7^{0}C for 30 minutes and cooled again at 0^{0}C for 15 minutes (Marangoni and Narine, 2002).

1.3.1.2 Flour

Flour used for cake manufacture is low-protein and from endosperm of soft wheat which has low starch damage. Starch damage means more water needed for preparing dough in comparison with normal cake flour which results from flour treatment after milling (McMullen et al., 2014). It aims to obtain a light; fluffy cake with a tender crumb. Flour obtained from rice and corn may not be suitable for cake as they do not have the gluten protein that is unique to wheat.

Wheat flour is a main ingredient for convectional cake baking (Fellers & Bean, 1988). It has a protein content of about 8% and is usually bleached, which gives it a very fine texture and a very light color. Thus, it gives a tender texture to the final product. Cake flour should be milled finely to prevent baked product from getting heavy. At the same time, it should be bleached in order to break down the protein present in the flour and make it white. To decrease the strength of the gluten, flour is chlorinated to have a smooth texture as a delicate tender crumb is desired. Chlorine gas creates high-ratio cake flour. Heat-treatment process can improve high-ratio cakes. After heat treatment, starch is combined with gluten which gives the flour desirable protein content for use in cake directly. Heat-treatment is applied within the range 100 to 140 C. Heating applied more than this range leads to more water amount requirement. In this case, baking temperature rises due to hydration of flour and denaturation of wheat proteins occurs which leads to higher batter viscosity as water solubility decreases. The gelation temperature of heat treated flour and/or starch is applied up to 0.5-1 C (Benoliel et al,. 1970). Moreover, characteristic of starch in flour is considered as a critical factor in high-ratio cakes (Gough et al,. 1978). Flour which is desired for cake manufacturing is starchy which can keep large amount of fat and sugar together.

Parameters such as protein, moisture, water absorbance and ash content of flour are analyzed in order to determine flour quality. (American Association of Cereal Chemists [AACC], 2000, No. 39-01, 39-01, 39-10, 39-11, 39-70A; International Association for Cereal Science and Technology, 1996, No. 156 and 202). Two methods have been applied to control moisture content of the flour by in the study conducted by Thomasson et al. (1995). For flour moisture less than 8%, the flour was placed in a cotton cloth and freeze-dried to the desired moisture. For flour moisture more than 8%, the flour was spread evenly in an aluminum pan and dried in a convection oven at 350 °C until the required moisture was obtained. It is obvious that moisture content of flour is of great importance as so many studies have been carried out about it. Heat treatment at normal moisture of flour which is usually considered as 13%, leads to an improved cake volume. Flour particle size is another factor which highly affects cake volume. Cake volume increases as the flour particle size decreases depending on wheat type which results in finer cake quality (Gaines and Donelson1985).

1.3.1.3 Egg

Egg is a functional ingredient for cake manufacturing. It is a key factor for emulsion formation and stabilization. Egg is made up of egg white and egg yolk which are separated by vitelline membrane and each of them has different functions. Their weight basis is considered as 11% shell, 58%egg white and 31% egg yolk of total weight (Campbell, Raikos, & Euston, 2003).

Formation of a stable emulsion requires lower interfacial surface tension. Egg yolk contains livetin and lipoproteins lower this tension at oil-water interface. Egg white proteins do not contribute to this issue (Kiosseoglou, 2004). Yolk proteins form a film round fat molecules.

Beside batter rheology, egg contributes to the cake texture during baking. At this stage, egg white is more active than egg yolk. Gas cells are trapped in fat phase during batter mixing. At baking process these gas cells are released to the aqueous phase as the fat crystals melt, the egg white proteins stabilize the gas cells. At the end of baking process, semi-liquid batter transforms into foam due to starch gelatinization and coagulation of egg protein. Proteins in egg white which involve in foam formation and stabilization are globulin and ovomucin. Foam stability can increase by interaction between lysozyme-ovomucin or ovotransferrin-ovalbumin (Weijers, van de Velde, Stijnman, van de Pijpekamp, & Visschers, 2006).

Moreover, egg involves in other functions in cake making such as creating favorable color (Sumnu & Demirkol, 2007), toughening as egg white improve starch gelatinization and tenderizing as egg yolk contains fat.

1.3.1.4 Salt

Salt not only creates its own specific flavor on the product, it is also used to enhance and modify the flavour of other ingredients. The reasons for using salt can be divided into three general categories: processing reasons, sensory and taste properties, and preservative aspects. In some cases it performs all three of these functions (Hutton, 2002). Salt affects the product five times greater than the sugar (E.B. Bennion, A.J. Bent, G.S.T. Bamford, 1997). It can improve crust color by reducing the caramelization temperature of dough (Sumnu and Sahin, 2008).

1.3.1.5 Water

Water is a key factor for keeping qualities and structure of baked products. The amount of water added to the ingredients should be controlled during batter preparation, baking, cooling and storage in order to optimize final product quality (Stanley P Cauvain, Linda S Young, 2008). Water solves soluble ingredients such as salt and sugar and results in creation of a homogenized batter.

Its function is as important as flour in cake. The proportion used in the recipe plays an important role in texture and shelf life of the final product. Water quality should be analyzed from the aspect of taste, chemical content and mineral content. The source of water should be the same as drinkable water.

To obtain desired dough characteristics, it is important to determine sufficient amount of water to hydrate the flour. A large amount of water will create softer dough while a lower amount of water will generate dough with a stiffer texture. Depending to the amount of water, sticky dough and dry dough can be obtained. After baking process, evaporated water should be released into the air; otherwise cake will reabsorb it which can affect texture of the final product (David S. Reid 2009).

Water content is referred to available free content in the product but not the water content. Humidity of the product relates to the chemical compound, temperature, water content, storage environment, absolute pressure and packaging which directly affect the shelf life (Kocak, 2010).Water can positively change cake quality if proper amount and source is determined.

1.3.1.6 Sugar

The most common sugar used in cake making is sucrose and considered as table sugar. It is made up of one molecule of fructose and one molecule of glucose linked by an an a-(1,2) glycosidic bond (Bennion & Bamford, 1997). It is obtained from sugar cane or sugar beets and gives sweet taste to the final product.

Purified sugar and raw sugar are two main classifications which differ in their process. Raw sugar is used for products related to health concern but the taste and the color is not acceptable in comparison with white sugar.

Sugar amount used in batter affects rheological properties and it is necessary to be studied. During cake batter mixing sugar breaks down crystal aggregates into crystals of smaller size during creaming step due to its abrasive effect on fat molecules. At the same time it decreases viscosity and stability as dissolves in batter (Bennion & Bamford, 1997). Sugar decreases water activity of the batter which leads to prevention of gluten formation. Sugar increases egg white protein denaturation temperature up to 13 °C by reducing water activity when added to the batter (Donovan, 1977). It also increases the thermal stability of proteins in aqueous solutions by changing their hydration properties (Kaushik & Bhat, 1998; Uedaira & Uedaira, 1980).

Sugar has many functions in cake baking which comprises different aspects such as controlling setting temperature, and thus oven rise, structure fixation and collapse. The volume of bakery products such as sponge cake and cupcake can be increased by adding sugar up to 50% sugar to water ratio (Delcour et al., 2010). Sugar can increase shelf life of the final product by bounding to water and lowering microorganism growth through the cake and at the same time it creates pleasant color through milliard reaction and caramelisation.

It is obvious that sugar is an important ingredient not only in cake making but also in all bakery industry as it affects the final product with different aspects such as controlling setting temperature, and thus oven rise, structure fixation and collapse (Delcour et al., 2010).

1.3.1.7 Leavening Agent

Leavening agents are a group of inorganic salts such as ammonium, sodium bicarbonates and baking powder which are commonly used in soft wheat products such as cakes. Their important role in dough makes them inevitable for cake recipe. They produce gases through chemical reactions leading to a porous texture in final bakery product (Gokmen et al., 2007). Volume of the bakery product can be affected by air incorporation into the batter and the ability of the batter to entrap leavening gases released from the baking powder used in the formula (Masoodi et al., 2000). It has been reported that the fat has shortening effect on bakery products which reduces resistance to gas pressure. Thus, the more fat amount used in the formula, the less baking powder is needed to aerate the product (Bennion and Bamford, 1997).

Air is incorporated in beaten egg whites by creaming shortening and mixing viscous batter and vapor is produced from water during baking process. Decomposition of bicarbonate and chemical reaction of sodium bicarbonate with an acid leads to carbon dioxide formation in the product. Air, vapor and carbon dioxide are all considered as leavening gases, but removing baking powder from the formula led to a compact structure of cake with lower volume (Hood and Lowe, 1948). Carbon dioxide is the main reason of cake volume which is followed by water vapor and air. Air is only responsible for a small proportion of volume increase in cakes.

Baking powders usually made up of an alkali component (sodium bicarbonate), acidic salts and filling material such as corn starch. They are soluble in water and as a result they produce carbon dioxide gas due to the reaction between alkali and acid (Dizlek, 2008).

Carbon dioxide can be produced through thermal decomposition of dissolved ammonium bicarbonate by this formula:

$$NH_4HCO_3 \rightarrow NH_3 + CO_2 + H_2O$$

Ammonia produced by this reaction will not leave taste if it completely escapes to the environment. Another chemical reaction that leads to carbon dioxide production is heating sodium bicarbonate:

$$2NaHCO_3 + heat \rightarrow Na_2CO_3 + CO_2 + H_2O$$

Sodium carbonate produced by this formula creates an unpleasant taste in the baked product and effects crumb color. Acid is used with sodium bicarbonate in order to prevent sodium carbonate production and the related bad taste:

$$NaHCO_3 + H^+ \rightarrow Na^+ + CO_2 + H_2O$$

According to this formula, acid is added to sodium bicarbonate in baking powder (Penfield and Campbell, 1990).

1.3.1.8 Vinegar

Vinegar is considered as a mild liquid acid which gives flavor and nutrients to so many food products such as mayonnaise. Its production is based on fermentation of medium containing ethanol by acetic acid bacteria. There are several factors that affect vinegar quality such as fermentative properties of bacteria, culture medium and the conditions applied to the production process (Nakayama, 1959). Grape wine and date are mostly used for preparation of vinegar leaving it to turn sour (Forbes, 1971).

Beside the flavor properties of food products obtained by vinegar, health concerns are of great importance. Daily intake of vinegar can be effective in the prevention of metabolic syndrome by reducing obesity (Kondo et al., 2014).

1.3.2 Cake Quality

Components that are mainly used in cake baking process are flour, water, sugar, milk and salt, leavening agent, flavors and additives. The quality and quantity of these components are important and influence on the properties of the final product as well as the stability of quality during shelf life. Wide range of cakes with different properties can be produced due to quality and quantity changes of these ingredients. These can range from light to dense, rich, cakes (Jordan et al., 2013).

Three major factors determine cake quality:

- The proportionality of ingredients for the particular type of cake being baked
- A proper and balanced formula
- The optimum mixing and baking process (Cauvain & Cyster, 1996; Cauvain &Young, 2006).

These factors effect cake properties such as shelf life, volume, firmness, crumb structure, tolerance to stalling and proper gelatinization degree (Gomez et al., 2007). These properties determine quality acceptance by the consumer and should be measured in order to compare with the desired standards related to consumer's demand.

Some useful tests are available that can specify these properties. Assessing the level of acceptance is performed through the scale which is a simple rating scale used to compare products in a competitive category. Hiring experts as panelist is a common method for defining quality of the product by getting like and dislike scores (Resurreccion, 2008).

Texture properties of bakery products have been always of great importance since firmness of the product defines its quality. For measuring hardness of the baked cakes, Instrumental Texture Profile Analysis (TPA) can be used for most of bakery products. Other parameters that are included in texture properties of baked cake are springiness, adhesiveness, cohesiveness, gumminess and chewiness which can be measured by TPA in a two compression process of a specific dimension of the product. The hardness value is the peak force of the first compression of the product. The hardness does not need to occur at the point of deepest compression, although it typically does for most products. Cohesiveness is how well the product withstands a second deformation relative to how it behaved under the first deformation. Springiness is how well a product physically springs back after it has been deformed during the first compression. Chewiness is related the energy amount needed for crushing a solid food by teeth to a state ready for swallowing. The energy required to splinter a semisolid food to make it ready for swallowing is considered as gumminess. Adhesiveness refers to easiness of adhesion to an oral cavity wall, especially to the upper jaw caused by the bakery product coming into contact with saliva in mouth and containing moisture when it is put into the oral cavity by the consumer (Clerici et al. 2009).

Important quality parameters of cakes can include texture, color, moisture content, density, temperature and pH which can be measured by different methods and devices. pH has important effect on structure and the taste of cakes (Pyler, 1988). Thus, the pH can be viewed as one of the objective measurements for the quality control of cakes. Excessive low pH value will result in producing a cake with acidic, bitter flavor. Excessive high pH level will produce a soda or soapy taste to the cake. The pH value of the cake is usually due to its leavening compound. At the end of mixing process, sodium bicarbonate in a batter is completely dissolved in the aqueous phase. As the result, the initial pH of the batter is due to hydrogen ions produced by the leavening acid. Hence, it comes naturally from this ingredient (Castaigne et al., 2000). During the stage of batter mixing, temperature rise influences on the final cake quality (Pyler, 1988). This temperature rise will influence on the viscosity of the batter and at the same time both batter aeration and batter stability. Thus, batter temperature should be under control for the best effect on the physical property of the final product.

1.3.3 Staling of cakes

Quality of industrial cakes can be determined by shelf life and tolerance to staling (Dargue, 1975; Jones, 1994). Shelf life of cakes can vary between 1 to 4 weeks depending on water activity, packaging, storage temperature and specific formulation (Hodge, 1977). A balanced formula for producing cake can influence shelf life and staling of the final product. Staling can refer to a series of physical and chemical changes which can be listed as below (Cauvain, 1998):

- Water transfer from crust to crumb
- Loss of moisture to the atmosphere from cakes
- Retrogradation of starch fraction which leads to crumb firmness
- Increase in crumbliness when cake loses its cohesion
- Change or loss of aroma and taste of the cake

Ingredients play the most significant role in cake staling. Among the ingredients, flour is considered to be the most important. Cakes stale slower than breads due to containing more fat and less flour. As the result, lower amount of unstable starch might slow cake staling rate and partial replacement of native starch is being proposed for cake four (Kim and Walker, 1992).

Staling due to the cake ingredients is complex as different ingredients have different effect on staling mechanism and texture of the product. According to a study about cake staling (Pence and Standridge, 1958; Hodge, 1977), storage at 20 to 27 °C compared to 1 to 4 °C accelerates cake staling rate. Packaging films with high water permeability can also enhance cake stalling rate (Hodge, 1977). Anti-staling agents used in bakery industry are listed as emulsifiers (lecithin, SSL, DATEM, MG, POEMS, GMS) (Giese 1996), enzymes (amylases, proteases, pentosanases, glucose-oxidase, celullases, lipases) (Sahlstrom et af. 1997 and Rose11 et af. 2001), sweeteners (fructose, glucose, maltose, maltotriose, honey) (Squires et al. 1998), polyols (sorbitol , mannitol), hydrocolloids (pentosans, galactomans, alginates, xantans) (Yackel 1992), proteins (albumins, gluten) (Every et al. 1998).

1.4 Microfluidization

Microfluidization is regarded as a procedure that brings together heat and technical shear conditions to modify the natural small rounded structural conformation of necessary macromolecules to unique coils.

It is a proper substitution for homogenization which consists of processing emulsions under high pressure through an apparatus called a Microfluidizer. This new technology has a different reaction chamber geometry which can exceed pressures 10–15 times higher than classical homogenizers which leads to formation of the finely separated particles (Paquin, 1999).

Microfluidization transfers mechanical energy to fluid particles under high pressure. The solution is pumped and split into two microstreams and these high velocity fluid jet streams are collided against each other with a high speed in a chamber, called the interaction chamber, where shear, turbulent and cavitation forces are generated and particle separation occurs (Korstvedt, Nikopoulos, Chandonnet & Siciliano, 1985, Oza, 1990 and Microfluidics International Corporation, 1995).

The turbulence in the chamber is caused through collision of the two streams. This turbulence dissipates the kinetic energy of the fluid through viscous effects. The outcome will be the pressure drop or velocity decrease. This is necessary for prevention of separated particle's rebound. At the same time, sufficiently high turbulent forces would break the weakened bonds. The intensity of microfluidization forces in the chamber can be represented by interaction chamber pressure, P, and successful fragmentation would require $P>P_c$, where P_c is the critical pressure required for fragmentation (Charlet, Paguin and Arul, 2003).

Microfluidization can be applied through more than 1 pass in order to get the desired high volumes of emulsions with very small globule sizes. It results in the reduction particle size which affects the technofunctional properties of the final product. It allows a modification of the dispersed or suspended properties of the material such as cell rupture, dispersed particle size reduction resulting in nano-particles, emulsion, liposome or de-agglomeration.

Microfluidization process has received more and more attention in food technology due to the control they give on the microstructure and thus the technofunctional properties of food (Skurtys & Aguilera, 2008).

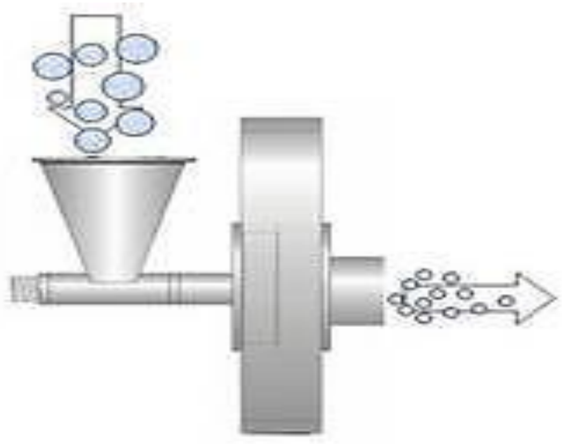

Figure 1.2 Microfluidization mechanism

Figure 1.2 illustrates whole the mechanism by which particle reduction occurs. This might be also an indirect indication of the microfluidization treatment resulting in transformation of large aggregates into small particles. These kinds of particles are functional in various ways such as being used as fat replacer, texturizer, and stabilizer in food products and controlled release microcapsules in cosmetic, pharmaceutical, and medical applications. Developments involved improved heat balance, emulsifying activity of these particles and physical functionalities. Among all these functions, being fat replacer is considered as the main issue for oil-in-water emulsion.

Regarding health care tasks, reducing the amount of fat intake will be so much beneficial. Along with this fact, fat replacers should create creamy taste and mouth feel in order to make microfluidized particles useful. Particles should be in such a small size that tongue cannot distinguish them separately. Generally the diameter of these particles should be in range of 0.1–3.0 μm. Obtaining this size is maintained through applying 80–130°C of heating and 500,000 min^{-1} mechanical shearing or microfluidization. Subjecting proteins to high-pressure shearing with or without heating, commonly termed microparticulation, results in ingredients with oriented capabilities.

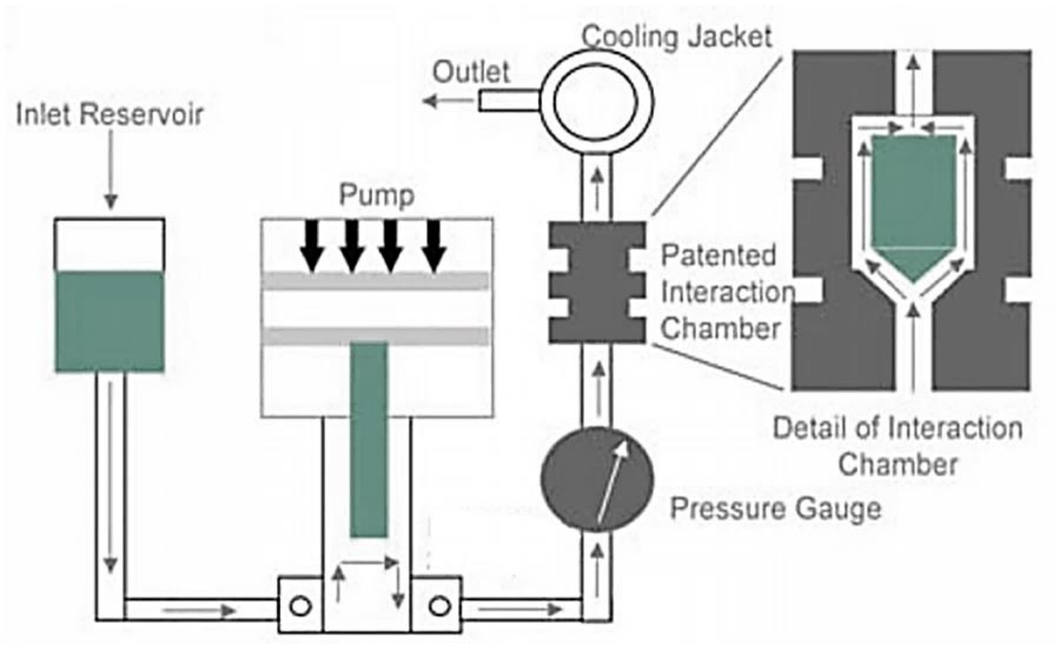

Figure 1.3 Microfluidizer mechanism diagram modified by Spence et al., (2010).

Microfluidization has been applied to so many macromolecules such as proteins and carbohydrates. Two basic important physicochemical parameters of proteins are Protein Solubility (PS) and Surface hydrophobicity (Ho). By microfluidization treatment, both of them were increased in comparison with untreated ones. As the result, microfluidization can improve many functional properties of proteins even those thermally denatured (Tang and Shen, 2012).

Small particles of so many proteins are achieved through microparticulation such as whey proteins, egg white, casein and soybean hull.

Hayakawa et al. (2004) have done this procedure through superfine grinding. According to their research, a jet mill created particles from egg white, casein and soy bean shell. Microparticulation by crushing of egg white was simpler than with casein or soy bean hull. As the result, hydrophobicity of casein improved by crushing to super fine particles but little or no impact was noticed on soy bean hull and egg white. Devices used in their operation were a stainless steel jet mill along with six jet nozzles which was used for superfine grinding, a stainless steel turbo classifier for fine separation, Microtac for measuring particle distribution, Absorption meter for measuring specific surface, a Fluorescence meter to determine hydrophobicity and a Scanning electron microscope for recording photomicrograph. According to their survey, Casein had a greater hydrophobicity than egg white at the same particle diameter size. For some materials, superfine grinding followed by particle classification may be useful in the production of highly hydrophobic protein ingredients for foods.

Sirikulchayanont et al. (2011) have done a similar application on Mung bean protein. After preparation of mung bean protein, the protein functionality was determined by pH-solubility profile. A vortex mixer was used to determine oil and water absorption capacity and surface hydrophobicity was measured by dissolving mung bean protein concentrate in 0.01 M phosphate buffer pH 7 to cover the concentration range 0.005 to 0.025 %w/v. A spectrofluorometer was used to measure the fluorescent intensity of the solution.

The microparticulation was done through dissolving the mung bean concentration in deionized water to obtain concentration of 5% w/w. For the purpose of increasing aggregation of heat denatured protein CaCl2 is added to the solution. After heating for 5 to 15 min at 83 ± 1°C, a homogenizer was used during the heating process. By homogenizing at the speeds of 5, 6, 7 and 8 for 5 minutes, the particle size was reduced. Homogenization was at the rpm of 23000. The effect of centrifugation force on particle size separation was evaluated by determination of size and size distribution of protein aggregates in precipitate and supernatant. The characteristics of this microparticulated particles made of mung bean protein showed that they could be used as fat replacer for oil-in-water emulsion.

Tobin et al., (2009) have investigated microparticulation of mixtures of whey protein and inulin. According to their investigation, producing lower caloric fat replacer is achieved through replacing lactose with inulin during whey protein microparticulation. The particles size could be grow by adding inulin due to increased viscosity. The resulting product had better modified sensory characteristics.

Another investigation has been carried out by Dissanayake et al.(2013) regarding gelling properties of microparticulated whey proteins. One of the most important factors that affect the gelling property is the size of particles. Process modifications which combines heating and hydrodynamic high-pressure shearing at the same time under controlled environmental conditions (pH, ionic strength) during microparticulation, may lead to further particle size reduction. In this study, two batches of whey protein retentate were used. One batch was heated at 90C for 20 minutes for complete protein denaturation and then microfluidized. The second one was just microfluidized without heating process which was considered as a control . Spray drying was done by the use of a pilot-scale spray dryer. The results showed that reduction of the particle size thus appears achievable at a lower pH and reduction of particle sizes are more likely to form gels which points out the great role of microparticulation in the food industry.

Microparticulation reduces the size of protein particles to less than 3-μm which forms creamy texture, smooth emulsion-like feel and create fat-like organoleptic effects. Being used as a fat replacer is one of the most important roles that is played in food industry.

1.5 Mayonnaise

Mayonnaise is a kind of semi-solid oil-in-water emulsion which is low in pH. It is traditionally prepared by carefully mixing a mixture of egg yolk, vinegar, oil, and spices (especially mustard) to maintain closely packed foam of oil droplets; it may also include salt, sugar or sweeteners, and other optional ingredients.

It can be stated that this salad dressing is probably one of the most common used sauces among the consumers. Its common ingredients are egg yolk, vinegar, salt, sugar, water and spices such as mustard (Liu et al., 2006). Mayonnaise, mustard, and ketchup are the moist seasoning sauces most consumed in Argentina. These products are consumed widely in a great amount, especially mayonnaise (Sosa, 2005).

This great amount of desire for this product led food engineers to formulate it in healthier way by reducing fat amount. It is obvious that consumers more readily adhere to nutritional guidelines concerning fat consumption. Reducing calorie content in a formula is a matter of substituting lower calorie ingredients for fat, but not changing the viscosity, texture characteristics, mouth feel, taste and flavour of the product as a sensible degree (Daugaard,L, 1993). The emulsion is formed by slowly blending oil with a pre-mix that consists of egg yolk, vinegar, salt, water and sugar because mixing the oil and aqueous phase at once will result in formation of a water-in-oil emulsion which is not desired (Liu et al., 2006). The oil droplets and the oil phase are considered as important factors, but both the continuous and the dispersed phases have an impact on the rheological properties. Particle size is also a factor of great importance which may affect rheology and stability in different kinds of emulsion such as mayonnaise (Wahren, 1982 and Rahalkar 1992). There are other different factors that are of great importance in mayonnaise rheological properties such as quantity and type of emulsifier, amount of oil phase, water quality, amount of egg yolk, viscosity and preparation method and order of addition of ingredient (Lynch.J, and Griffin,C , 1974).

Table 1.7 Functions of fat replacers in salad dressings. Derived from Dietary guidelines for healthy Americans, (1996).

Fat replacers	Functions
Lipid based	Emulsify, Provide mouth feel, Hold flavorants
Carbohydrate based	Increase viscosity, Provide mouth feel, texturizer
Protein based	Texturizer, Provide mouth feel

Low fat mayonnaise was studied by HP et al. (2010), by using polysaccharide gums such as xanthan gum, citrus fiber and guar gum as fat replacers. The results showed that XG + 10 g kg(-1) GG and CF + 5 g kg(-1) GG could be used in LF mayonnaise formulations based on its multiple functions on processing properties. hydrolysed starch particles were also used by Ying Ma, (2005) as fat mimetic in mayonnaise which had acceptable sensory analysis results. According to a study conducted by Wendin, (1997) mayonnaises containing guar gum were thicker, tougher and more elastic than samples containing propylene glycol alginate. Rice starch was analyzed in low fat mayonnaise preparation by Abraham et al, 1991. It was indicated that rice starch particles provide opacity and fat mimetic properties with the desired mouth feel required for salad dressings especially mayonnaise. Converted starches are capable of forming gels with water which has a desired taste, structure and a smooth consistency that are consistent with oily products such as mayonnaise. This study was carried out by Lenchin et al. (1984).

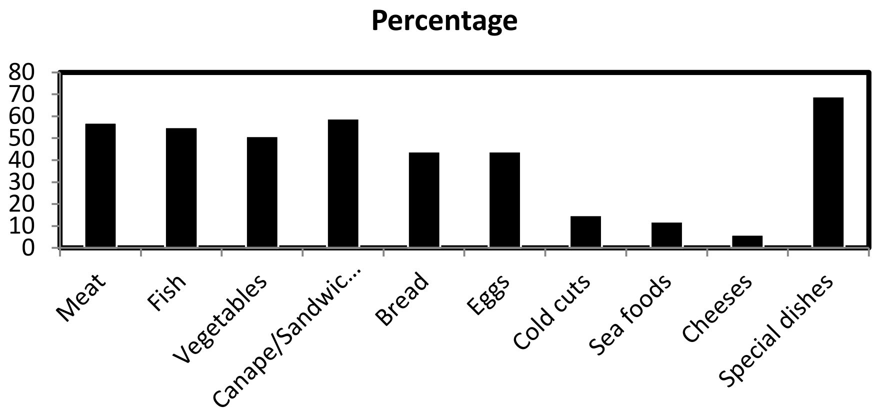

Figure 1.4 Habits of mayonnaise consumption. Derived from Italian Government Statistics.

Figure 1.4 illustrates frequency of mayonnaise consumption in different food styles. Mayonnaise is mostly used in sandwiches and canapé.

So many studies have been conducted so far about mayonnaise as it is one of the most desired food stuff among consumers with wide range of age. Lowering fat content of mayonnaise has been always of great concern of food engineers to enhance nutrition value of the salad dressings.

1.6 Aim of the Study

Low calorie foods have been always of great importance in food industry. Lowering fat content of popular food products such as bakery products and salad dressings can help consumers with cholestrol control and weight managment. The main aim of this study was reducing fat in the food such as cake and mayonnaise, without affecting the food's texture and rheology, by using inulin powder and its microfluidized emulsion as a fat replacer. Microfluidization process was carried out in this study to investigate particle size reduction of inulin in textural and rheological properties of the final product.

Firmness, cohesiveness and adhesiveness were tested to analyze textural properties of the samples. Rheological properties were also measured in order to determine microfluidized and non-microfludized inulin effects on cake batter and the baked cake.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

For preparing low fat mayonnaise and low fat cake, inulin was provided from Smart Kimya Ltd. (Cigli, Turkey). Sugar, salt, baking powder, milk powder, egg white powder and vinegar were obtained from local market. Cake oil and cake flour was obtained from ETI Food Industry Co. Inc. (Eskisehir, Turkey).

2.2 Methods

2.2.1 Preparation of Inulin Emulsion

Inulin emulsions used for this study were 15%, 22.5% and 30% (w/w). Inulin powder was poured into water in order to obtain the stated percentages. Emulsifier (Sodium Stearoyl Lactylate) was added to the mixture to get a homogeneous emulsion with the amount of 1 gram per 100 gram emulsion. Inulin, water and emulsifier were mixed by a homogenizer for 2 min. Prepared emulsion was then kept at refrigerator for one day since all the emulsions were used in gel form in this study. Samples which were tended to be microfluidized were transferred to microfluidizer immediately after preparation. The inulin dispersions were submitted to three passes in microfluidizer at 30 MPa. High shear application increases temperature of the system up to 75℃ which was cooled up to 20 ℃ by using ice in the process. This process led to gelation of even 15% (w/w) inulin emulsion which was the lowest inulin amount used for preparing the emulsion. Microfluidized samples were then kept at refrigerator for a day before cake batter preparation. Each inulin emulsion was used to replace 25%, 50% and 75% of oil content in cake samples and 12.5%, 25% and 37.5% of mayonnaise samples

2.2.2 Preparation of Cake

Cake making process relies on three steps; mixing ingredients, baking and cooling. The basic ingredients were 100% flour, 100% water, 50%shortening, 12% milk powder, 8% egg white powder, 6%baking powder, 80% sugar and 1.5 %salt on 100 gr flour basis. Oil reduction was carried out by replacing oil with each inulin emulsion in different percentages such as 75%, 50% and 25%. The cake sample containing 25%oil and 75% inulin emulsion was considered as C25. The samples with 50%oil, 50%inulin and 75%oil, 25%inulin were considered as C50 and C75.respectively. control sample was represented as C100, since it is the full fat product. Ingredients else than oil, remained unchanged during low fat batter preparation. Mixing process was carried out step by step starting with adding egg white powder to baking powder and shortening. A laboratory blender was used to mix the ingredients at low speed (85 rpm) (Toastmaster, 1776CAN, China) for 1 min. Milk powder, sugar and salt were added to the previous ingredients and mixed for 2.5 minutes at low speed. The final step was adding flour and water to the mixture and mixing with the blender for 2 minutes at low speed (85 rpm), then for 1 min at medium speed (140 rpm) and finally 2 additional minutes at low speed (85 rpm). Baking process was performed for 15 minutes at 175 °C for 60 g of dough poured into silicon moulds. Baked cakes were cooled for 1 hour at 25± 2°C for further analysis.

2.2.3 Preparation of Mayonnaise

Mayonnaise is all about mixing basic ingredients in which the order of the ingredients added to the formula is of great importance. Oil should be added to the pre-mixture of vinegar, salt, water, sugar and emulsifier that has been mixed before. If all the ingredients are mixed all together, water in oil emulsion will be created which is not desired by the consumer. In this study on basis of 100 g mayonnaise sample, the recipe contains ingredients as 6% water, 3% emulsifier (Polysorbate 80), 8% vinegar, 2% salt, 1% sugar and 80% oil. All ingredients used were purchased from local market. In this experiment oil was replaced by inulin emulsion with different percentages (12.5%, 25% and 37.5%). Mayonnaise samples preparation was as follow: first water, vinegar, emulsifier, salt and sugar were mixed together homogeneously by the mechanical stirrer. In case of oil replacement, inulin emulsion prepared (15%, 15%MF, 22.5%, 22.5%MF, 30%, 30%MF) were added in each related sample for all the 12.5%, 25%, and 37.5% replacements. Stirring process was carried out till a homogeneous mixture was obtained. Finally oil was added to the mixture along with stirring by a stirrer for 4 min and 2000 rpm. Samples were kept in refrigerator for 1 day before testing.

2.2.4 Rheological Analysis

TA AR 2000 ex, rheometer was used to measure rheological properties of cake and mayonnaise samples. Parallel plates with 40 mm diameter and 1 mm gap were adjusted to put the dough sample between them. The extra semi-solid sample near the edges of the plates was cleaned by a spatula and no empty space was remained between the plates. The experiment was carried out at 25℃. Oscillatory and flow measurements were done in duplicate in order to enhance the accuracy of the data obtained by the device.

2.2.5 Weight Loss

Weight loss measurement was carried out twice from the same sample. Dough weight and baked cake weight of the same sample were measured separately to calculate weight loss during baking as equation (2.1);

$$\text{Weight loss (\%)} = \left(\frac{\text{Wi}-\text{Wf}}{\text{Wi}}\right) \times 100 \qquad (2.1)$$

Wi indicates batter weight before baking process and Wf is weight of baked cake.

2.2.6 Color Measurement

Color measurement was carried out by Konica Minolta CR-10 Tristimulus Colorimeter. Color change was determined by the equation (2.2);

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

Where L value is the range between black (0) to white (100), a value is the range between red (-100) to green (100) and b value is related to the range between blue

(100) to yellow (100). White paper was selected for the reference of color measurement. L°, a° and b° were color values of the reference point which were 92.9, 0.7 and 9.1 respectively. L*, a*, b* color values related to the surface color of cakes were recorded by the device and calculated by the equation (2.2).

2.2.7 Staling Analysis

Baked cakes were cooled for 1 h at room temperature. Some of them were used for textural analysis after cooling and some of them were stored at packages at room temperature in order to prevent water release to the environment. Textural analyses were carried out for these samples at second and fourth day of storage the same as the first day of baking process.

2.2.8 Texture Analysis

Cake samples were analyzed using a texture analyzer (TA.XT *plus*, England). A sharp knife was used to cut the cake with the thickness of 2 cm and the cake was placed on the top of platform. Device was set to 1.7 mm/s pre-test speed, 1 mm/s test speed along with 40 s holding time. Texture analysis was repeated for the first, second and fourth day of storage duration. Data obtained by this test were indicator of firmness, adhesiveness and cohesiveness of the samples. Two cake samples from the same inulin percentage were used to carry out the test for four replicates. Two different parts of each cake were used in order to carry out the test for four replicates. Cohesiveness, adhesiveness and hardness were obtained.

2.2.9 Scanning Electron Microscopy (SEM)

For analyzing electroscopic structure of inulin, 15% (w/w) inulin emulsion was prepared by adding 15 gram inulin powder into 85 gram water and mixing till a homogeneous mixture is obtained. The sample was microfluidized at 30 MPa and frozen for 2 days in freezer. The sample was then freeze dried by Christ Alpha 2-4 LD plus for 48 hours. Original inulin powder and freeze dried inulin were analyzed and compared by Quanta 400f Field Emission SEM, Eindhoven, the Netherlands) scanning electron microscope at Central Laboratory of Middle East Technical

University. Analysis was carried out by magnifications of 500X, 10000X and 20000X.

2.2.10 Statistical Analysis

Statistical analysis was carried out to analyze the difference between the types of the samples, inulin percentage replacement and storage time. ANOVA (analysis of variance) was used by MINITAB 16 statistical program to analyze the data obtained by this study. Tuckey Single Range Test was used to compare means of significant differences ($p \leq 0.05$).

CHAPTER 3

RESULTS AND DISCUSSION

Rheology measurement, texture analysis, color measurement, scanning electron microscopy, moisture loss and water loss were carried out in this study to determine inulin effects in cake and mayonnaise being used as fat replacers. Texture analyses were also done for cakes being stored for 2 and 4 days in order to study staling of the samples. For mayonnaise, rheology tests were carried out in order to study inulin effect on rheological properties of the samples.

3.1 Rheological Analyses

3.1.1 Rheology of Cake Batter

It is important to determine the rheological properties of cake batters due to their effect on cake processing and at the same time on final characteristics of cake (Ronda et al., 2011). Since rheology is the matter of the product deformation, a good understanding of shear stress and yield stress is necessary in bakery products (Steffe, 2001).

Table 3.1, 3.2 and 3.3 are indicators of yield stress, flow behavior index and consistency index values of samples with 75%, 50% and 25% oil replacements, respectively. In each table effect of different inulin emulsion percentages on these parameters were recorded for all oil replacements. Yield stress is considered as a material property at the transition between solid and liquid behavior (Husband, Aksel, & Gleissle, 1993). Structure of materials that are consisted in a network may be prevented from flowing which indicates the presence of yield stress as force required to start flow (Zhu, Sun, Papadopoulos, & De Kee, 2001). Inulin in gel form may increase yield value due to flocculation of emulsion. The crystalline structure of inulin leads to higher yield stresses in the product since microfuidization creates porous structure enhancing gelling property (Zimeri and Kokini, 2001).

As it is seen in tables 3.1, 3.2 and 3.3, yield stress exists for all the samples which makes Herschey-Bulkley model proper for the shear stress (τ) versus shear rate (γ) data at 25 °C;

$$\tau = \tau_0 + K\,(\gamma°)^n \qquad (3.1)$$

Where τ is shear stress (Pa), τ_0 is the yield stress (Pa), γ is the shear rate (s^{-1}), n represents flow behavior index and K is the consistency index (Pas^n).

Flow behavior index values for all the samples were below 1 which shows shear thinning behavior of dough samples. Consistency index value of all the dough samples were also recorded by rheometer. Consistency index is in relation with the proportion of inulin since this dietary fiber interacts with liquid phase of the dough. Considering the hygroscopic characteristic of inulin, it binds with water and form a gel like structure which leads to increased values of consistency index as the inulin proportion increases. Gelling property of inulin improves the consistency of the product (Nagar et al., 2002). A relation exists between consistency and the capacity of retaining air (Gomez et al., 2010). Swami et al. (2004) has reported that increase in level of air corporation can decrease consistency index value. Texture measurements of cake samples carried out in this study also revealed that samples with higher hardness values were belonged to cakes containing higher amount of inulin. This also proves the effect of inulin in reducing air retention of the product. Air retention occurs during creaming of fat and sugar.

Table 3.1 Herschel-Bulkley parameters of cake batters of 25% oil phase content at 25 °C.

75% oil replacement	τ_0 (Pa)	n	K (Pas^n)
Control	120	0.5	120
15%inulin (w/w)	120	0.5	120
15%MF inulin (w/w)	165	0.35	165
22.5%inulin (w/w)	135	0.4	126
22.%MF inulin (w/w)	200	0.4	190
30%inulin (w/w)	210	0.39	200
30%MF inulin (w/w)	240	0.358	220

Table 3.2 Herschel-Bulkley parameters of cake batters of 50% oil phase content at 25 °C.

50% oil replacement	τ_0 (Pa)	n	K (Pas^n)
Control	120	0.5	120
15%inulin (w/w)	144	0.45	100
15%MF inulin (w/w)	159	0.44	175
22.5%inulin (w/w)	165	0.39	144
22.%MF inulin (w/w)	180	0.41	213.4
30%inulin (w/w)	210	0.45	190
30%MF inulin (w/w)	290	0.36	247

Table 3.3 Herschel-Bulkley parameters of cake batters of 75% oil phase content at 25 °C.

25% oil replacement	τ_0 (Pa)	n	K (Pas^n)
Control	120	0.5	120
15%inulin (w/w)	118	0.4	98
15%MF inulin (w/w)	144	0.5	130
22.5%inulin (w/w)	145	0.5	120
22.%MF inulin (w/w)	190	0.45	189.4
30%inulin (w/w)	180	0.4	165
30%MF inulin (w/w)	343	0.5	249.4

According to the Figs. 3.1, 3.2 and 3.3 which are related to 75%, 50% and 25% of oil replacements respectively, replacement of oil by inulin increased shear stress versus shear rate.

The variation in shear stress depends on some factors: the capacity of inulin about retaining water (Soukoulis, Lebesi, & Tzia, 2009), interaction of inulin with protein present in the product which leads to an increase in molar mass and thus viscosity (Gonzalez-Tomás, Coll-Marqués, & Costell, 2008).

Higher oil replacements by inulin recorded higher values of shear stress versus shear rate. The lowest shear stress was observed for control samples which were close to the lowest inulin amount used in formula. This shows higher viscosity of cake batters prepared by inulin as a dietary fiber. According to a study carried out by Schaller-Povolny and Smith (2001), inulin has the ability to bind water molecules and possible interactions with protein which in return increases viscosity of the product. This fact was consistent with cake batter samples in this study.

Decreasing particle size by microfluidization also increased required shear stress which causes increased water absorption since weight loss values were lower in microfluidized samples in comparison with non-microfluidized ones. Limiting free water in the product can lead to viscosity increase. As it is obvious in weight loss table (3.7), amount of water loss in cakes with higher percentage of inulin is more than other samples. In the case of adding inulin to the formulation, the shear stress grows for the batter to start flow which can be due to the flacky structure of the microfluidized inulin which is obvious in the photographs taken by scanning electron microscop. Microfluidization may leads to more interaction due to particle size reduction (Ciron., 2011).

Water absorption in inulin is due to hydroxyl group which are more able to interact with water than other parts. This property makes inulin to be used as fat replacer in cake which shows that high viscosity is indicator of finer samples (Petrovsky et al., 2010).

Rheological properties can be used as an aid in process control and design, and at the same time as mean in the prediction of the material's reaction to the complex flows and deformation conditions often found in practical processing situations which can be inaccessible to normal rheological measurement. Yield stress is another rheological parameter that can define batter performance (Kocak, 2010). It is defined as the point at which material begins to deform plastically. As shown in figs. 3.1, 3.2 and 3.3, yield stress increases as percentage of inulin replacement increases. More free water results in lower yield stress in cake batter. The greater yield of the batter is related to the higher batter viscosity. This viscosity is achieved through entanglement of fiber used in the formula the same as shear stress versus shear rate, yield stress increased by microfluidization. Reducing particle sizes leads to higher water absorption and higher viscosity. Thus, yield stress increases by applying microfluidization method. It is concluded that microfluidization increases both yield stress and shear stress versus shear rate resulting in higher viscosity of the batters with more amount of water absorption (Chinnan et al., 2010).

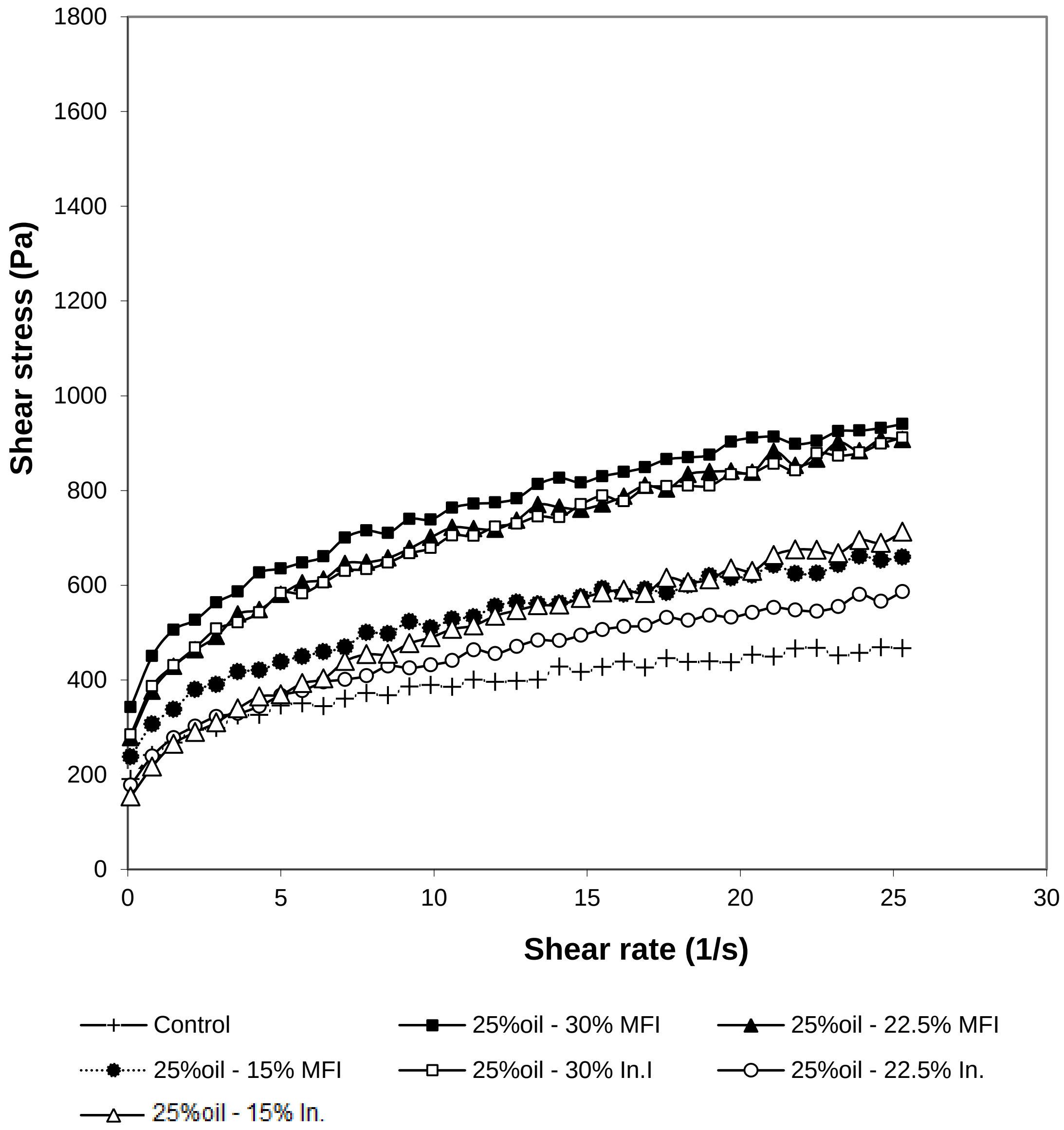

Figure 3.1 Effect of different inulin percentage replacement on C25 cake samples

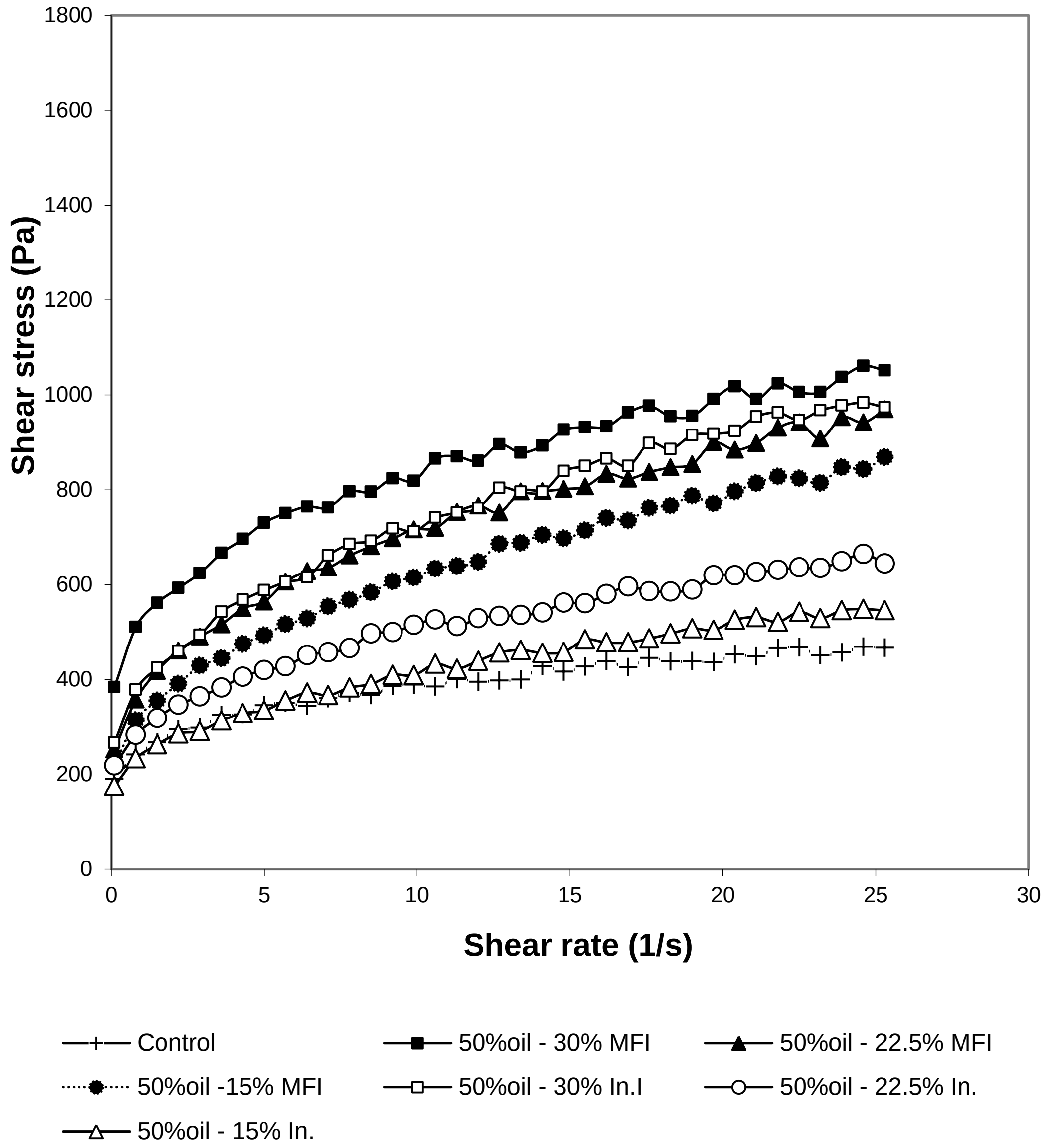

Figure 3.2 Effect of different inulin percentage replacement on C50 cake samples

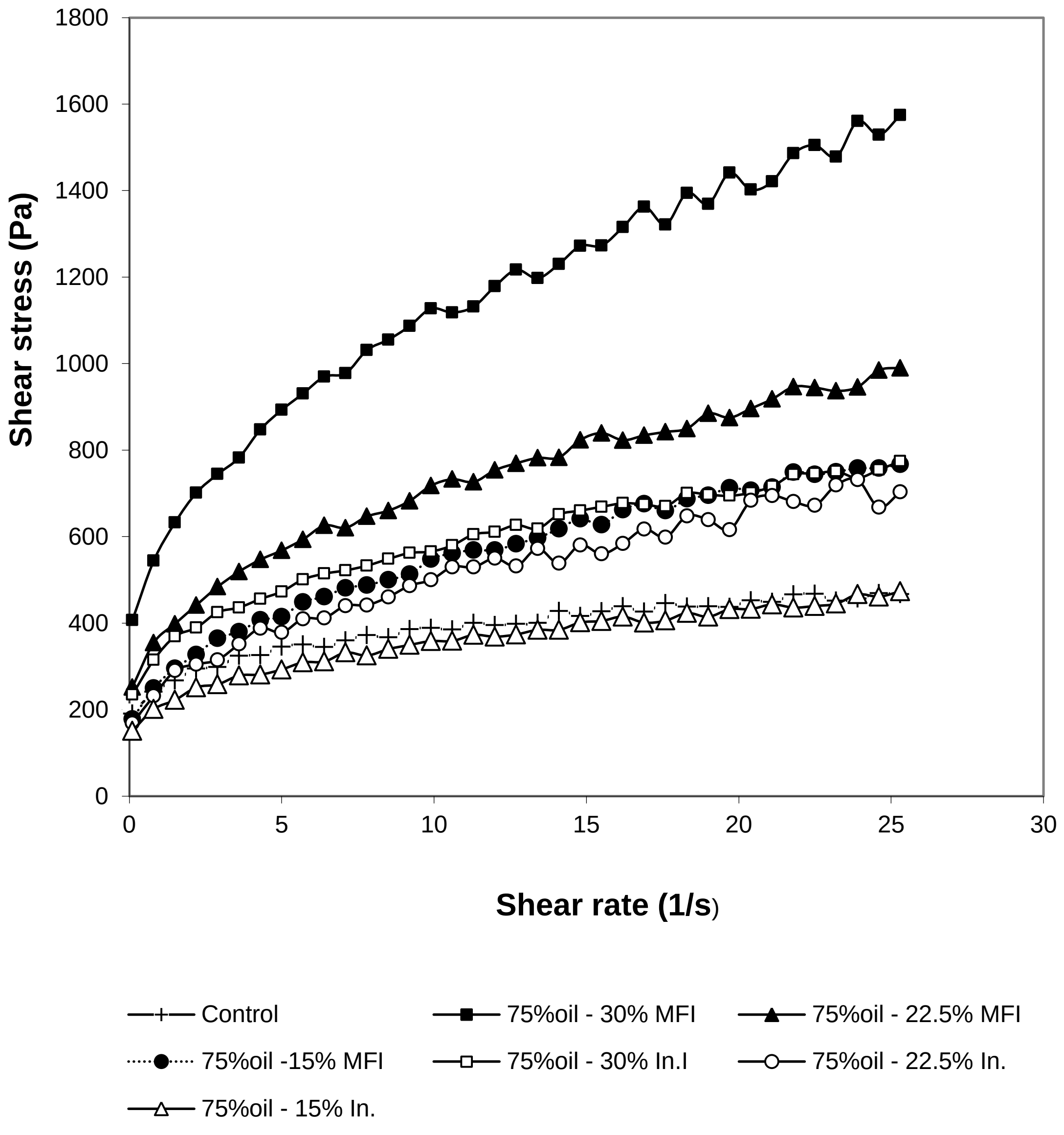

Figure 3.3 Effect of different inulin percentage replacement on C75 cake samples

Elastic modulus is referred to the value which indicates the bakery product's resistance to being deformed elastically at the time force is applied to it. Both elastic and viscous moduli were evaluated for all the cake batter samples. Figures 3.4, 3.5 and 3.6 show the elastic values for 75%, 50% and 25% of oil replacements. For all the samples it was observed that higher amount of inulin used to prepare inulin emulsion resulted in higher elastic modulus and viscous modulus. Microfluidization process also increased the value of these two factors probably because of more water holding capacity.

As it has been stated before, 25%, 50% and 75% of 15%, 22.5% and 30% (w/w) inulin emulsion was used in oil suspension of the formula. According to figures 3.4-3.9, as the percentage of inulin in inulin-water emulsion was increased, elastic modulus and viscous modulus tended to increase which was the indicator of more elastic cake batter. High elastic values may be due to entanglement of inulin as a dietary fiber (Demirkesen et al., 2010). As the oil content of cake batter increased, even lower percentage of inulin content in emulsion had higher elastic modulus and viscous modulus values than control sample. Fibers can provide lubricity and gel like structure by tending to interact with water and effect rheological properties of the products. Comparing microfluidized samples with non-microfluidized ones by the figures 3.4, 3.5 and 3.6, it can be stated that as an example C25, C50 and C75 with 15% MF inulin emulsion had higher elastic modulus in comparison with the same sample along with 22.5% non-microfluidized inulin emulsion whereas elastic modulus of the sample with 15% non-microfluidized inulin was lower than 22.5% non-microfluidized sample. Higher shear rates for longer period of time is obtained through microfluidization which leads to higher moduli values. It supplies consistent pressure and uniform particle distribution (Mert, 2012).

Highest elastic modulus value was observed for sample containing C25, C50 and C75 with 30% MF inulin emulsion. Fat breaks down the protein matrix and creates softer texture of the product and lowers the elasticity of the dough samples (Meyer et al., 2011). By replacing oil by inulin, harder texture is obtained which has been discussed in detail in texture profile analysis section of this study. According to figure 3.6, the lowest value was obtained for C25 with 15% non-microfluidized inulin emulsion since it contains the more fat in comparison with figure 3.4 and 3.4. Inulin has high water holding capacity due to hydroxyl groups which are more able to interact with water. This fact can be attributed to higher elastic values in comparison with full fat samples.

Elastic modulus values were higher than the viscous modulus values obtained by oscillatory test which shows solid like behavior of dough samples. Lower elastic modulus and viscous values is indicator of less elastic and less viscous properties of dough samples (Sahin, 2007). Ahmed, (2012) used lupine seed in wheat flour for cake formulation at concentrations of 5, 10 and 15%. According to their results, all the samples had greater elastic modulus value rather than viscous modulus value and this indicates that this indicates the solid state properties of all dough’s and showed that dough promoted dispersion and not gel-like structure. Both elastic and viscous modulus value were increased as the amount of lupine seed was increased in the formula. According to another study carried out by Psimolui, (2013) as fat replacement increased over 65%, elasticity of cake batter increases. It is concluded that, both increase of inulin amount and microfluidization led to higher elastic and viscous modulus values.

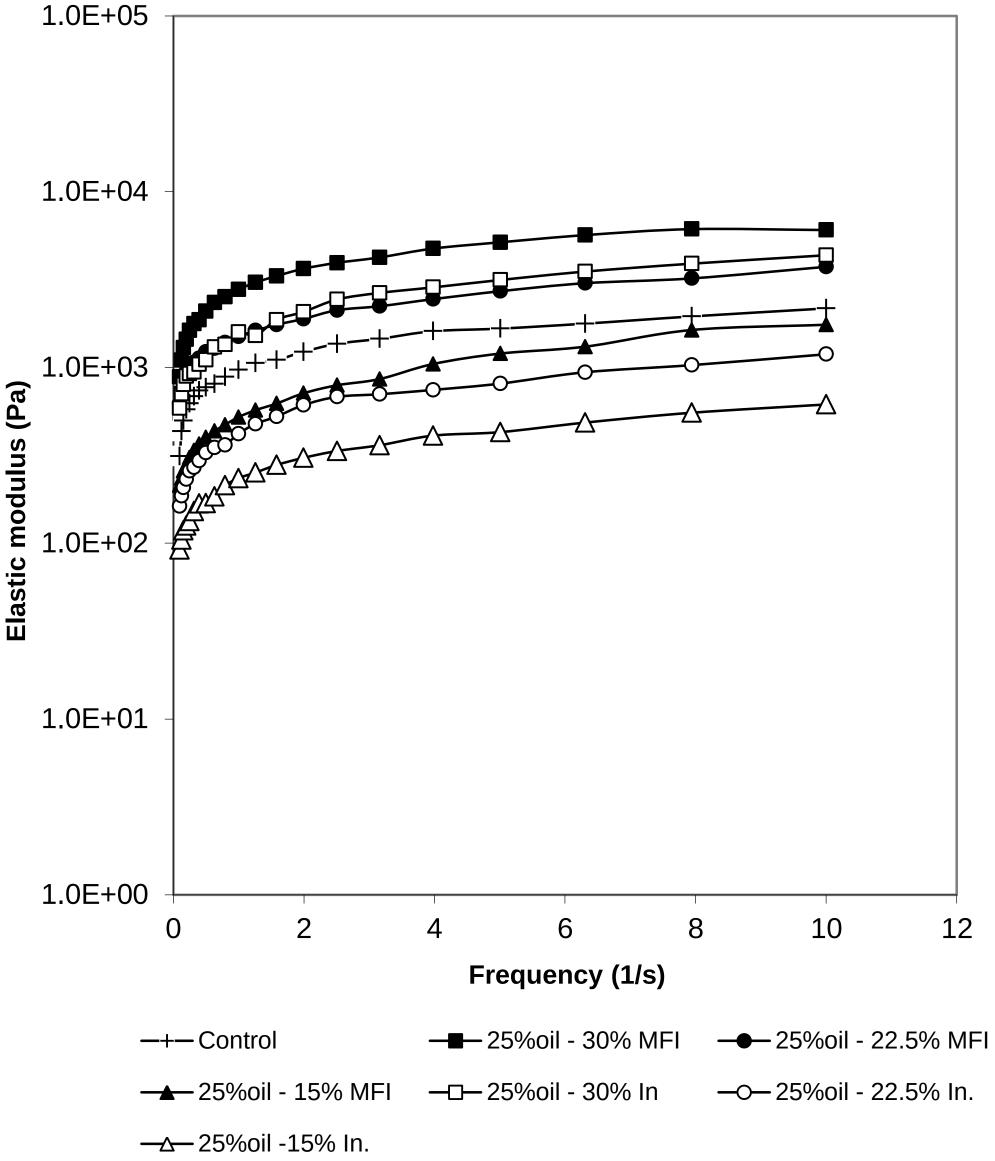

Figure 3.4 Elastic modulus for C25 cake doughs

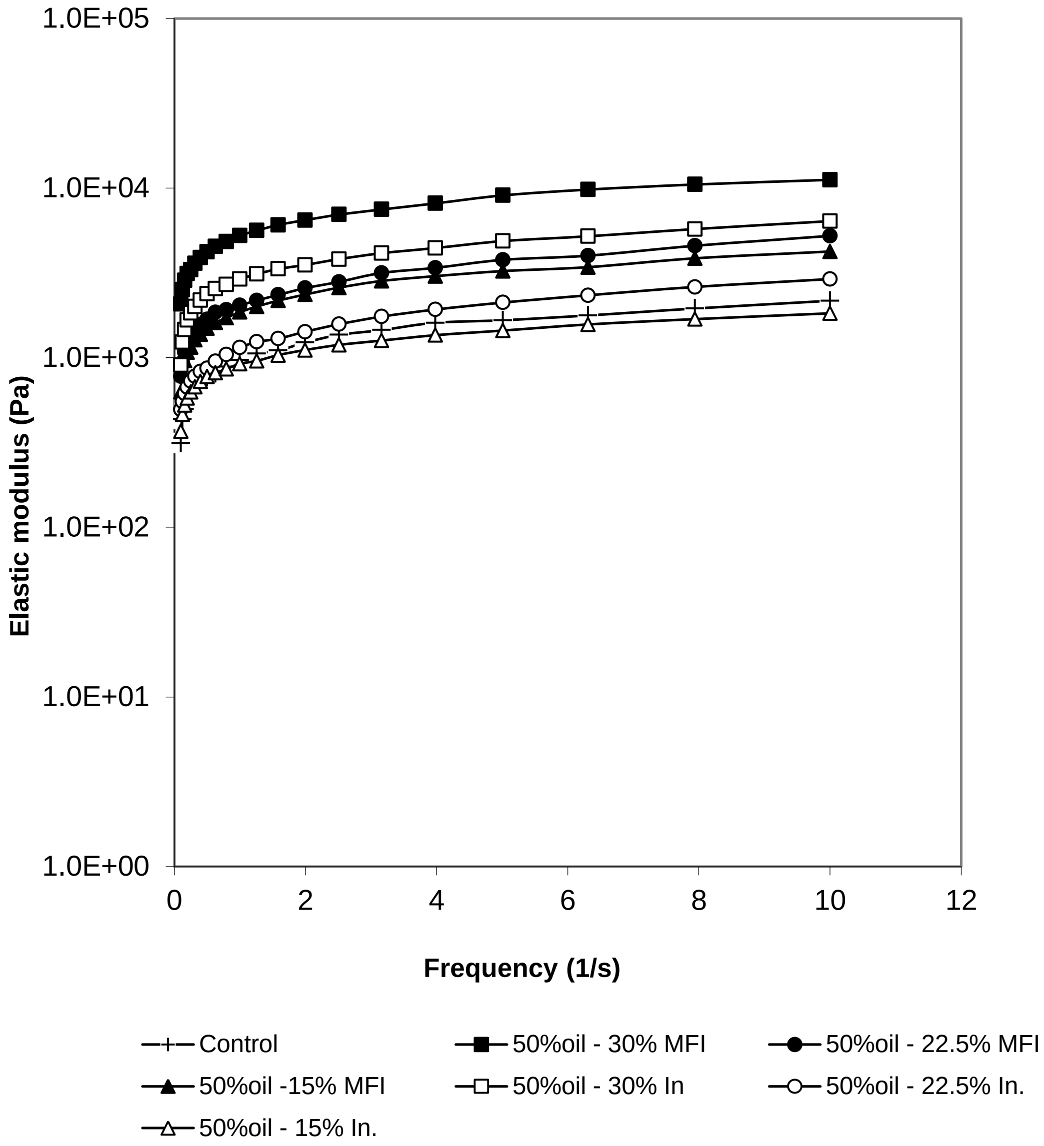

Figure 3.5 Elastic modulus for C50 cake dough

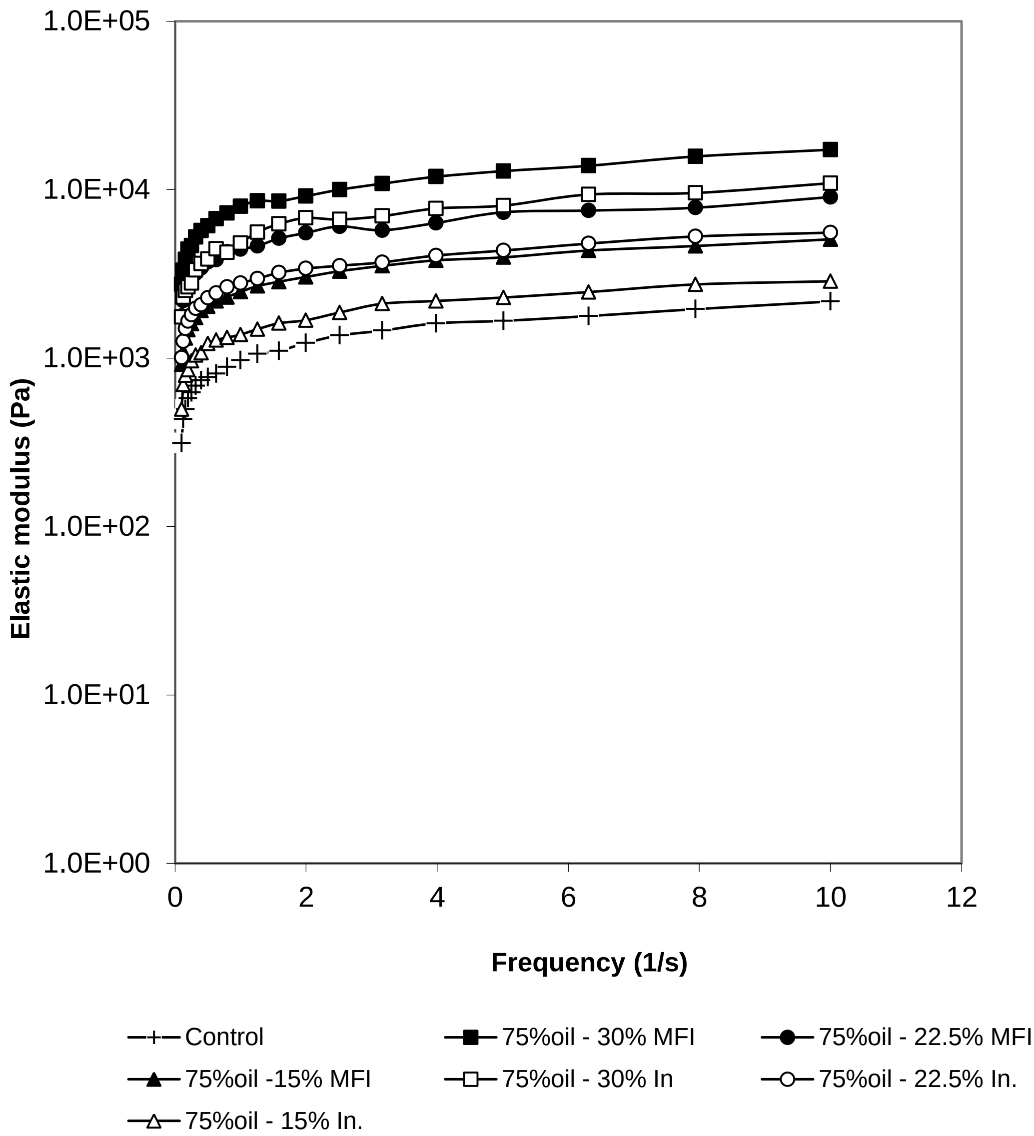

Figure 3.6 Elastic modulus for C75 cake dough

Figures 3.7, 3.8 and 3.9 are indicators of viscous modulus of cake batter with 75%, 50% and 25% oil replacement respectively. Batter viscous increase might be attributed to the high water retention capacity of the fibers. Higher batter viscoelastic values can lead to higher air retaining properties of cakes during baking process. “Inulin may have bound up loose moisture, leading to the development of a gelled-type structure and thus retarding flow” (Hennely et al., 2005). Figure 3.7 represents 75% of oil replacement by inulin. The samples with lower inulin had lower viscous modulus than control sample due to higher water amount used in the preparation of inulin. According to figure 3.8, these values were higher than the control sample which can be due to lower inulin emulsion used in the product. Nagar et al. (2002), reported that inulin causes the formation of a viscous gel network with higher adhesiveness values which is consistent with the data observed in figure 3.7, 3.8, 3.9 and the values obtained for the adhesiveness values of the texture analysis section obtained by the texture profile analyzer.

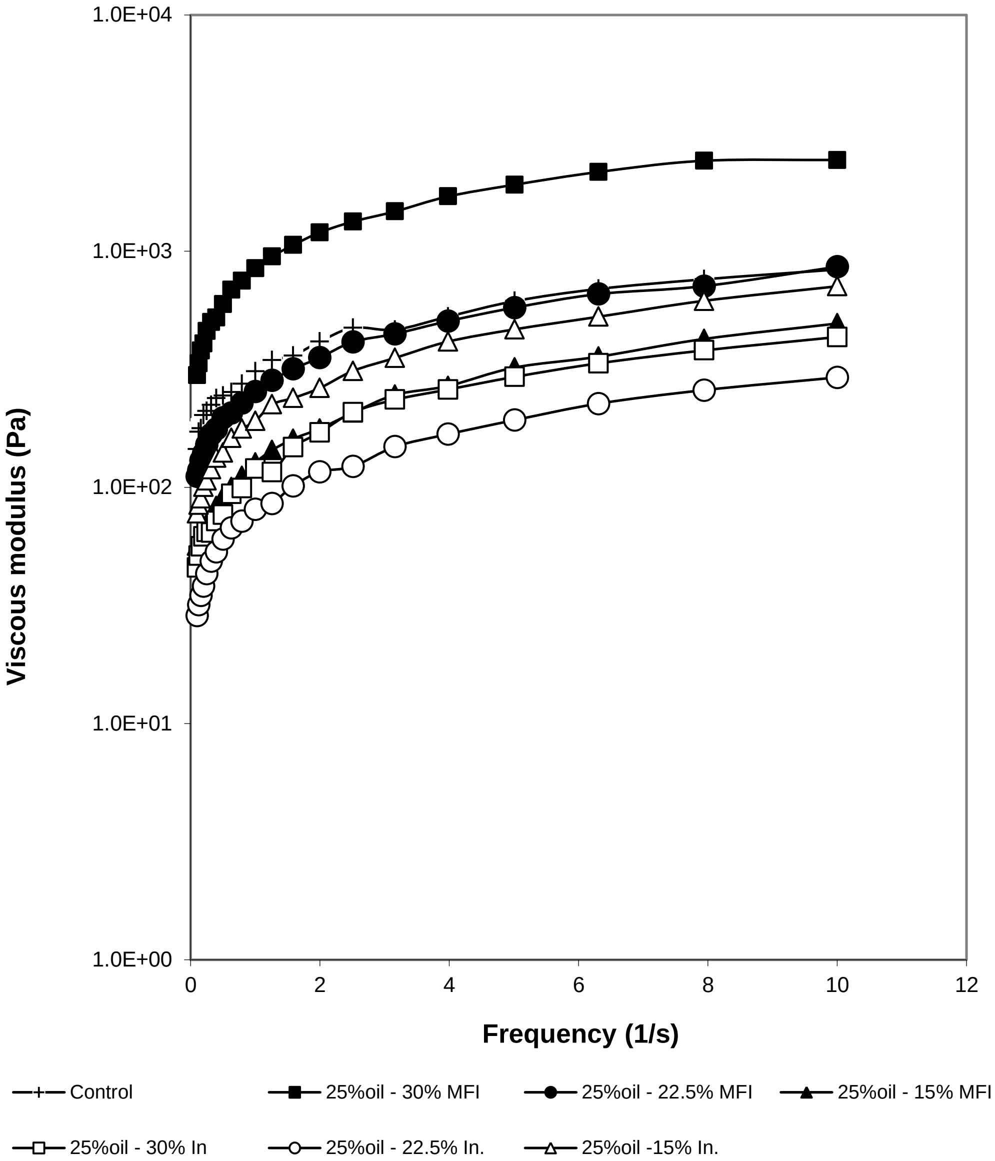

Figure 3.7 Viscous modulus for C25 cake dough

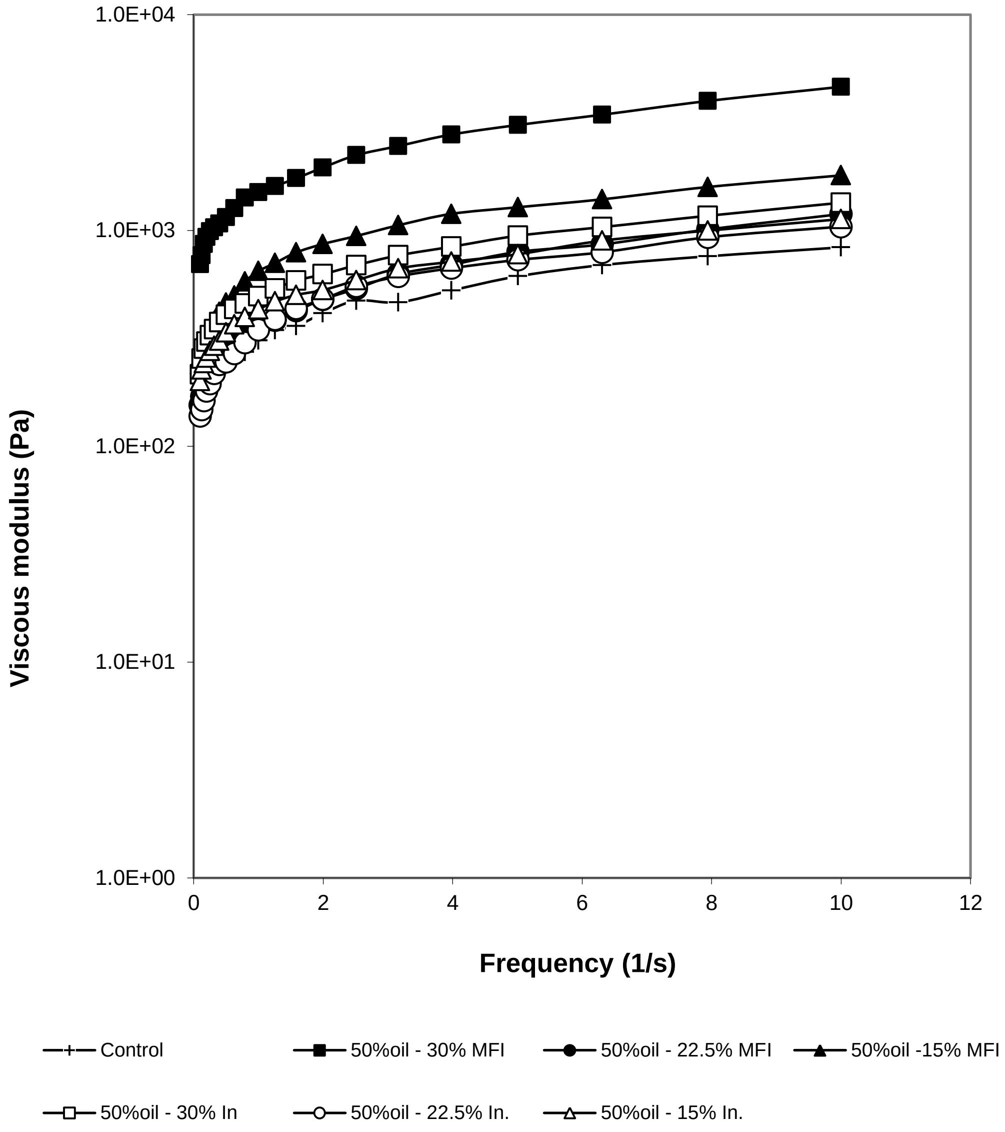

Figure 3.8 Viscous modulus for C50 cake dough

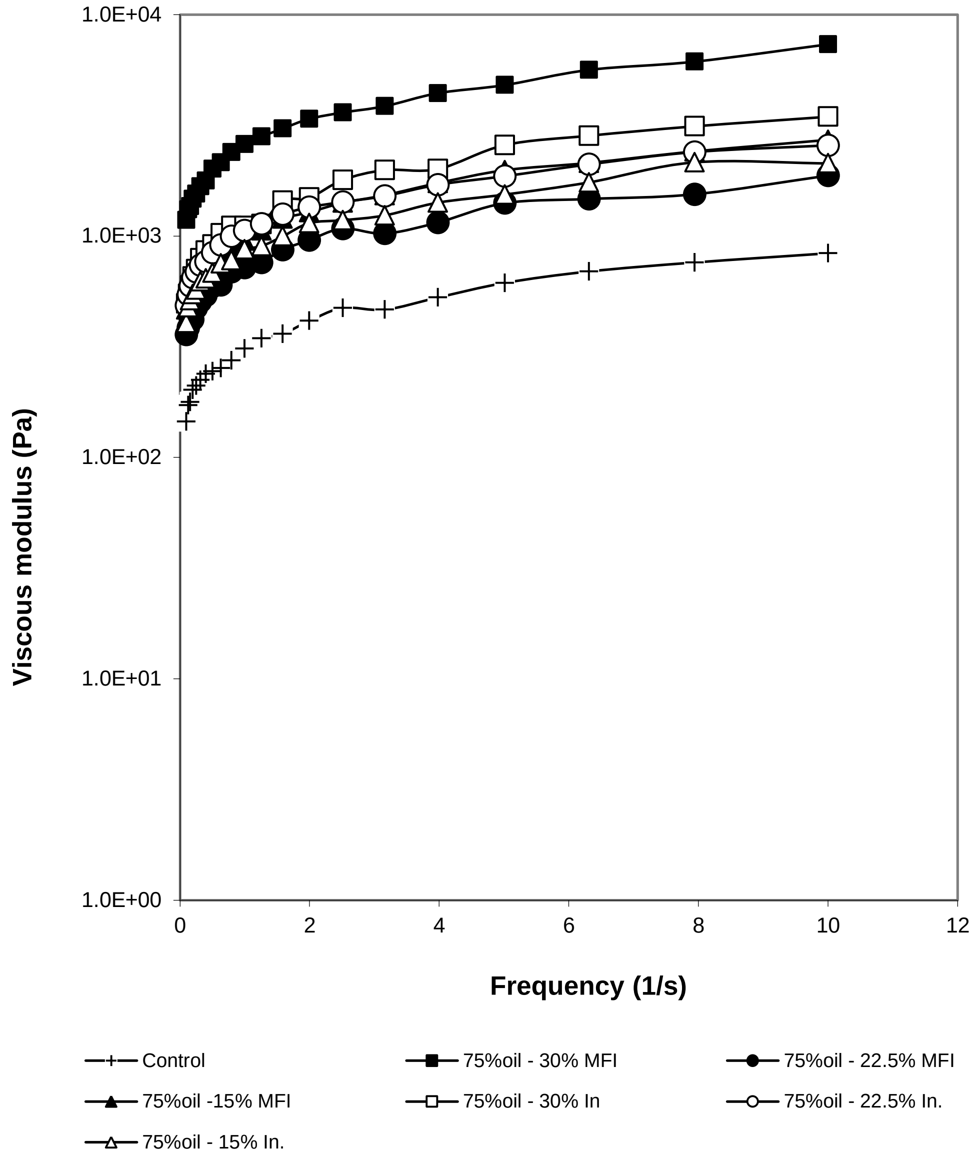

Figure 3.9 Viscous modulus for C75 cake dough

3.1.2 Rheology of Mayonnaise

Fat plays an important role in creating viscosity, texture, color and taste in mayonnaise. Determining rheological properties of the mayonnaise contributes to analysis of different inulin percentages used as carbohydrate-base fat replacer. Rheological and textural properties of mayonnaise are very complex, as the structure is semisolid due to its viscoelastic properties, but it gradually becomes liquid under applied shear, even if the shear is only moderate (Stern et al., 2001).

In this study, each 12.5%, 25% and 37.5% oil substitution was carried out by 15%, 22.5% and 30% microfluidized and non-microfluidized inulin emulsions. Three samples were prepared by adding water instead of the related oil substitution amount so that each group has a specified water sample without any oil and inulin content.

The critical value of the shear stress for the fluid flow is referred to yield stress. Yield stress, also is defined as a minimum shear stress required initiating flow. The existence of yield stress in fluids is reported to be a controversial topic (Barnes & Walters, 1985; Cheng, 1986; Hartnett & Hu, 1989; Evans, 1992; Schurz, 1992; Steffe, 1992). Table 3.4, 3.5 and 3.6 represent yield stress, flow behavior index and consistency index of all dough samples. A yield stress exists for each curve. This fact shows that the samples act as viscoplastic material since the pseudoplastics show a curve started from the zero point of the shear stress axis in shear stress versus shear rate diagram. Materials such as salad dresses are desired to act as solid when kept in market shelf, and as fluid when tends to be used by the consumer. This property is consistent with viscoplastic materials. It behaves like solid when adequate force is not applied to the material. If insufficient shear stress amount is applied, apparent viscosity change does not occur through all the samples. Tooth paste can be considered as another example of this flow. It does not flow until an adequate amount of force is applied to the product. It is consistent with the desired rheological property of mayonnaise and other salad dressings such as ketchup. If the shear stress applied to the flow is less than the yield stress, the fluid acts like solid. The shear stress which exceeds the yield stress will cause the fluid start to flow. Higher yield stress amount can enhance stability of the product when it is kept in market shelf or refrigerator before being used. Compact network structure is responsible for the increase in yield stress (L.Ma and Canovas, 1995). At increasing shear rate amount, shear stress does not appear to increase the same it increased at lower shear rates. Thus, at higher forces applied to the samples, the apparent viscosity tends to decrease. Flow behavior index (n) is observed to be less than one (n<1) in all the samples. As the flow behavior index decreases, the product tends to be more sensitive to shear rate.

Herschel-Bulkley model was found to be the best fit to the shear stress (τ) versus shear rate (γ) data for all the samples at 25 °C:

$$\tau = \tau_0 + K (\gamma^\circ)^n \qquad (3.2)$$

Where τ is shear stress (Pa), τ_0 is the yield stress (Pa), γ is the shear rate (s^{-1}), n represents flow behavior index and K is the consistency index (Pas^n).

Table 3.4, 3.5 and 3.6 represents parameters of Herschel Bulkley for mayonnaise samples. Table 3.4 gives data about the effect of different emulsion concentration used in 30% oil replacements in mayonnaise sample. Table 3.5 and 3.6 give the related data for 25% and 37.5% oil replacements, respectively. Flow behavior index value provides us the required information whether the flow is shear thinning or shear thickening. Flow behavior indexes were from 0.3 to 0.6 (<1). This can be attributed to shear thinning behavior of mayonnaise samples. McClements (1999) reported that this fact may be due to the droplets that are close to each other in the emulsion, thus they have the ability to interact with each other and form a three-dimensional network of aggregates droplets. Increasing shear rate can deform this network and initiate flow.

Higher yield stresses along with consistency index were reported for samples containing 30%MF inulin. Since inulin is considered as a dietary fiber, the entanglement of fibers may lead to a resistance to flow and the observation of yield stress values.

Increasing amount of inulin also increased consistency index parameter. This parameter gives an idea about the viscosity of the material. The related increase can be attributed to the lower gas retention of mayonnaise sample due to the presence of inulin fibers. Swami et al. (2004) has reported that increase in level of air corporation can decrease consistency index value. Texture measurements of cake samples carried out in this study also revealed that samples with higher hardness values were belonged to cakes containing higher amount of inulin. This also proves the effect of inulin in reducing air retention of the product which can be attributed to mayonnaise samples too. Consistency of the batter is an important factor as a correlation exists between capacity of retaining air and consistency (Gomez et al., 2010).

Table 3.4 Herschel Bulkley parameters of mayonnaise samples of 12.5% oil replacement at 25 °C.

12.5% oil replacement	τ_0 (Pa)	n	K (Pas^n)
Control	82.8	0.4	82.8
0%inulin(w/w)	67.1	0.3	67.1
15%inulin(w/w)	80	0.35	80
15%MF inulin(w/w)	86.9	0.33	86.9
22.5%inulin(w/w)	73.8	0.32	73.8
22.%MF inulin(w/w)	106.7	0.33	106.7
30%inulin(w/w)	85.1	0.3	85.1
30%MF inulin(w/w)	117	0.35	117

Table 3.5 Herschel-Bulkley parameters of mayonnaise samples of 25% oil replacementat 25 °C.

25% of oil replacement	τ_0 (Pa)	n	K (Pas^n)
Control	100	0.4	50
0%inulin(w/w)	43.2	0.3	11
15%inulin(w/w)	49.5	0.35	15
15%MF inulin(w/w)	69.3	0.6	14
22.5%inulin(w/w)	60.8	0.41	30
22.%MF inulin(w/w)	90.9	0.35	41
30%inulin(w/w)	88	0.34	33
30%MF inulin(w/w)	126	0.3	60

Table 3.6 Herschel-Bulkley parameters of mayonnaise samples of 37.5% oil replacement at 25 °C.

37.5% of oil replacement	τ_0 (Pa)	n	K (Pas^n)
Control	100	0.4	50
0%inulin	22.1	0.3	11
15%inulin	22.5	0.35	15
15%MF inulin	36.9	0.6	14
22.5%inulin	24.8	0.41	30
22.%MF inulin	47.7	0.35	41
30%inulin	34	0.34	33
30%MF inulin	64.4	0.3	60

According to Flow curves of shear stress versus shear rate, increasing amount of powder inulin in inulin-water emulsion led to an increase in shear stress versus shear rate at all the substitution percentages. The lowest rate belongs to the control sample with 0% inulin-100%water (oil phase) in the formula. The highest amount was observed for the sample containing 30% microfluidized inulin. As the inulin content of the mayonnaise increased, the shear stress versus the shear rate increased too. The higher the yield stress needed for the sample to start to flow, the higher shear stress and viscosity was observed. In mayonnaise, the oil droplets and oil phase is of great importance which has great impact on rheological properties of the product. Particle size also affects stability and rheology of mayonnaise (Wendin et al., 1997).

Microfluidization increased shear stress of the samples versus shear rate, thus increased the viscosity by reducing inulin particle size which tends to act as fat replacer in mayonnaise. It can be stated that inulin contributed to formation of internal structures which can cause viscosity increase and thus higher yield stress and shear stress amount along with the specific shear rate. Figures 3.10, 3.11 and 3.12 represents shear stress values related to 12.5%, 25% and 37.5% oil replacements of mayonnaise samples. Higher amount of inulin led to higher amount of yield stress needed for the sample to flow. Control sample with no oil and inulin had the lowest yield stress and among the samples without water content in oil phase. Microfluidization process leads to preparation of more homogeneous and more stable emulsions (Ketenoglu et al., 2014). By such a high pressure, particle size reduction occurs which leads to a more stable emulsion. De Castro et al. (2012) also reported that high-pressure homogenization between 20 and 100 MPa pressure reduced droplet sizes and distributions. Shear stress versus shear rate of microfluidized 22.5% mayonnaise sample was higher than sample with non-microfluidized 30% inulin content, although higher amount of inulin tended to increase shear stress. Microfluidized fibers, whose sizes are reduced by microfluidization have very large surface area, so they may position themselves on the surface of the oil droplets which increase emulsion stability and prevent aggregation (Mert et al., 2014).

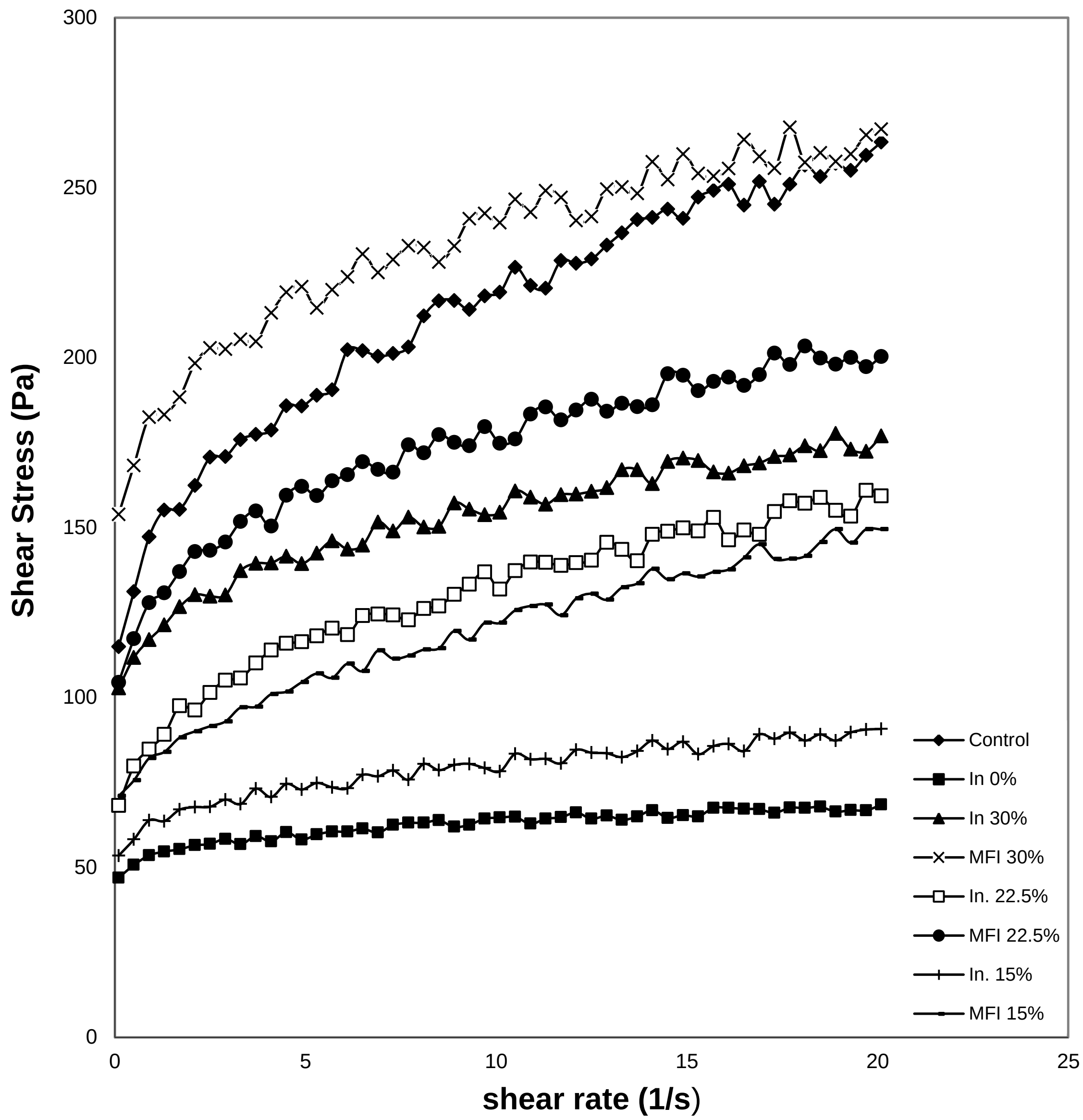

Figure 3.10 Flow curves for 12.5% oil replacement of mayonnaise samples by different inulin percentages

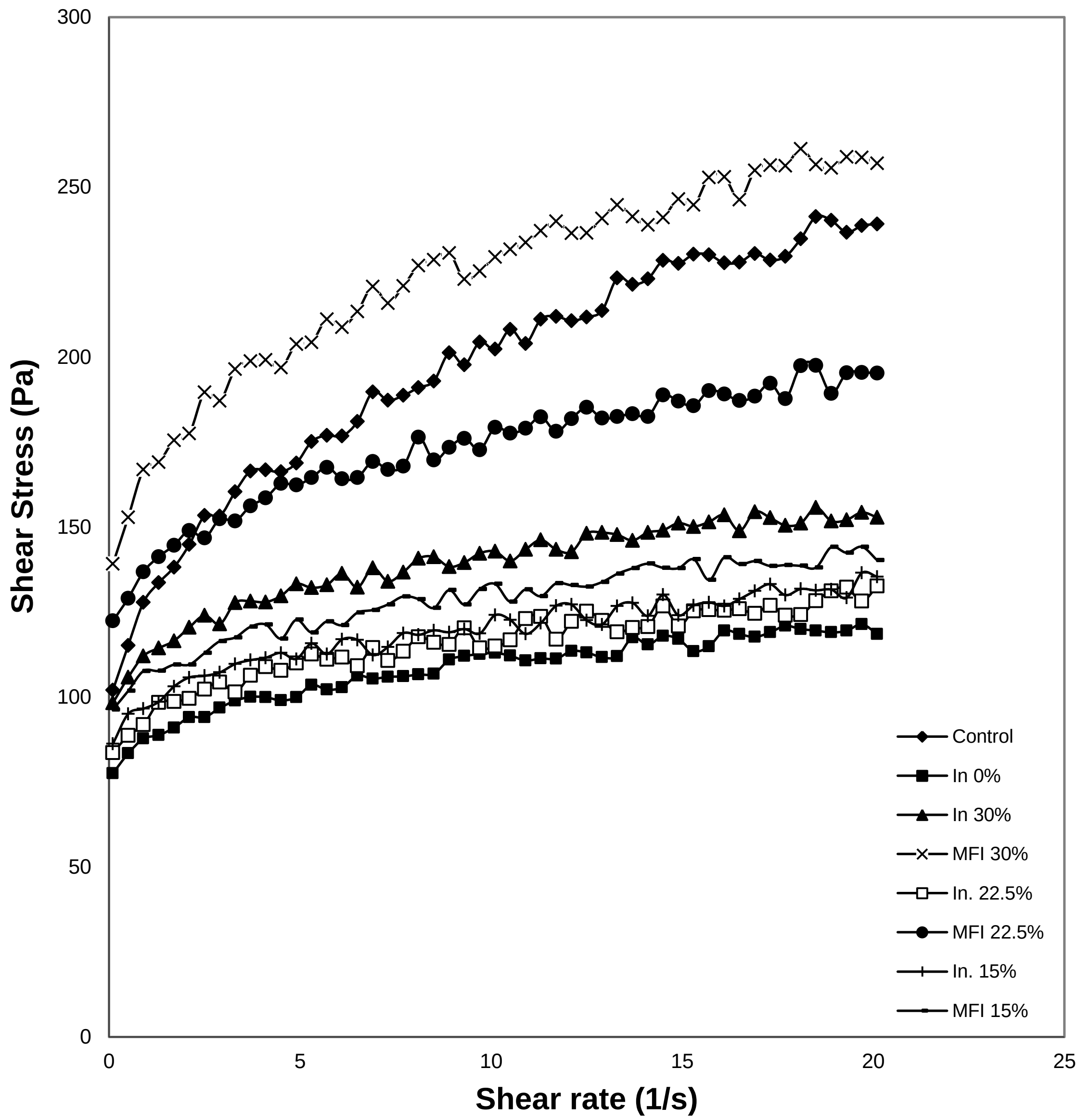

Figure 3.11 Flow curves for 37.5% oil replacement of mayonnaise samples by different inulin percentages

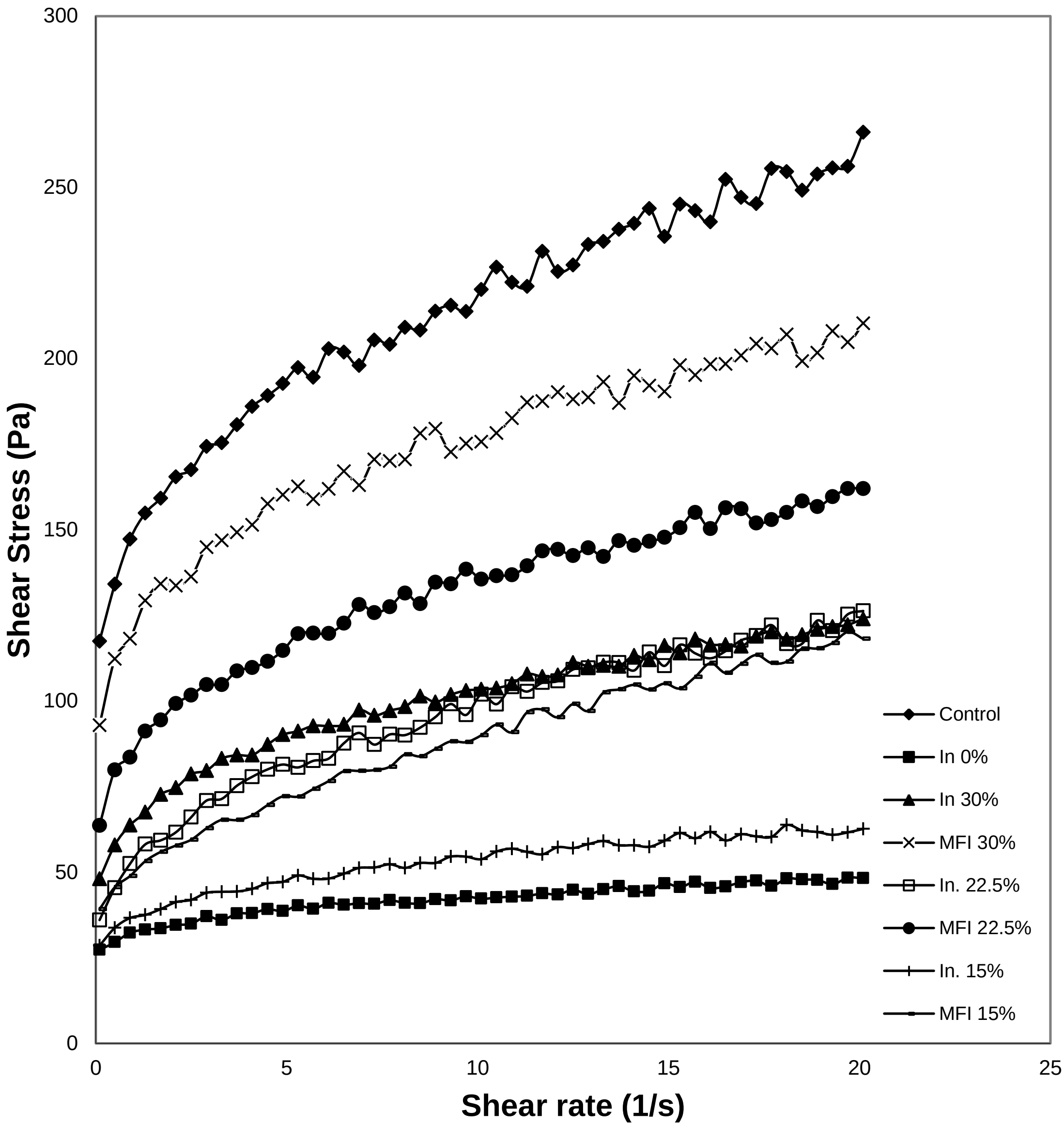

Figure 3.12 Flow curves for 37.5% oil replacement of mayonnaise samples by different inulin percentages

Elastic modulus and viscous modulus of the mayonnaise samples with 12.5%, 25% and 37.5% oil replacement by inulin were analyzed. To determine the elasticity, the study used two different types of samples: (1) the oil was replaced by water ("0% inulin"); and (2) the oil was replaced by inulin emulsion ("15%, 15%MF, 22.5%, 22.5%MF, 30% and 30%MF inulin sample”). In both cases, the oil was replaced by 12.5%, 25% and 37.5% water or inulin. Figures 3.13- 3.15, represents elastic modulus values for 12.5%, 25% and 37.5% oil replacements and figures 3.16-3.18 for viscous modulus values, respectively. According to the results, the lowest elastic modulus belongs to the sample containing 0%inulin in all replacement percentages. Among the samples containing inulin, the lowest elasticity was observed for 15% non-MF inulin. The highest value was recorded for mayonnaise sample containing 30% MF inulin. It can be stated that the compact packing of oil droplets into network effects elastic properties and deformation resistance of the related emulsion (Liu et al., 2006). Microfluidized fibers, whose sizes are reduced by microfluidization have very large surface area, so they may position themselves on the surface of the oil droplets which increase emulsion stability and prevent aggregation (Mert et al., 2014).

Mayonnaise rheology and texture can depend on the distribution of the oil, the interaction between oil droplets, and the egg yolk emulsifier. Alteration of the mayonnaise’s microstructure leads to different rheological properties. This means that the rheology is sensitive to any change in the mayonnaise microstructure (Stokes and Telford, 2004). The benefit of high pressure homogenizers in comparison with other technologies is that more uniform droplets size distribution are obtained since the product is subjected to high shear that significantly decrease the diameter of the original droplets (Martin-Gonzalez et al., 2009). Microfluidization aids the decrease of particle size and increase the stability of the mayonnaise which acts as a semi-solid fluid. In emulsions, droplet size is perhaps the most important factor in determining properties like consistency, rheology, shelf life stability, color and taste. In general, emulsions with smaller droplet size result in great stability (Ignácio and Lannes, 2013).

Many factors can determine the stability of fluids. Dispersions have wide variations in performance depending on particle size, shape, concentration, and any attraction with the continuous phase in which they are suspended. Higher elasticity indicates formation of a network structure which will stabilize the suspension (Franck, 2011).

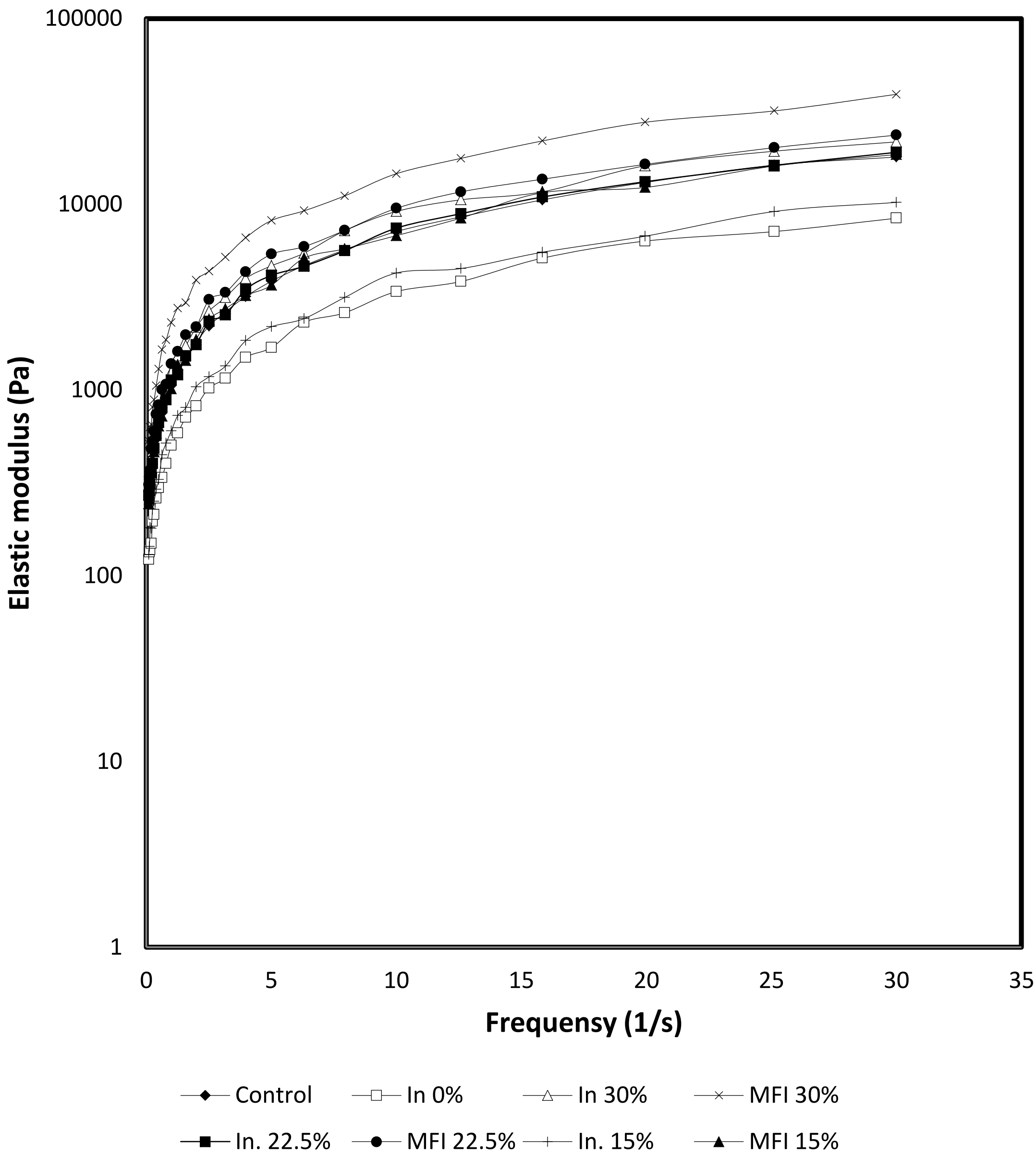

Figure 3.13 Elastic modulus for 12.5% oil replacement of mayonnaise samples with different inulin percentage replacement

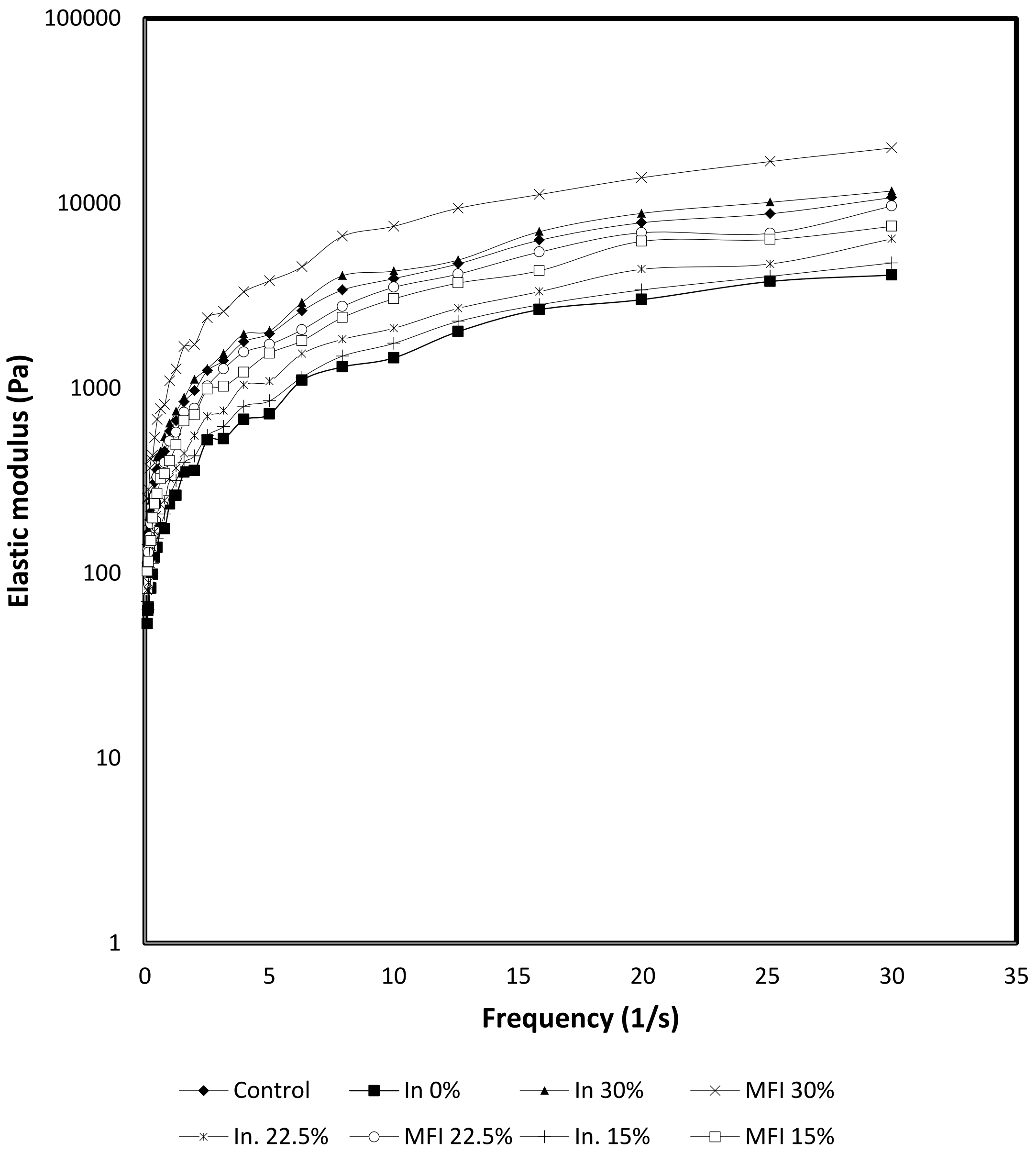

Figure 3.14 Elastic modulus for 25% oil replacement of mayonnaise samples with different inulin percentage replacement

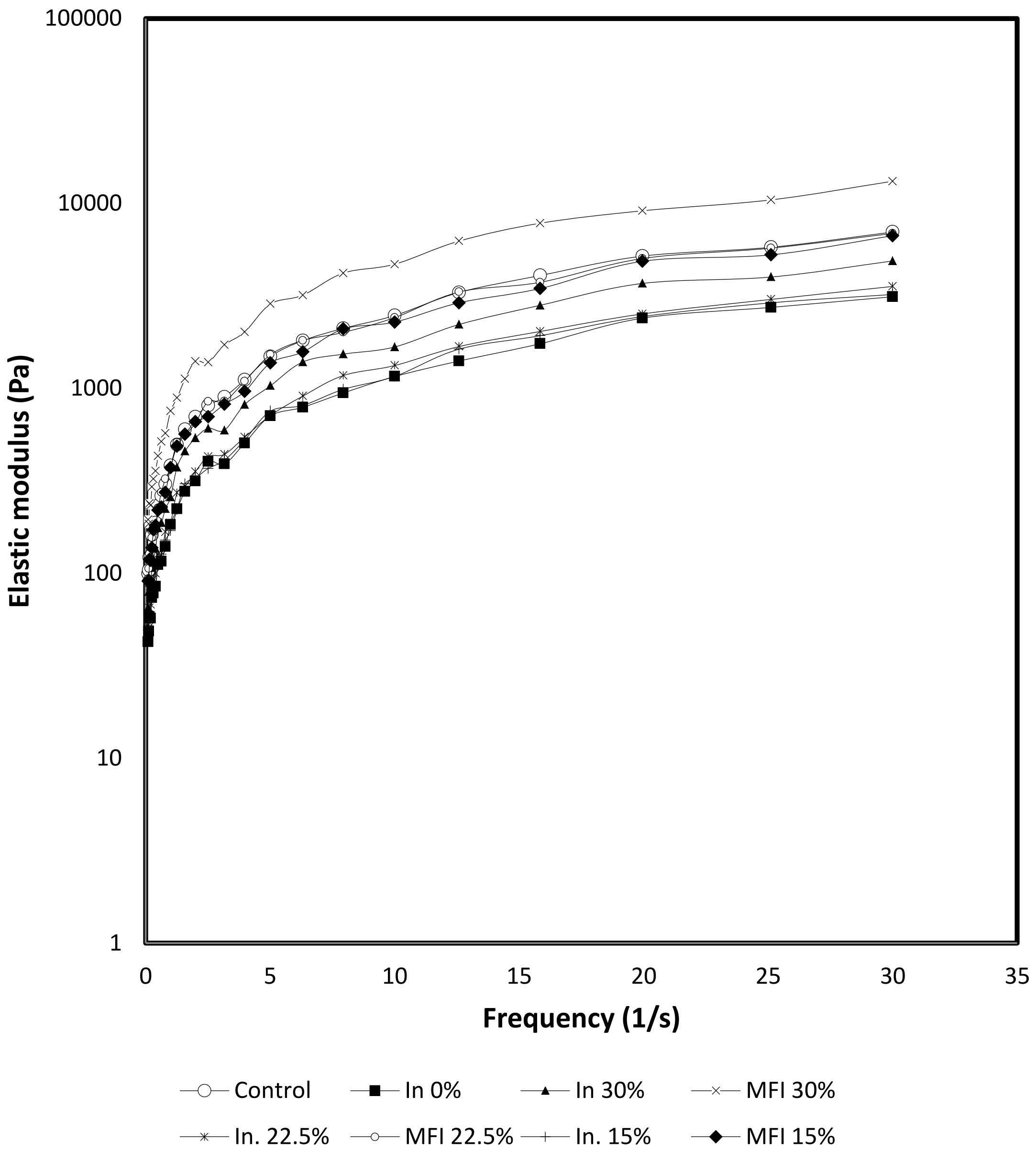

Figure 3.15 Elastic modulus for 37.5% oil replacement of mayonnaise samples with different inulin percentage replacement

According to the figures 3.13- 3.18, it is obvious that viscous modulus values are lower than elastic modulus values for all mayonnaise samples. This suggests that low fat mayonnaises are weak and gel-like, as is typical of dressings and emulsions (L.ma and Canovas, 1994). A high storage modulus shows that higher stresses are necessary before the emulsion can flow. On the other hand, it also means that emulsion stability is enhanced in low stress situations (Aslanzadeh et al., 2012). It can be implied that the possibility of any structural changes taking place during storage is reduced by using inulin as fat replacers in mayonnaise samples. Figure 3.16, 3.17 and 3.18 shows viscoelastic modulus values of 12.5%, 25% and 37.5% oil replacement of mayonnaise samples, respectively. Comparing these figures, it is seen that as the oil content of the samples decreases, viscoelastic modulus values decreased too. Mayonnaise along with higher oil concentrations has more gel-like property than at lower oil concentrations (L.ma and Canovas, 1994). This fact is due to the existence of more packing of oil droplets in higher oil concentrations in comparison with lower concentrations of oil in the product (Jaynes, 1985). The oil concentration in the food product affects the magnitude of elastic and viscoelastic modulus (L.ma and Canovas, 1994). It can be concluded that samples containing inulin as dietary fiber show more stability in comparison with control sample. Rheology of mayonnaise can provide valuable information that can be used in quality control of commercial production, storage stability, sensory assessments of consistency, knowledge and design of texture, design of unit operations, and knowledge of the effects of mechanical processing on the structure of the emulsions (Gallegos and Berjano, 1992)

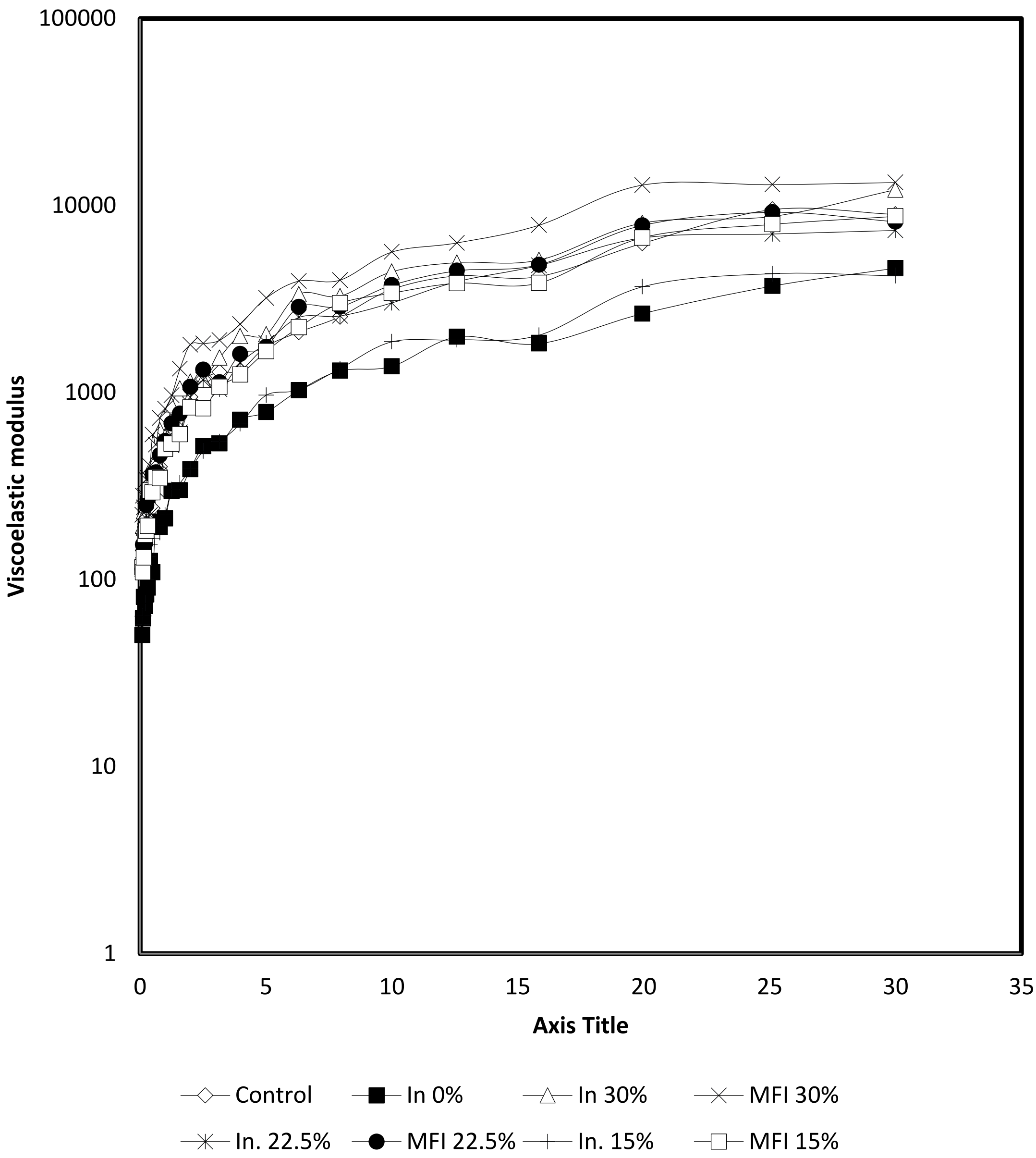

Figure 3.16 Viscous modulus for 12.5% oil replacement of mayonnaise samples with different inulin percentage replacement

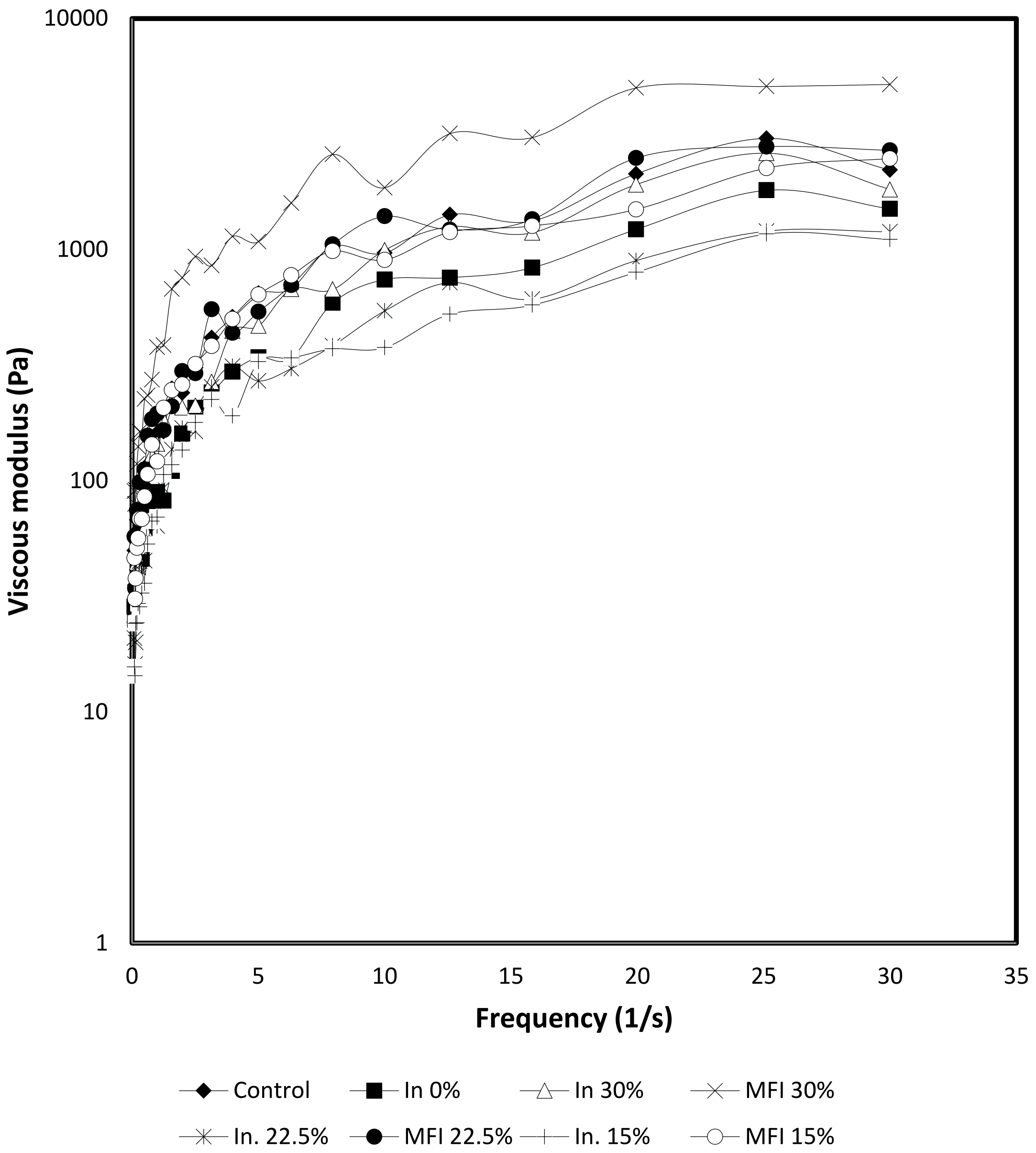

Figure 3.17 Viscous modulus for 25% oil replacement of mayonnaise samples with different inulin percentage replacement

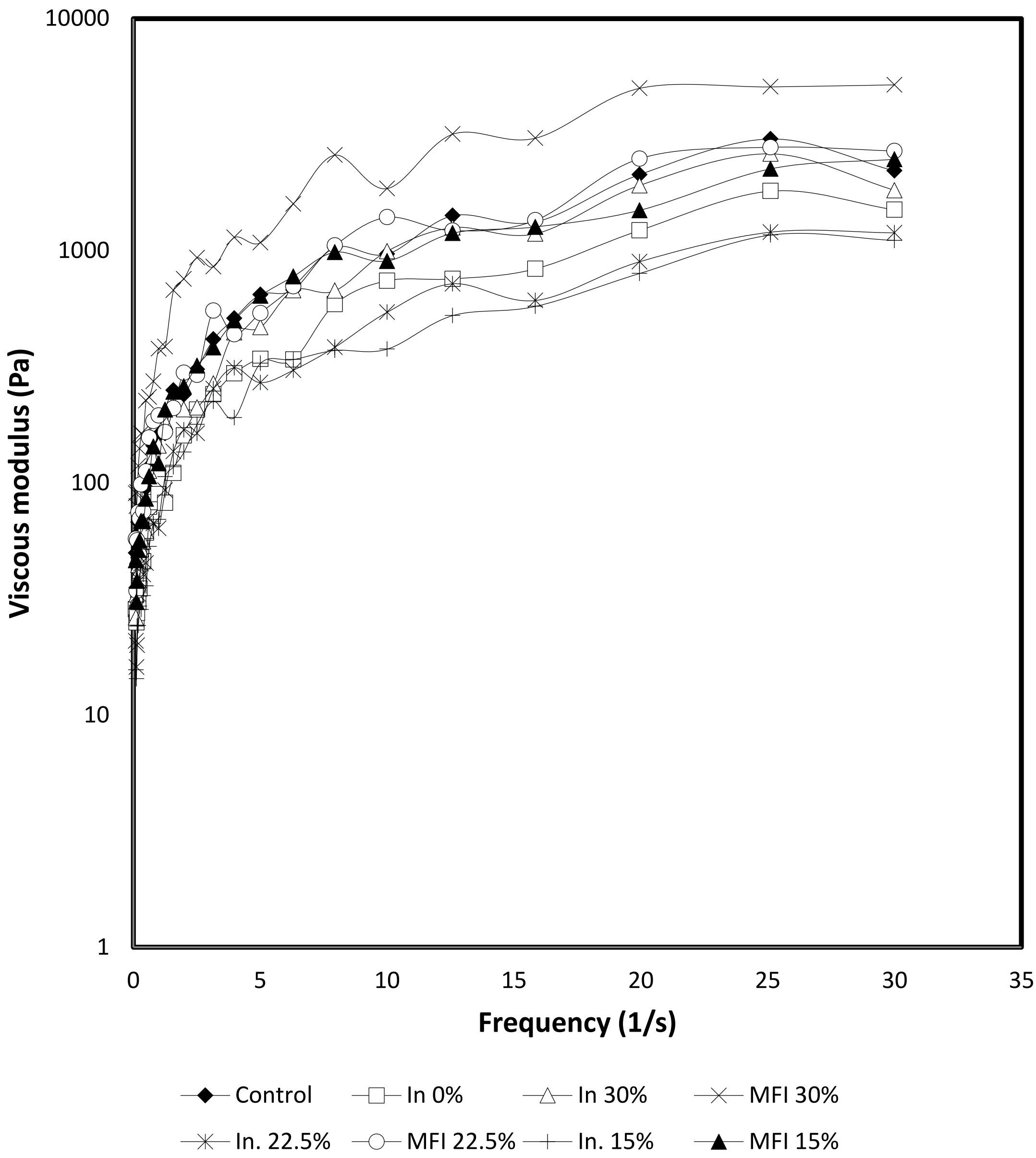

Figure 3.18 Viscous modulus for 37.5% oil replacement mayonnaise samples with different inulin percentage replacement

3.1.3 Rheology of Inulin Emulsion

The concentrations of inulin used in this study were 15%, 22.5% and 30% (w/w). all these emulsions were used in 25%, 50% and 75% oil replacement for cake samples and 12.5%, 25% and 37.5% oil replacement for mayonnaise samples. As seen in the figure 3.19, initial inulin amount affected rheological properties of both microfluidized and non-microfluidized emulsions. It also shows that lower amount of inulin led to lower shear stress value versus shear rate. Gel formation was faster for the emulsions with higher amount of inulin in comparison with lower inulin content. Microfluidization enhanced gelling properties of the emulsion. Gelation happened more quickly because the smaller particles that were formed by microfluidization decreased the critical inulin concentration needed for gelation (Ronkart et al., 2009). Both microfluidized and non-microfluidized samples of 30% inulin acted as a solid material within 1 hour. 22.5% and 15% microfluidized and non-microfluidized samples needed 1 day to become solid at refrigerator temperature.

As it is seen in figure 3.19, microfluidization increased required yield stress for emulsions to initiate flow. Reduction of the particle size leads to more particle interactions and formation of more complex network can causes higher holding capacity of the emulsion. This fact was consistent with rheological properties of microfluidized samples. Highest shear stress value versus shear rate belonged to 30% microfluidized inulin emulsion and the lowest value was observed for 15% non-microfluidized inulin emulsion. Highest inulin concentration had higher shear stress value due to a reduction of the particle size which caused more particle interactions and the formation of a network of solid particles which held water and inulin solubilized in it (Ronkart et al., 2009).

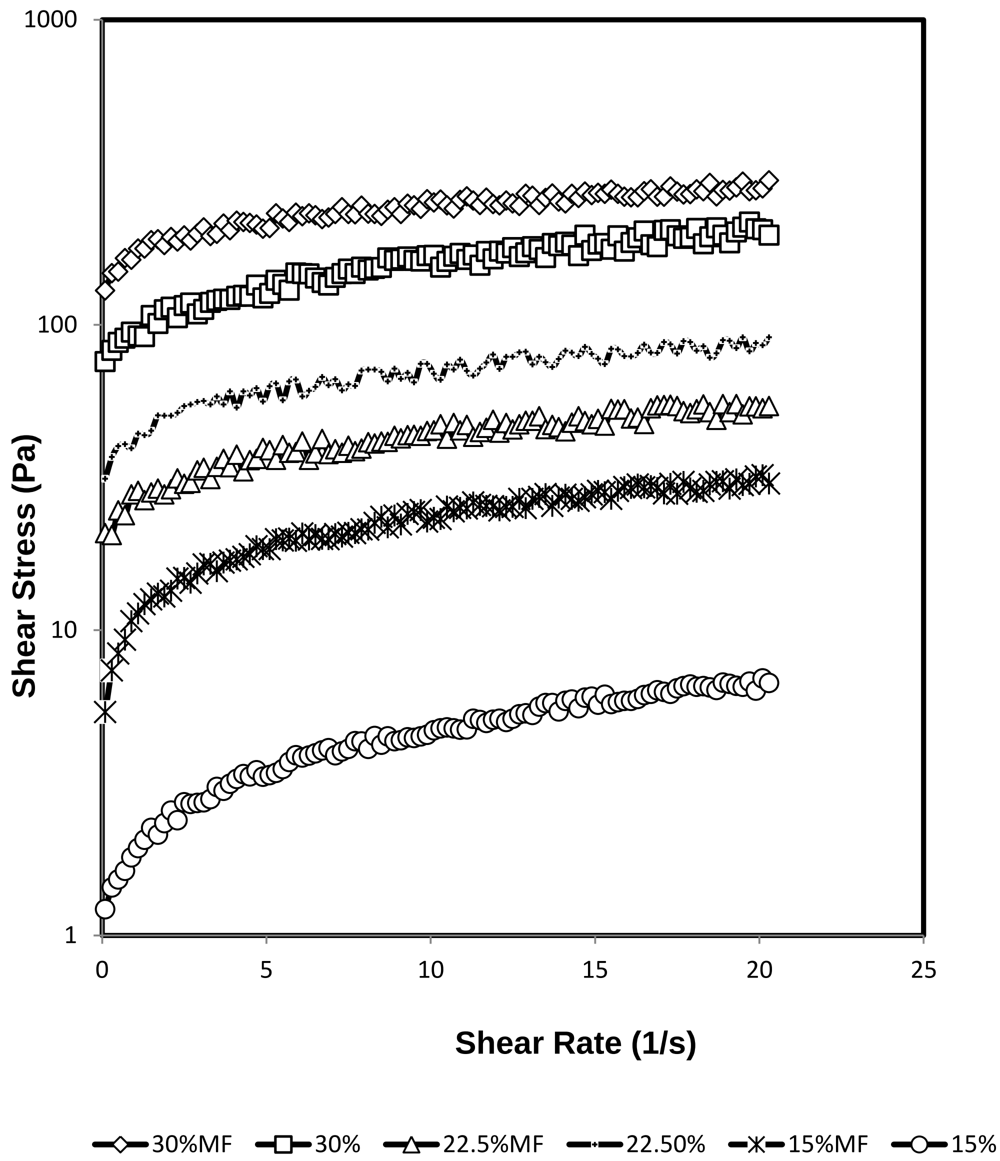

Figure 3.19 Effect of different inulin percentages on rheological property of the emulsion

Herschel-Bulkley model was found to be the best fit to the shear stress (τ) versus shear rate (γ) data for all the samples at 25 °C:

$$\tau = \tau_0 + K\,(\gamma°)^n \qquad (3.3)$$

Where τ is shear stress (Pa), τ_0 is the yield stress (Pa), γ is the shear rate (s^{-1}), n represents flow behavior index and K is the consistency index (Pas^n).

The consistency index parameter K can provide information about viscosity of the fluid. However, to be able to compare K-values for different fluids, they should have similar flow behavior index (n) (Bjorn et al., 2012). According to the figure 3.21, the highest consistency was indicated for 30% microfluidized samples and the lowest value was for 15% non-microfluidized inulin emulsion. The values of the consistency and the flow behavior of a food sample depend on the specific shear rate range being used so that when evaluating rheological properties of different samples, they should be determined over a specific range of shear rates (Mothe and Rao, 1999). Shear rate of all the evaluations were 20 (1/s). The values in figures 3.20 show that inulin emulsion with the specific concentrations of this study act as viscoplastic materials since flow behavior index is lower than 1 and yield stress is higher than 0. Higher amount of inulin had lower flow behavior index (K). Microfluidization decreased flow behavior index (K) of the emulsions of same inulin content. When the flow behaviour index is closer to 1, the fluid behavior tends to change from a shear thinning to a shear thickening fluid. When n is above 1, the fluid acts as a shear thickening fluid (Bjorn et al., 2012). Lower flow behavior index values caused by microfluidization are more sensitive to shear rate in comparison with samples with higher flow behavior index. It can be concluded that microfluidized samples with higher inulin content are more sensitive fluids in comparison with non-microfluidized samples containing lower inulin content.

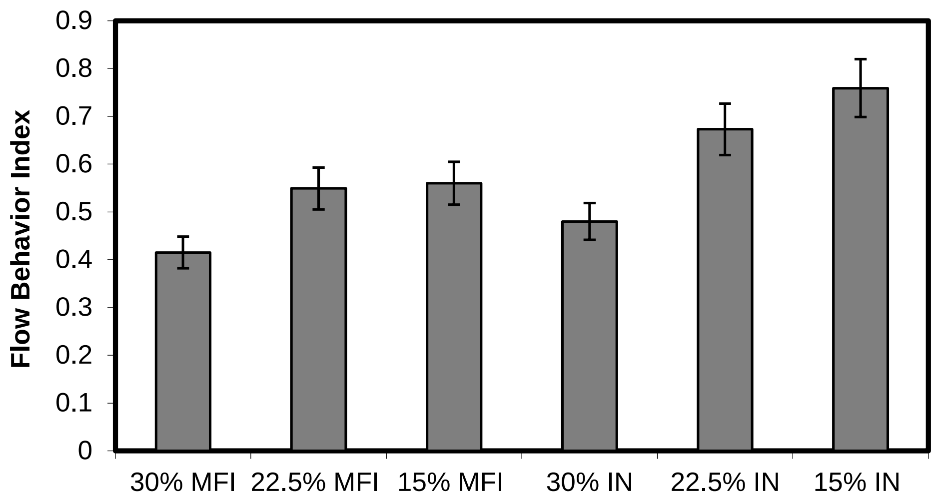

Figure 3.20 Flow behavior index of inulin emulsions with different inulin percentages

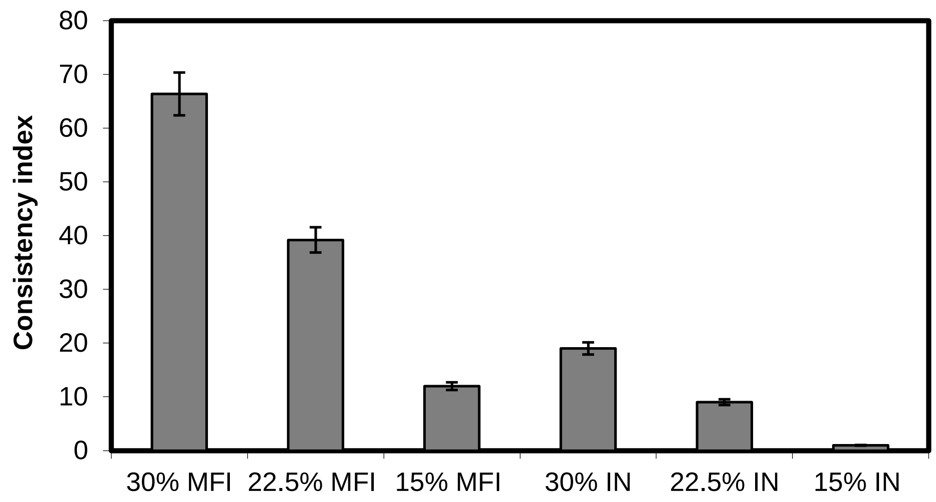

Figure 3.21 Consistency values of inulin emulsions with different inulin percentages

Application of microfluidization process alters rheological and textural properties of food samples by reducing particle size. Properties of inulin emulsion were also changed by application of this high shear device which in return can change rheological and textural properties of food containing this emulsion as fat replacer. Increasing amount of inulin along with microfluidization process enhanced shear stress values versus shear rate which can be indicator of increasing viscosity values. Considering the percentage of inulin present in the emulsion and the force conducted by the miccrofluidizer, a semi-solid food sample can act as solid material. According to Ronkart et al. (2012), this alteration is the same as shifting milk into yogurt. This fact is due to reduction of particle size and formation of a network with higher water holding capacity. Higher shear devices and homogenizers can lower the required inulin amount as fat replacer in foods without changing desired rheological and physical properties.

3.2 SEM Analysis of MF and Non-MF Inulin

Scanning electron microscopy photographs of the microfluidized sample and non-microfluidized inulin sample that is considered as control were taken at 500X, 10000X and 20000X magnifications after freeze drying process. As it is seen in the figures 3.22, 3.24 and 3.25 for control samples, inulin particles are in spherical shape with non-porous surface structure. Microfluidization process applies high shear which disintegrates inulin particles and creates porous structure. At 10000X magnification of microfluidized sample (figure 3.26), it is obvious that particles which are smaller than particles of control sample attached together and created a porous crystal structure which can increase water holding capacity. At 500X magnification (figure 3.25), it is shown that the particles themselves have disintegrated structures which can enhance this property as well.

Increased water holding capacity due to porous structure of microfluidized samples can lead to less water loss during baking process which is consistent with the results of water loss analysis of this study. Water retention in the emulsion leads to faster gelling properties of the emulsion in microfluidized inulin emulsions. This result was consistent with the study conducted by Ronkart (2010), which also showed the crystal structure of the microfluidized inulin sample and thus higher water holding capacity. Tlhe microfluidization process reduced the solid inulin particle size which in turn resulted in a smoother texture similar to that of yogurt or margarine depending on the inulin concentration. This sensorial property is important for developing new products for formulations when inulin is used as a fat replacer (Nowak, von Mueffling, Grotheer, Klein, & Watkinson, 2007).

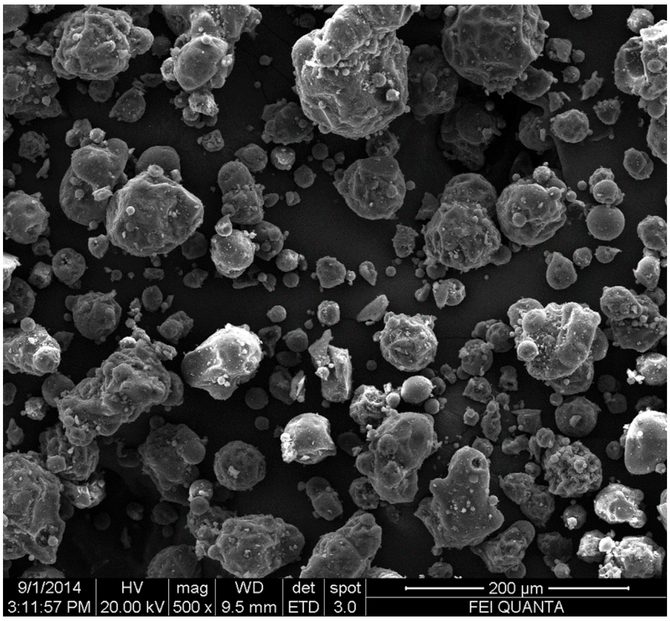

Figure 3.22 SEM image of non-MF inulin. Magnification: 500X

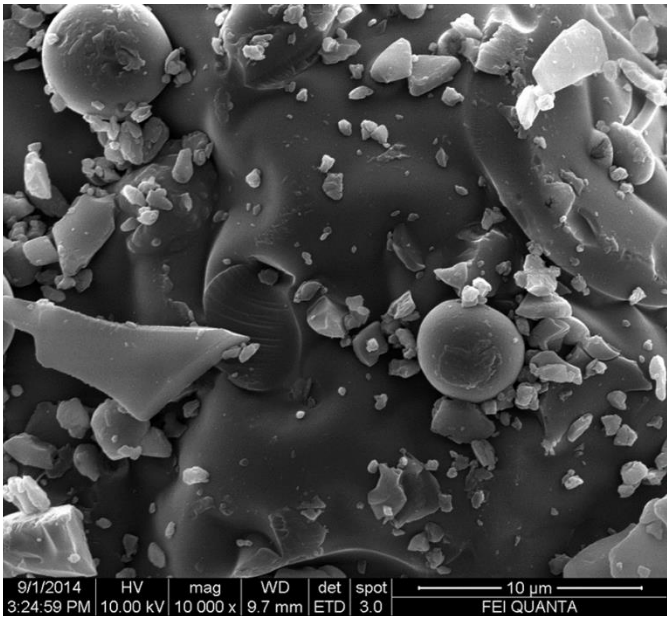

Figure 3.23 SEM image of non-MF inulin. Magnification: 10000X

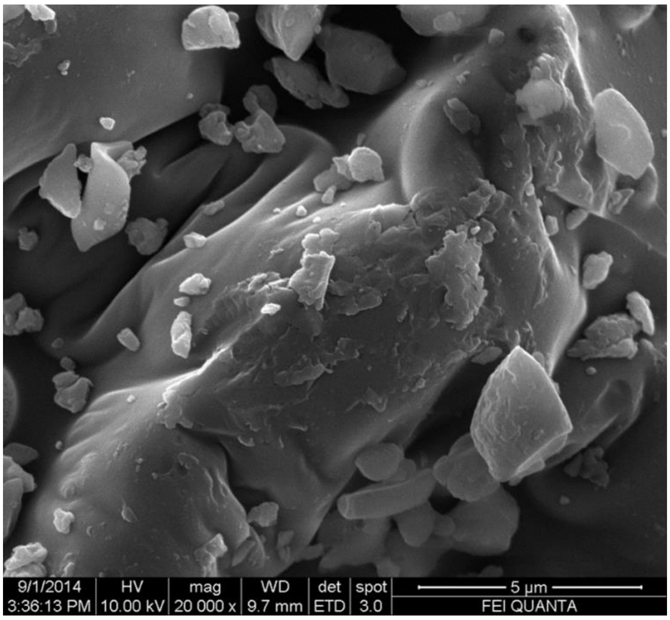

Figure 3.24 SEM image of non-MF inulin. Magnification: 20000X

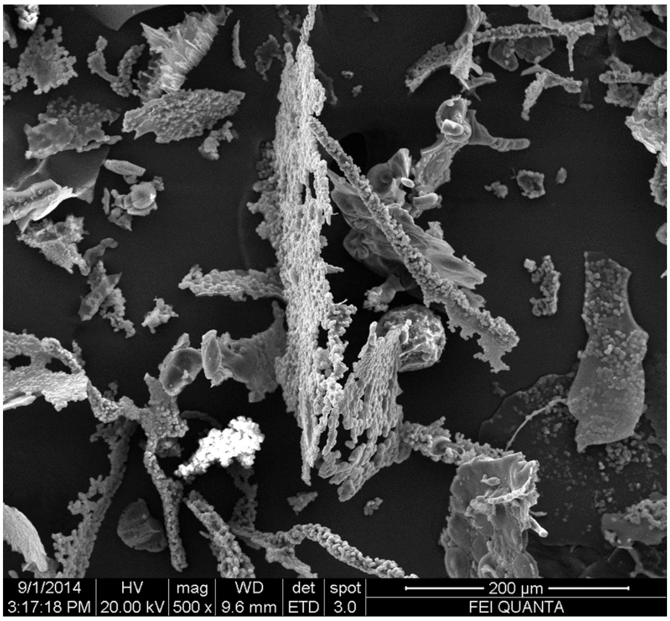

Figure 3.25 SEM image of MF inulin. Magnification: 500X

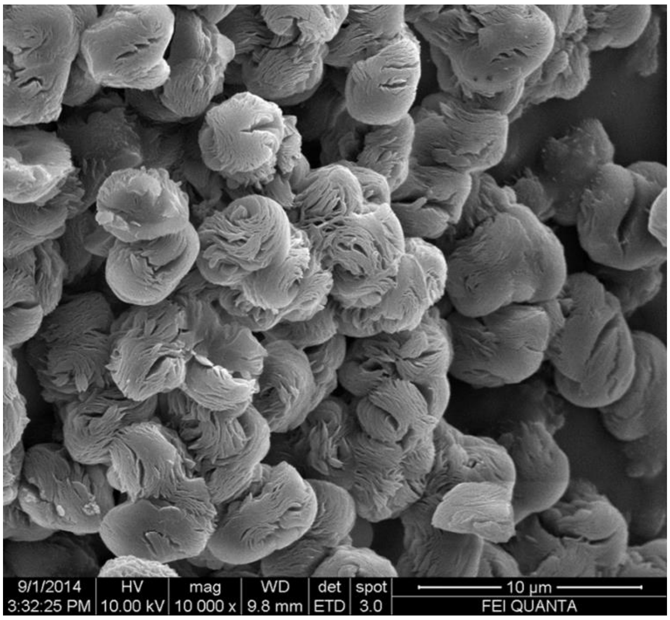

Figure 3.26 SEM image of MF inulin. Magnification: 10000X

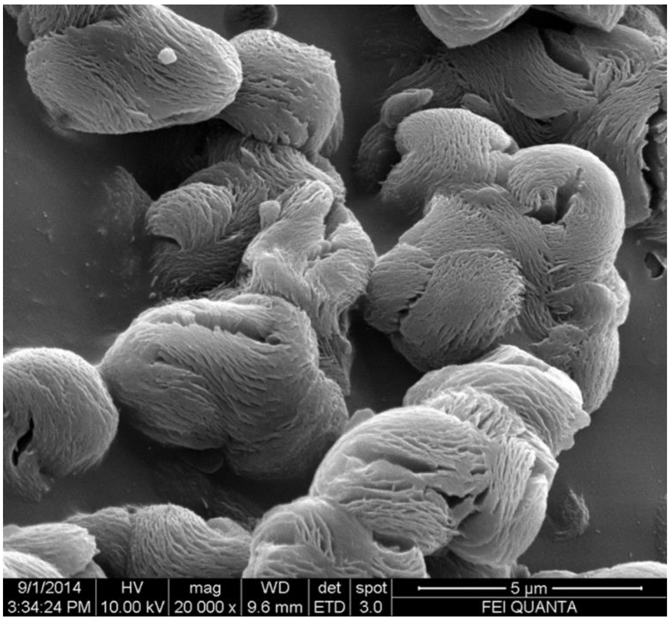

Figure 3.27 SEM image of MF inulin. Magnification: 20000X

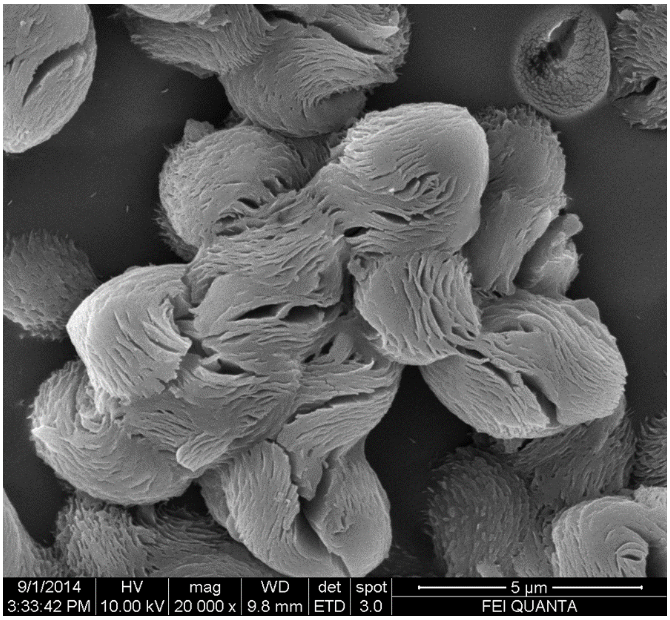

Figure 3.28 SEM image of MF inulin. Magnification: 20000X

3.3 Texture Measurements

3.3.1 Texture Profile of Fresh Cake Samples

3.3.1.1 Hardness

Hardness, cohesiveness and adhesiveness of the cake samples with inulin used as fat replacer were recorded as texture parameters. Inulin emulsion was prepared through 15%, 22.5% and 30% of dry powder inulin and water. Each emulsion was used through cake samples with 75%, 50% and 25% oil content which are considered as C25, C50 and C75 respectively. Increase of amount of inulin used in both emulsion and cake formula caused hardness increase in cake samples. According to figure 3.29, higher hardness belonged to samples with higher amount of inulin. Inulin tends to integrate to the gluten network, it also dilutes it, resulting in lower gas retention ability and harder cake crumbs (Foschia et al., 2013). Garcia et al. (2011) reported that cake crumbs with higher inulin had wider bubble size distribution which resulted in harder cake texture by increasing amount of inulin used in the formula. Fat replacement makes cake matrix irregular by reduction of oil as lubricant which causes starch granules not to fully embed. Inulin limits gluten and starch hydration during mixing and baking process which also makes cake structure to be in an irregular pattern (Rodrigues-Garcia et al., 2012). Samples with higher amount of oil had softer texture. So many studies have been conducted toward fiber impact on bakery products. It has been reported that fibers have impeding effect in intermolecular interactions which can change texture properties of cakes and other bakery products (Collar et al., 2007). Microfludization also increased hardness value of fresh cake samples which can be due to higher water binding capacity. The highest hardness value was observed for the microfluidized samples with highest amount of inulin. The lowest hardness value was recorded for sample with 75% oil and 25% inulin (15%w/w inulin emulsion) content.

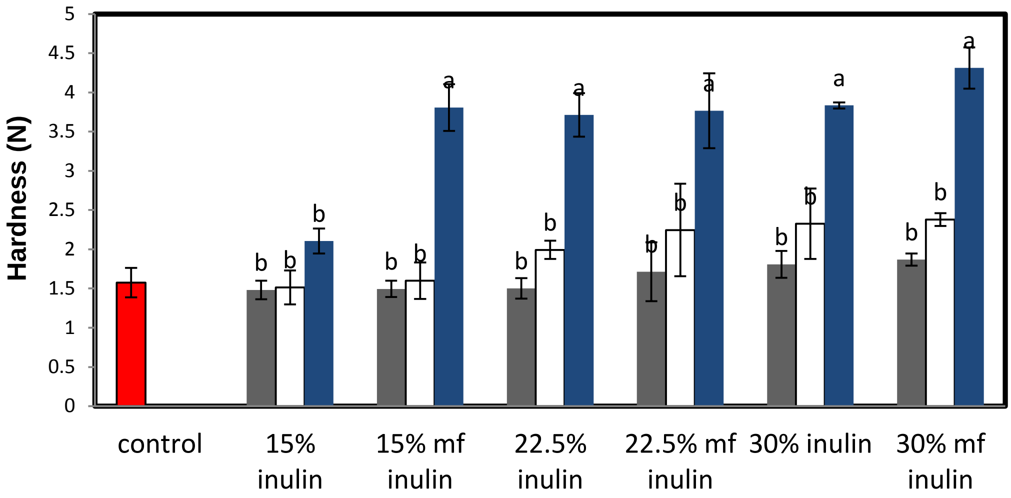

Figure 3.29 Hardness values for fresh cake samples with (dark gray bar) C75, (white bar) C50, (blue bar) C25.

3.3.1.2 Adhesiveness

Adhesiveness is considered as the degree to which the cake adheres to mouth surfaces during mastication. This force is required to remove the material that adheres to the mouth (generally the palate) during the normal eating process (Szczesniak, 2001). It is also defined as the work necessary to overcome the attractive forces between the surface of the food and the surface of other materials (Guinard & Mazzucchelli, 1996; Pons & Fizsman, 1996). Sticky mouthfeel is created by excess adhesiveness which is not desired by the consumer.

As shown in the Fig 3.30, adhesiveness increased as the amount of inulin used in the formula increased. According to ANOVA results, inulin amount used in the formula had significant effect on adhesiveness of cake samples. Microfluidized samples had higher adhesiveness in comparison with non-microfluidized ones. Microfluidization reduces particle size and increases water holding capacity. The highest adhesiveness value was observed for 30% microfluidized inulin content sample which acts as lubricant and presence of fructan in inulin can cause adhesiveness increase (Garcia et al., 2012). The lowest adhesiveness was observed for samples containing 15% inulin emulsion in figure 3.30. According to the study conducted by Cavender and Kerr (2013), microfluidization of ice cream mixes with locust bean or xanthan gum at 220 -250 MPa resulted in hardness and adhesiveness increase of the final ice cream product. Excess moisture leads to the increase of adhesiveness. According to Paquin et al. (2004), whey protein isolate and xanthan gum were used as fat replacer in low fat food system. As the amount of these fat replacers decreased, lower adhesiveness values were obtained through the study which was mostly influenced by interaction moisture. In general, higher amount of inulin along with microfluidization process resulted in higher adhesiveness.

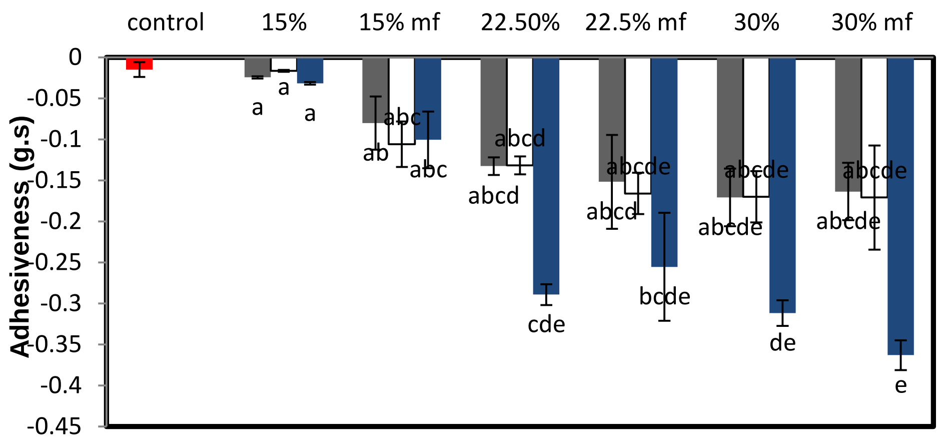

Figure 3.30 Adhesiveness values for fresh cake samples with (gray bar) C75, (white bar) C50, (blue bar) C25

3.3.1.3 Cohesiveness

Cohesiveness is referred to how well the product tolerates a second deformation relative to how it behaved under the first deformation. It measures the difficulty of breaking down in the gel's internal structure. In general, both, springiness and cohesiveness could be indicative of an increase in bond formation within the three dimensional protein networks in cakes. Equal amounts of total solid matter in all cake products may cause an insignificant difference between the cohesiveness values of all samples (Kalinga and Mishra 2009).

Cohesiveness has an adverse relation with hardness. Samples with higher hardness value had lower cohesiveness. As hardness increases by using inulin as fat replacer, cohesiveness tends to decrease. Microfluidization decreases cohesiveness values according to the Figs 3.31, both lower cohesiveness and higher hardness are considered as two main texture changes during cake storage while increase of hardness and decrease of cohesiveness was observed at longer storage times (Gélinas, 2008). Dough development and water incorporation into the flour occur during mixing. The disulphide, hydrogen, and ionic bonds maintain the cohesiveness and lead to gas retention during baking process. Changes in these linkages occur during storage (water migration, starch crystallization, fat hydrolysis), leading to a disarrangement of the structure (Esteller et al., 2004).

As the moisture is transferred from the cake to the atmosphere, the product gets more compact texture which leads to higher hardness and lower cohesiveness values at storage time. According to a study carried out by Gomez et al at 2007, wheat flour replacement by chickpea flour also induced an increase in the firmness but reduced cohesiveness increasing the tendency to hardening. Esteller et al. (2004) reported that cohesiveness decrease was caused by the loss of intermolecular attraction among ingredients, drying, and a trend to crumbliness with ageing. It is concluded that increasing amount of inulin and microfluidization process leads to cohesiveness decrease in cake samples.

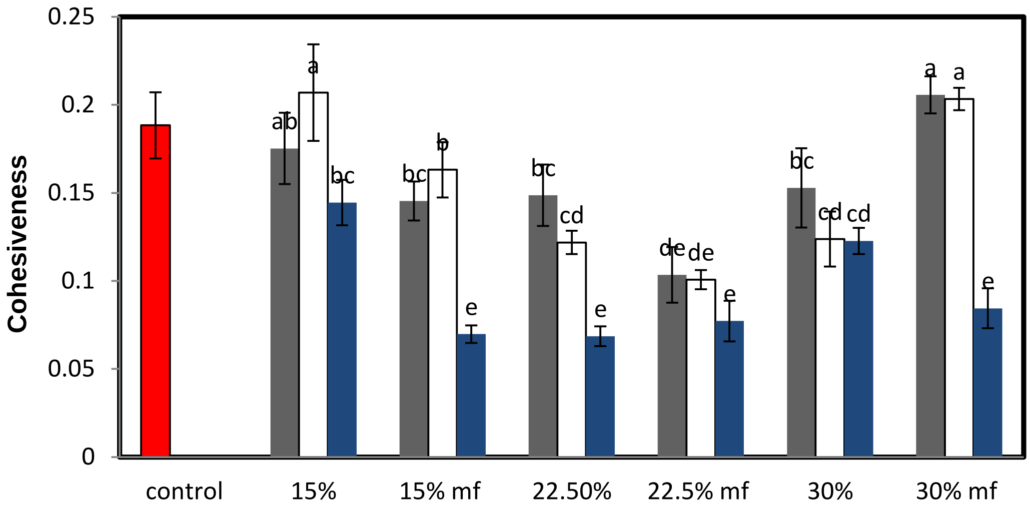

Figure 3.31 Cohesiveness values for fresh cake samples with (gray bar) C75, (white bar) C50, (blue bar) C25

3.4 Weight Loss

According to table 3.7, weight loss of cake samples decreased as inulin amount used in the formula increased. This reduction is due to water holding capacity of inulin which limits available free water in the product. Microfluidization increases water holding capacity which leads to lower weight loss of the product as it is seen in table 3.7, higher weight loss was observed for control sample and the sample with lowest inulin amount in emulsion which was 15% with no application of microfluidization. As the result, the lowest weight loss was obtained for cake samples containing 30% of microfluidized inulin in emulsion in all replacement levels. Both inulin amount and microfluidization decreases weight loss in cake samples.

Loss of desired texture affects shelf life of the final product. Since water loss causes texture alteration, the less the water loss, the longer the shelf life. As it is seen in the results, inulin and microfluidization can enhance shelf life of the cake product.

Table 3.7 Weight loss values for fresh baked cake samples

Weight loss (%)			
Inulin emulsion (%)	Oil replacement (%)		
	C25	C50	C75
15%	12.08±0.01[cd]	12.23±0.02[c]	12.54±0.04[b]
15%MF	12.98±0.02[a]	11.88±0.09[de]	11.26±0.01[f]
22.5%	11.25±0.01[f]	10.37±0.08[h]	11.78±0.02[e]
22.5%MF	10.94±0.05[g]	9.88±0.01[i]	9.61±0.09[j]
30%	9.09±0.06[k]	8.08±0.05[m]	8.01±0.01[m]
30%MF	8.41±0.06[l]	7.91±0.02[m]	8.37±0.02[l]

Results are given as the mean values. Values followed by different letters are statistically different ($p \leq 5$).

3.5 Color of Cakes

Inulin effect on crumb color of cake samples were measured 1 h after baking process. As observed in the table 3.8, cakes containing inulin had lower ΔE values in comparison with control sample. Lowest color was observed for the sample containing 25% of inulin emulsion (15%). Higher amount of inulin led to darker color of cake in comparison with lower inulin content cakes which may be due to reducing sugars in inulin powder. Maillard reaction occurs during baking process by reducing sugars. Low molecular weight fructan are hydrolyzed to fructose during baking process which can create darker color in cake crumbs. ΔE value for control cake was recorded 45.2 which was close to the samples containing 30% microfluidized inulin emulsion. Microfluidization increased ΔE value in comparison with non-microfluidized samples. ΔE values related to C25, C50 and C75 samples of 15% (w/w) of inulin emulsion were 28.1, 30.1 and 30.4 respectively, whereas the values belonging to the microfluidized samples of the same percentages were 34.5, 33.5 and 32.9, respectively. According to ANOVA results, inulin amount had significant ($p \leq 0.05$) effect on ΔE values of cake samples. Inulin is considered as carbohydrate storage which is extracted from chicory roots. Yilmaz et al. (2011) reported that the reaction of phenolic compounds of chicory like chlorogenic acid with iron creates a dark colored complex, which results in discoloration of cakes after cooking. It is included that increasing amount of inulin along with microfluidization process led to darker color of cake samples but lighter than the control full fat sample.

Table 3.8 ΔE values of cake samples

Color (ΔE)			
Fat Replacer Level (%)			
	C25	C50	C75
Control	45.2±0.9		
15%	28.1±0.9^{i}	30.1±0.2^{hi}	30.4±0.1^{hi}
15%MF	34.5±0.8^{de}	33.5±0.1^{ef}	32.9±0.1^{efg}
22.50%	28.9±0.8^{hi}	31.0±0.5^{ghi}	31.3±0.4^{fgh}
22.5%MF	34.4±0.7^{de}	36.7±0.5^{d}	33.5±0.2^{ef}
30%	39.8±0.9^{c}	40.6±0.1^{bc}	41.6±0.1^{bc}
30%MF	42.4±0.7^{ab}	44.3±0.8^{a}	44.7±0.7^{a}

Results are given as the mean values. Values followed by different letters are statistically different ($p \leq 5$).

3.6 Staling Analysis of Cake Samples Stored for 2 and 4 Days

Hardness values of cake samples were increased during 2 and 4 days of storages. According to ANOVA results, inulin amount in emulsion and the total amount of the emulsion used in cakes effected hardness of the samples during storage time. Figures 3.32- 3.37 represent 30%, 30%MF, 22.5%, 22.5%MF, 15% AND 15%MF inulin emulsion effect on hardness of C25, C50 and C75 cake samples during 2 and 4 days of storage. According to the figure 3.32, hardness value for C25 of 30% inulin emulsion content fresh cake sample was 1.8088225 N. This value increased to

2.1315775 N and 2.7790875 N for 2 and 4 days of storage, respectively. As seen in the figure 3.33, values for the microfluidized sample of the same percentage were 1.86818 N, 2.710703 N and 3.194758 N for fresh cake sample, stored for 2 days and 4 days samples, respectively. This increase order was observed for other inulin emulsion concentrations too.

Decrease in moisture content can be considered as main reason of firmness during storage. As a result, moisture content is shown to be inversely proportional to the rate of firming (Ozkoc et al., 2009). Consumer considers a moist cake as the fresh cake (SYCH et al., 1987). Considering table 3.7, it is obvious that as the oil replacement was increased, weight loss was decreased. This fact can explain the increasing of firmness values as the inulin amount in the cake samples decreases in all inulin concentrations of inulin emulsion. It has been also reported that the firmness of the crumb occurs as the result of the macroscopic migration of moisture from the inner part of the cake to the surface and environment (Guy, 1982).

According to a study carried out by Maleki (1980), along with 2 hours of cooling, the moisture content dropped to 41%. Moisture decrease continued at longer storage time but with a lower rate as water migration speeded down. Considering the fact that water acts as plasticizer, decreasing moisture content leads to acceleration of starch-protein and at the same time starch-starch interactions which in return creates firmer texture (Ozkoc et al., 2009). SYCH et al., reported that there is a positive correlation between hardness and adhesiveness of cake samples during storage which were consistent with the results obtained in this study.

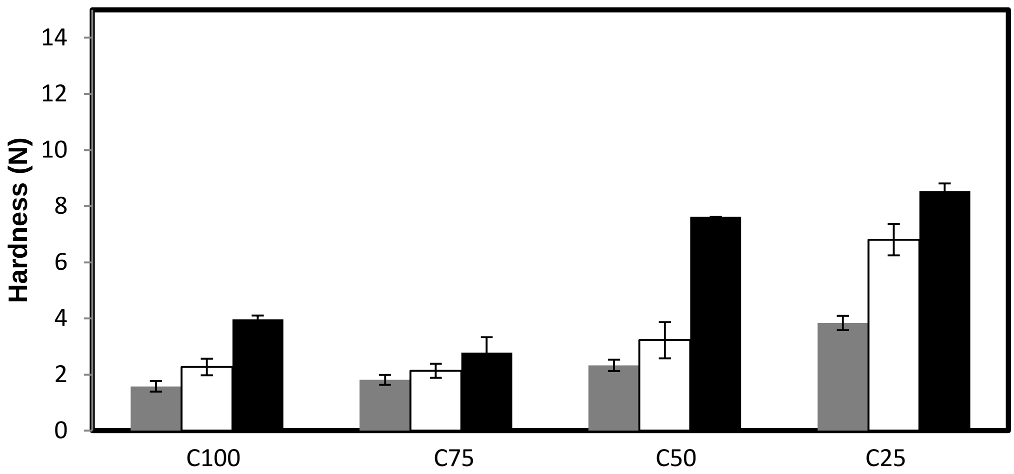

Figure 3.32 Hardness values for cake samples with inulin emulsion (30%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

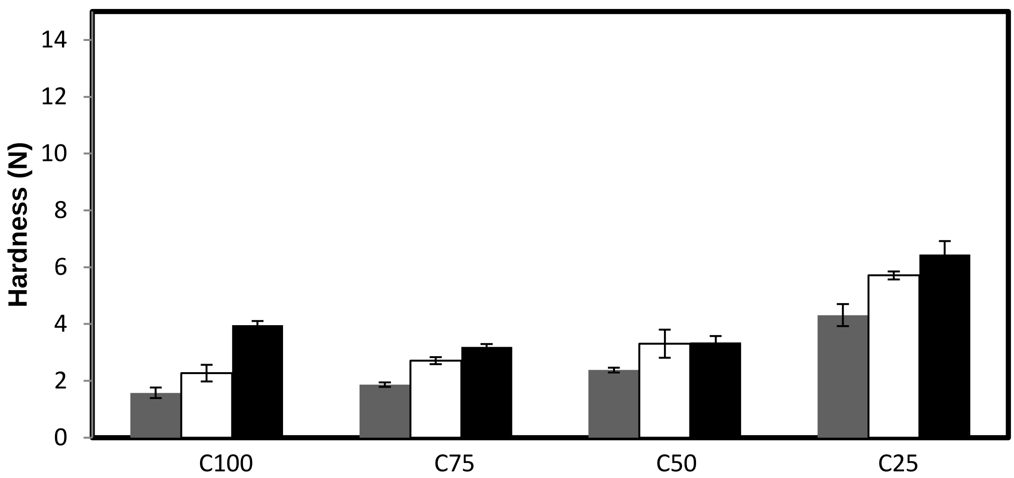

Figure 3.33 Hardness values for cake samples with microfluidized inulin emulsion (30%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

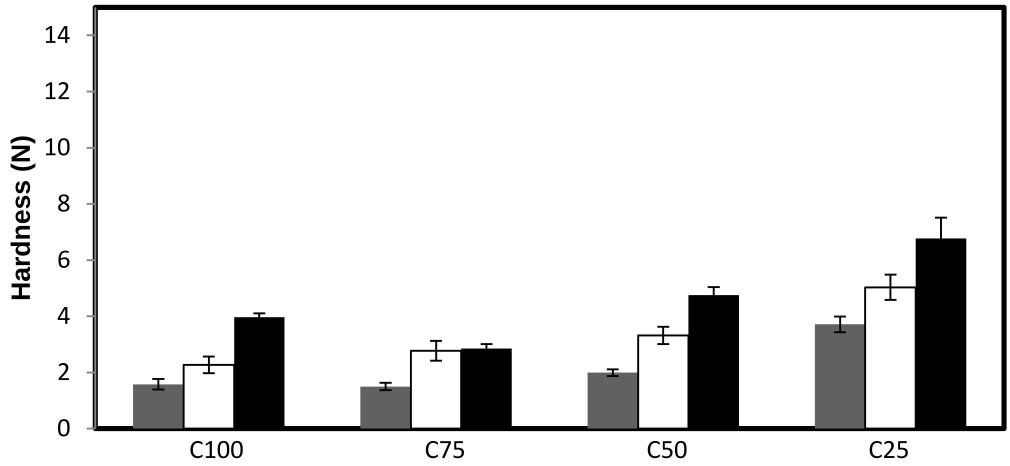

Figure 3.34 Hardness values for cake samples with inulin emulsion (22.5%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

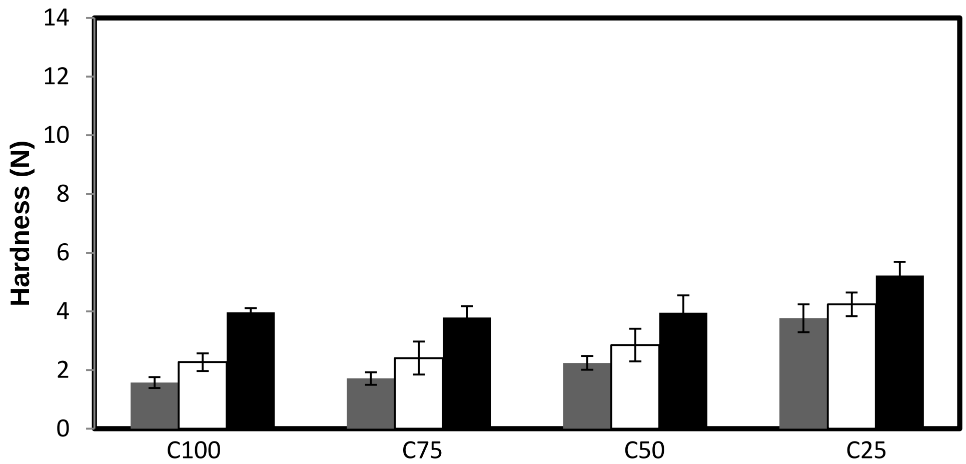

Figure 3.35 Hardness values for cake samples with microfluidized inulin emulsion (22.5%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

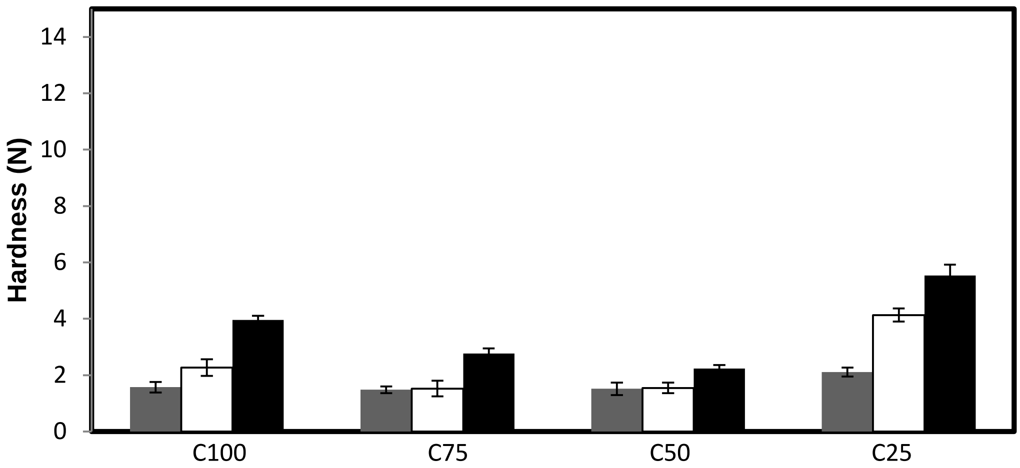

Figure 3.36 Hardness values for cake samples with inulin emulsion (15%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

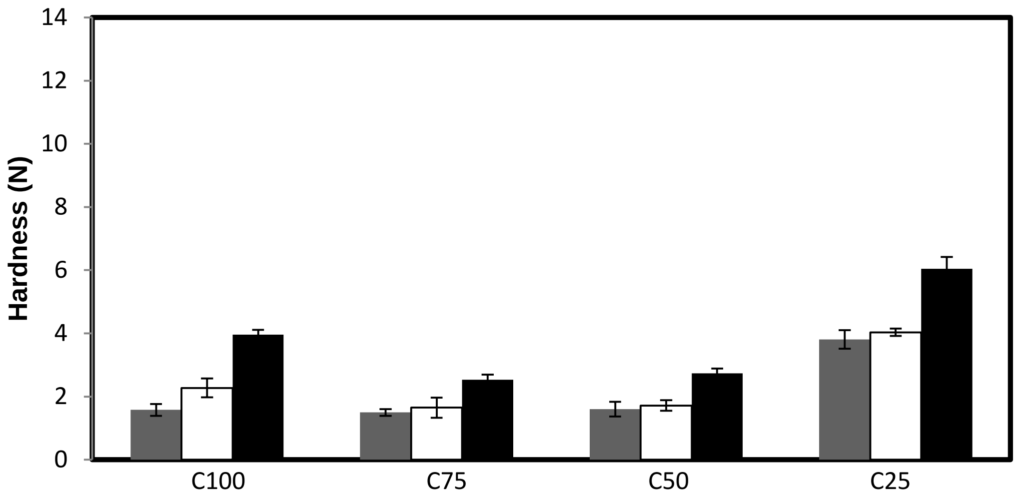

Figure 3.37 Hardness values for cake samples with microfluidized inulin emulsion (15%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

Storage time led to higher adhesion in all cake samples. At longer storage time, moist tends to be transferred to the surface which increases adhesiveness. According to figures 3.38- 3.43, adhesiveness values of all the groups have been increased during storage time. Control sample had also higher adhesiveness value during storage time of 2 and 4 days. Since the cakes with higher inulin amount had higher adhesiveness values, storage time led to higher adhesiveness in comparison with samples with lower inulin amount. Adhesiveness occurs through migration of moisture to the surface of the cake samples (L. Kim et al., 2001). During storage time, this migration continues and leads to higher adhesiveness values. Other fat replacers have been used in so many studies. According to a study conducted by L. Kim et al. (2001), cakes with maltodextrin higher adhesiveness values during storage time. The values tended to be increased at longer storage time.

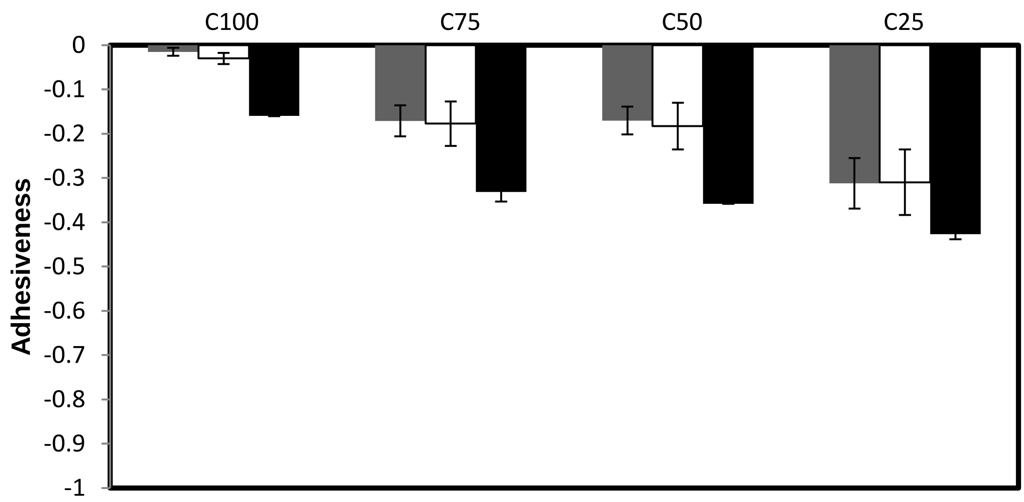

Figure 3.38 Adhesiveness values for cake samples with inulin emulsion (30%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

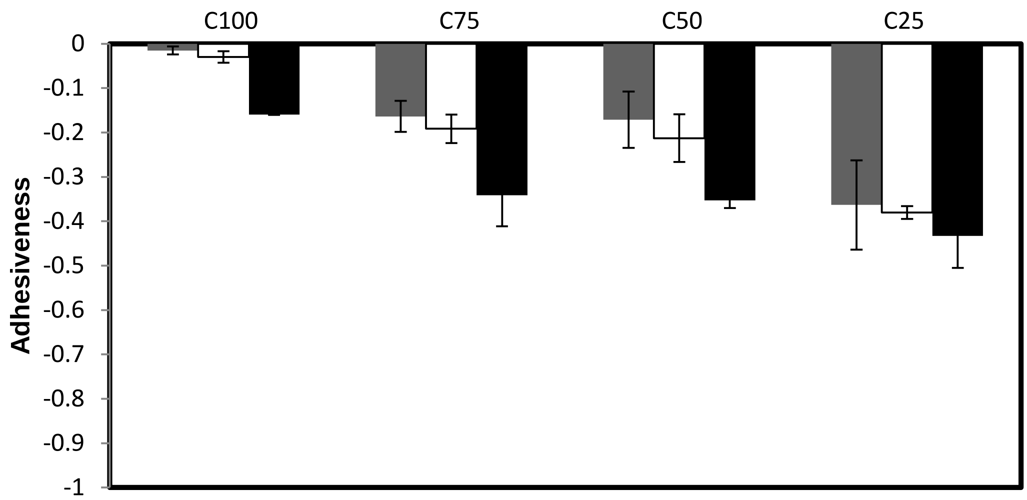

Figure 3.39 Adhesiveness values for cake samples with microfluidized inulin emulsion (30%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

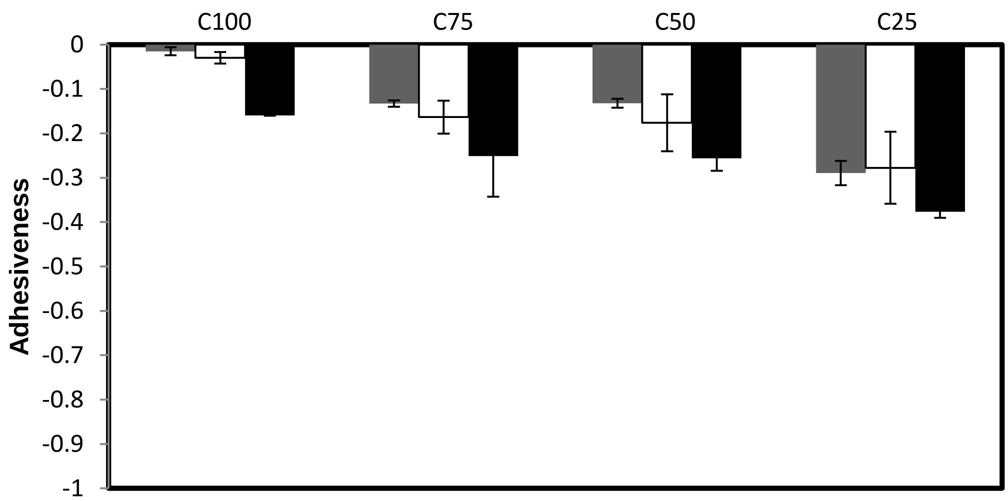

Figure 3.40 Adhesiveness values for cake samples with inulin emulsion (22.5%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

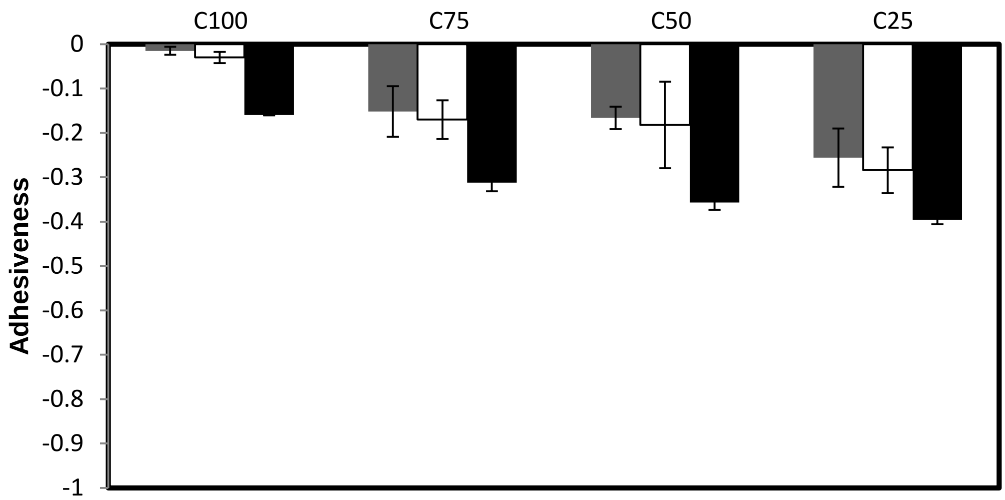

Figure 3.41 Adhesiveness values for cake samples with microfluidized inulin emulsion (22.5%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

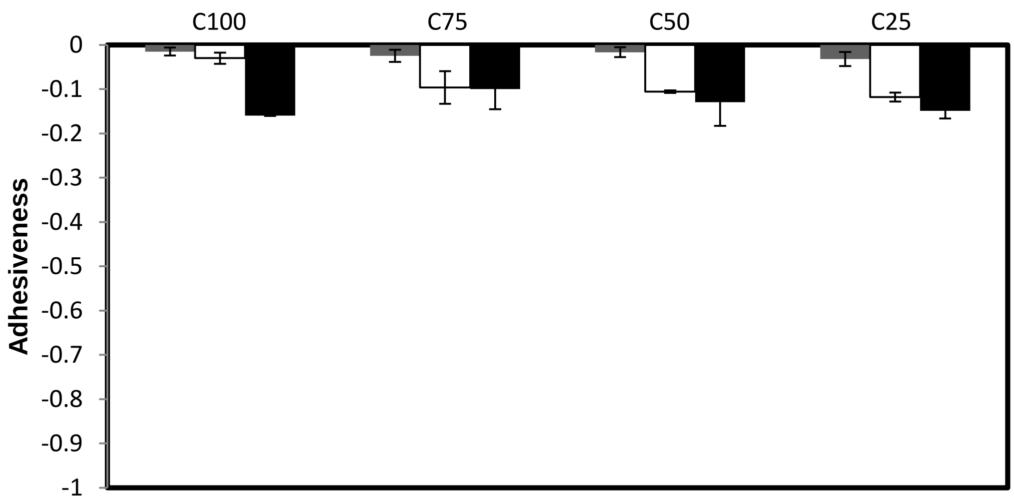

Figure 3.42 Adhesiveness values for cake samples with inulin emulsion (15%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

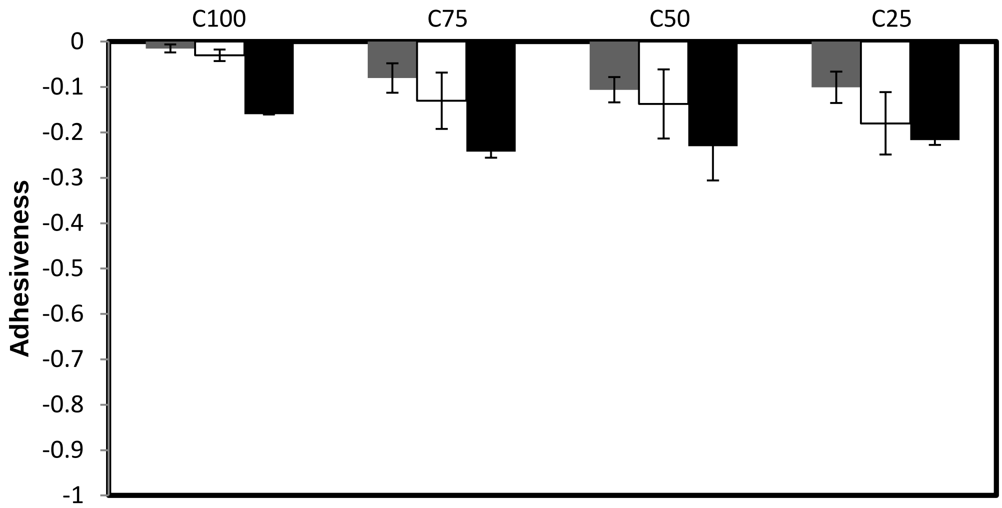

Figure 3.43 Adhesiveness values for cake samples with microfluidized inulin emulsion (15%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

Cohesiveness tended to decrease during storage time. This fact was shown in the figures 3.44- 3.49 for both microfluidized and non-microfluidized samples. Results showed that with an increase replacement of oil by inulin, cohesiveness values seemed to be decreased. Storing cake samples for 2 and 4 days had the same result. As it has been mentioned before, both lower cohesiveness and higher hardness are considered as two main texture changes during cake storage while increase of hardness and decrease of cohesiveness was observed at longer storage times (Gélinas, 2008). As the moisture is transferred from the cake to the atmosphere, the product gets more compact texture which leads to higher hardness and lower cohesiveness values for cake samples at storage time.

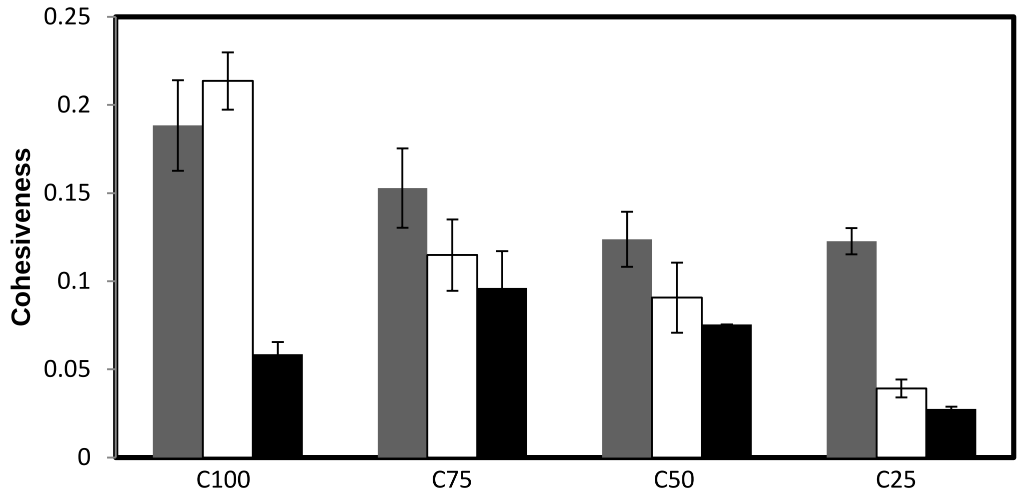

Figure 3.44 Cohesiveness values for cake samples with inulin emulsion (30%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

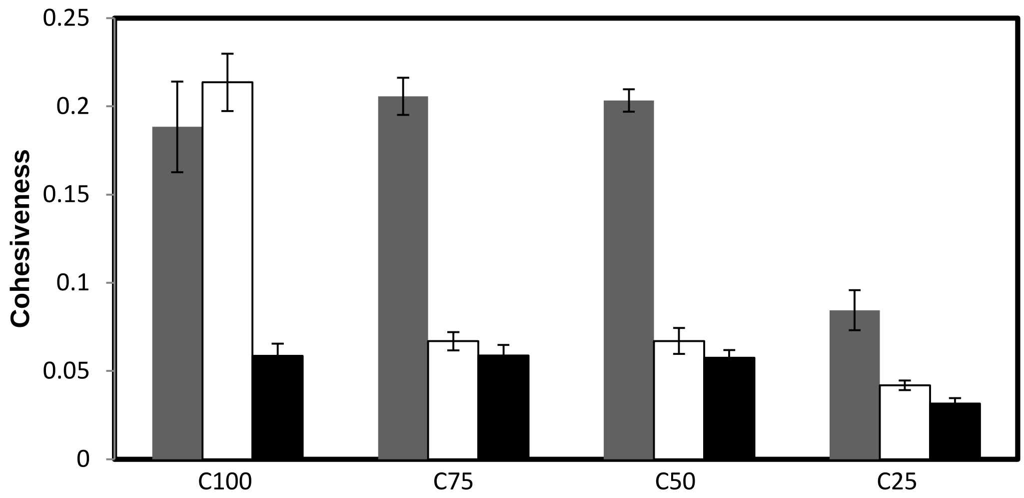

Figure 3.45 Cohesiveness values for cake samples with microfluidized inulin emulsion (30%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

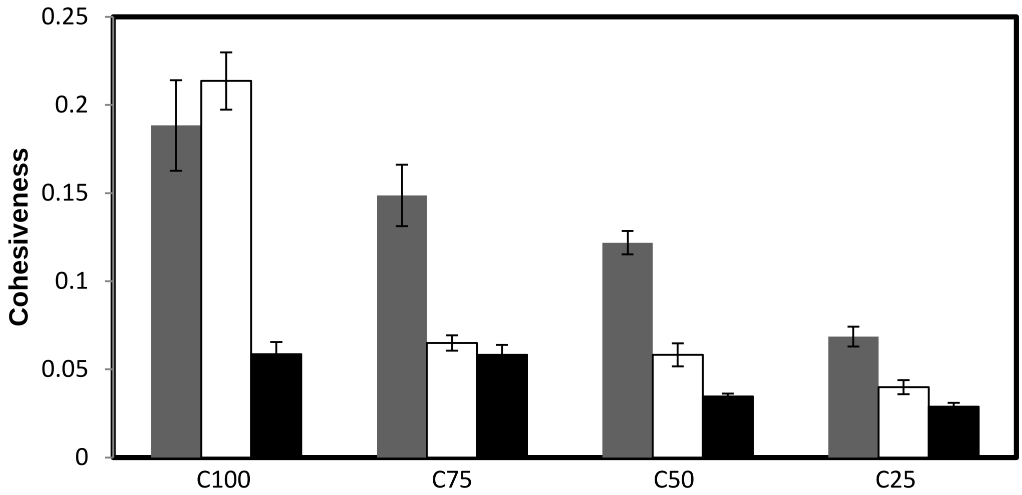

Figure 3.46 Cohesiveness values for cake samples with inulin emulsion (22.5%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

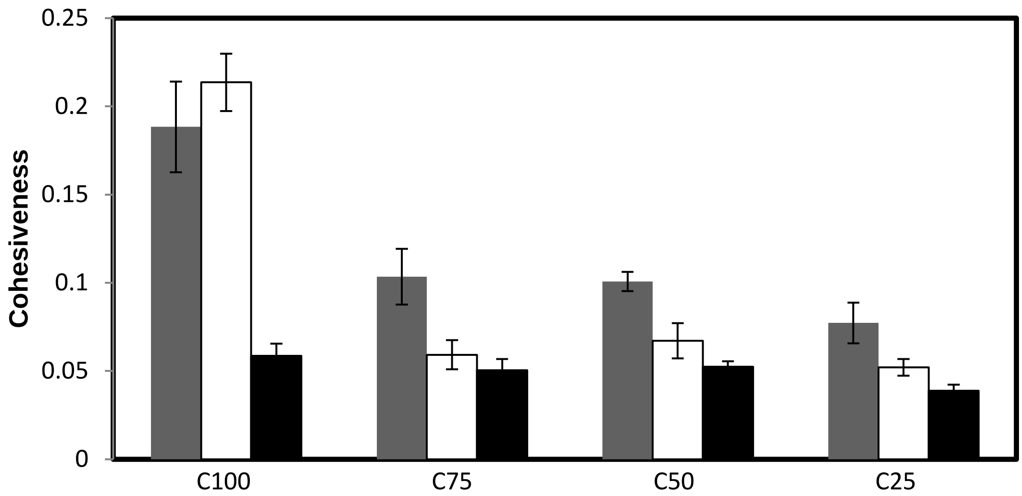

Figure 3.47 Cohesiveness values for cake samples with microfluidized inulin emulsion (22.5%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

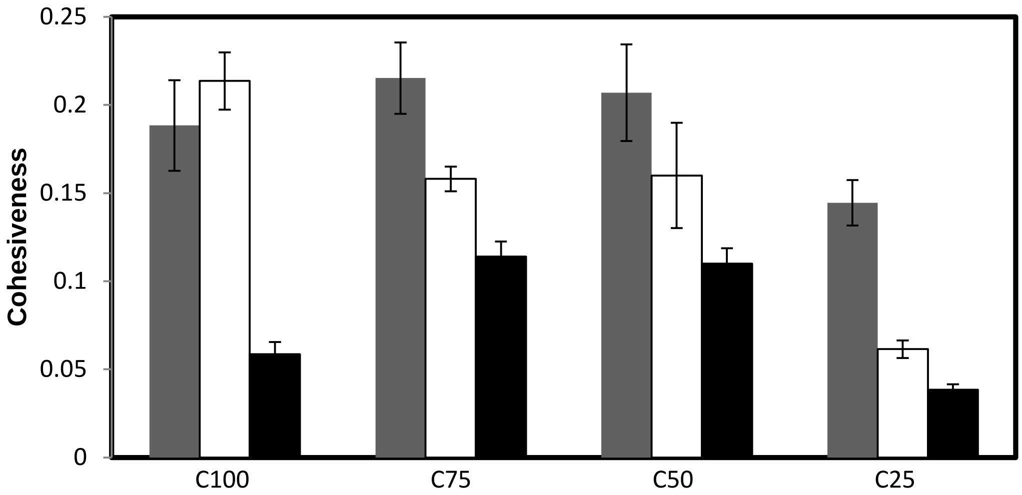

Figure 3.48 Cohesiveness values for cake samples with inulin emulsion (15%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

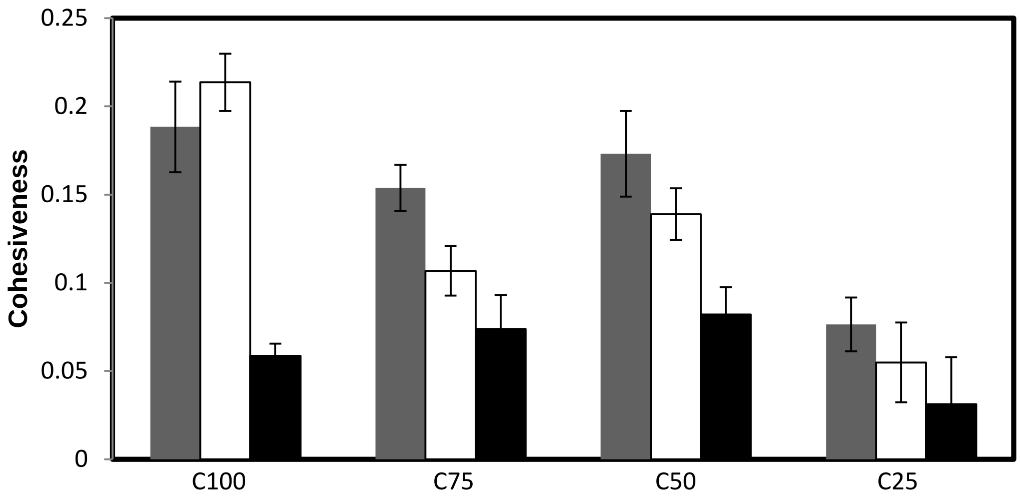

Figure 3.49 Cohesiveness values for cake samples with microfluidized inulin emulsion (15%w/w) where (gray bar): fresh samples, (white bar): samples stored for 2 days, (black bar): samples stored for 4 days. Standard deviations are shown by bars.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

In this study it was aimed to analyze rheological, textural properties and staling of cakes and rheological properties of mayonnaise including microfluidized and non-microfluidized inulin in the formula as fat replacer. Inulin is a dietary fiber that can enhance consumer's health by lowering amount of fat used in production of cake and mayonnaise which are considered as high fat food productions in food industry.

In rheological measurements, cake dough samples and mayonnaise samples were well fitted to Herschel-Bulkley model. Inulin utilization in the formula led to the increase of shear stress value versus shear rate, elastic modulus and viscous modulus of the dough samples and the mayonnaise. As the amount of inulin addition was increased, higher values of shear stress, elastic modulus and viscous modulus were obtained according to the results. Microfluidization process also increased these values. The samples were considered as viscoelastic material as specific amount of force was needed to change their rheological behavior from solid to liquid.

Texture analysis indicated different properties by addition of inulin in the formula. Increasing amount of inulin led to firmer cake samples. Cohesiveness and adhesiveness of cake samples were also studied. According to the results, increase of adhesiveness values and decrease of cohesiveness values were observed as the microfluidized inulin amount contained in the formula was increased. Inulin decreased ΔE values of the cake samples in comparison with control samples. At the same time, cake samples including higher amount of inulin had darker color than samples including lower amount of inulin.

Scanning electron microscopy of the microfluidized and non-microfluidized inulin samples revealed structure differences as the microfluidizer applies high shear to the particles. Microfluidized inulin sample had porous surface with smaller particle size which can enhance water holding capacity. This property can enhance shelf life of the cake samples if microfluidized inulin is used throughout the formula. Lower amount of water loss during cake baking process is consistent with the higher water holding capacity of samples containing microfluidized inulin.

It can be concluded that microfluidized inulin can act as fat replacer by lowering oil used in the cake baking process and mayonnaise production by optimizing textural and rheological properties of the samples and increasing shelf life. For further studies it can be recommended to use inulin not only as fat replacer but also as sugar replacer as it has sweet taste and thus lowering sugar amount and producing healthier cake samples

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APPENDIX A

CAKE SAMPLES

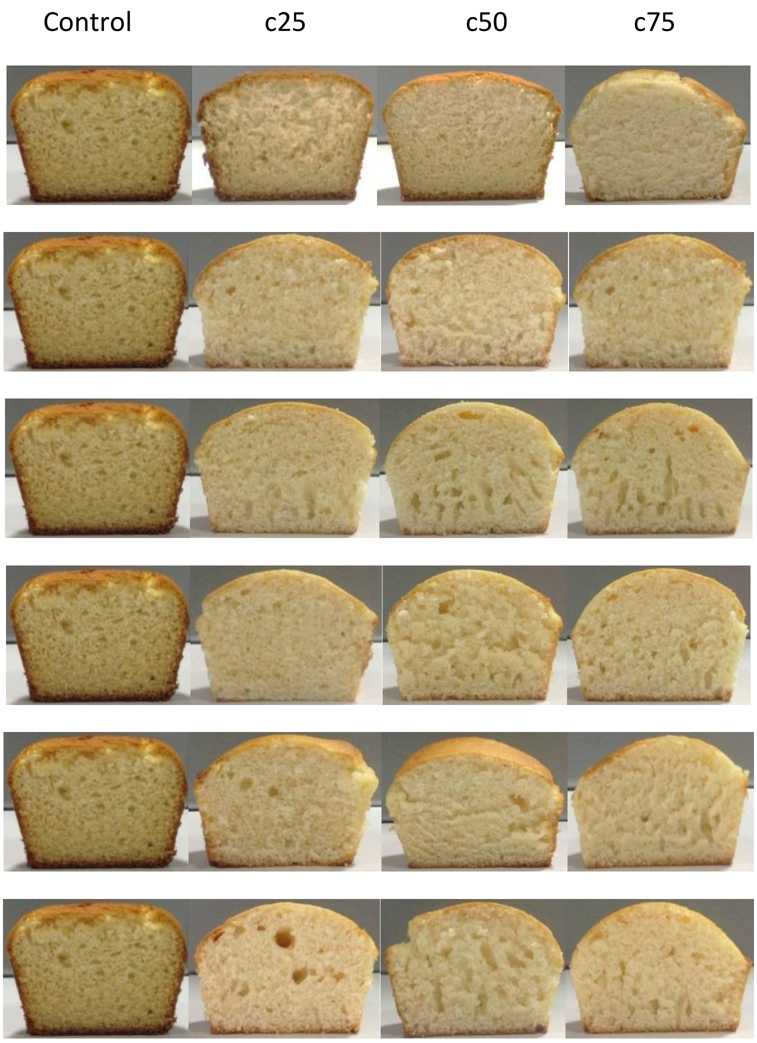

Figure A.1 From top to bottom: inulin (30%w/w), (30%MFw/w), (22.5%w/w), (22.5%MFw/w), (22.5%MFw/w), (15%w/w), (15%MFw/w).

APPENDIX B

STATISTICAL ANALYSES

Table B.1 Results of Tuckey's mean comparison test for adhesiveness of fresh baked cake sample

General Linear Model: adhesiveness versus sample, inulin%

```
Factor    Type   Levels  Values
sample    fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%   fixed       3  0.150, 0.225, 0.300


Analysis of Variance for adhesiveness, using Adjusted SS for Tests

Source          DF    Seq SS    Adj SS    Adj MS      F      P
sample           5  0.191302  0.191302  0.038260   6.08  0.000
inulin%          2  0.375609  0.375609  0.187805  29.83  0.000
sample*inulin%  10  0.095789  0.095789  0.009579   1.52  0.157
Error           54  0.340007  0.340007  0.006296
Total           71  1.002708


S = 0.0793501   R-Sq = 66.09%   R-Sq(adj) = 55.42%


Unusual Observations for adhesiveness

Obs  adhesiveness        Fit    SE Fit   Residual  St Resid
 10     -0.100341  -0.311751  0.039675   0.211411      3.08 R
 23     -0.117400  -0.363160  0.039675   0.245760      3.58 R
 24     -0.525240  -0.363160  0.039675  -0.162080     -2.36 R
 30     -0.281270  -0.131890  0.039675  -0.149380     -2.17 R
 33     -0.479260  -0.289342  0.039675  -0.189918     -2.76 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95.0% Confidence

sample   N     Mean  Grouping
c50     12  -0.1038  A
c25     12  -0.1055  A
```

```
c25mf   12  -0.1319  A B
c50mf   12  -0.1477  A B C
c75     12  -0.2108    B C
c75mf   12  -0.2398      C

Means that do not share a letter are significantly different

Grouping Information Using Tukey Method and 95.0% Confidence
inulin%   N     Mean  Grouping
0.150    24  -0.0567  A
0.225    24  -0.1879    B
0.300    24  -0.2251    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

sample  inulin%  N     Mean  Grouping
c50     0.150    4  -0.0093  A
c25     0.150    4  -0.0129  A
c75     0.150    4  -0.0312  A
c25mf   0.150    4  -0.0803  A B
c75mf   0.150    4  -0.1007  A B C
c50mf   0.150    4  -0.1059  A B C
c50     0.225    4  -0.1319  A B C D
c25     0.225    4  -0.1327  A B C D
c25mf   0.225    4  -0.1519  A B C D
c25mf   0.300    4  -0.1636  A B C D E
c50mf   0.225    4  -0.1661  A B C D E
c50     0.300    4  -0.1701  A B C D E
c25     0.300    4  -0.1710  A B C D E
c50mf   0.300    4  -0.1710  A B C D E
c75mf   0.225    4  -0.2555    B C D E
c75     0.225    4  -0.2893      C D E
c75     0.300    4  -0.3118        D E
c75mf   0.300    4  -0.3632          E

Means that do not share a letter are significantly different
```

Table B.2 Results of Tuckey's mean comparison test for cohesiveness of fresh baked cake samples

General Linear Model: cohesiveness versus sample, inulin%

```
Factor   Type   Levels  Values
sample   fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%  fixed       3  0.150, 0.225, 0.300


Analysis of Variance for cohesiveness, using Adjusted SS for Tests

Source          DF     Seq SS     Adj SS     Adj MS      F      P
sample           5  0.0648089  0.0648089  0.0129618  64.86  0.000
inulin%          2  0.0345442  0.0345442  0.0172721  86.43  0.000
sample*inulin%  10  0.0411749  0.0411749  0.0041175  20.60  0.000
Error           54  0.0107912  0.0107912  0.0001998
Total           71  0.1513192


S = 0.0141364   R-Sq = 92.87%   R-Sq(adj) = 90.62%
Unusual Observations for cohesiveness
```

```
Obs  cohesiveness       Fit    SE Fit   Residual  St Resid
  4      0.184760  0.152848  0.007068   0.031913      2.61 R
 49      0.145824  0.175221  0.007068  -0.029398     -2.40 R
 56      0.174594  0.206942  0.007068  -0.032348     -2.64 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95.0% Confidence

sample   N     Mean  Grouping
c25     12  0.15889  A
c50mf   12  0.15572  A
c25mf   12  0.15150  A
c50     12  0.15084  A
c75     12  0.11194    B
c75mf   12  0.07713      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

inulin%   N     Mean  Grouping
0.150    24  0.15083  A
0.300    24  0.14880  A
0.225    24  0.10338    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

sample  inulin%  N     Mean  Grouping
c50     0.150    4  0.20694  A
c25mf   0.300    4  0.20562  A
c50mf   0.300    4  0.20339  A
c25     0.150    4  0.17522  A B
c50mf   0.150    4  0.16312    B
c25     0.300    4  0.15285    B C
c25     0.225    4  0.14859    B C
c25mf   0.150    4  0.14545    B C
c75     0.150    4  0.14447    B C
c50     0.300    4  0.12376      C D
c75     0.300    4  0.12276      C D
c50     0.225    4  0.12183      C D
c25mf   0.225    4  0.10343        D E
c50mf   0.225    4  0.10065        D E
c75mf   0.300    4  0.08444          E
c75mf   0.225    4  0.07720          E
c75mf   0.150    4  0.06975          E
c75     0.225    4  0.06860          E

Means that do not share a letter are significantly different.
```

Table B.3 Results of Tuckey's mean comparison test for hardness of fresh baked cake samples

General Linear Model: hardness versus sample, inulin percentage

```
Factor              Type   Levels  Values
```

sample	fixed	6	c25, c25mf, c50, c50mf, c75, c75mf
inulin percentage	fixed	3	0.150, 0.225, 0.300

Analysis of Variance for hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
sample	5	54.7963	54.7963	10.9593	82.88	0.000
inulin percentage	2	7.0240	7.0240	3.5120	26.56	0.000
sample*inulin percentage	10	4.4413	4.4413	0.4441	3.36	0.002
Error	54	7.1408	7.1408	0.1322		
Total	71	73.4024				

S = 0.363645   R-Sq = 90.27%   R-Sq(adj) = 87.21%

Unusual Observations for hardness

Obs	hardness	Fit	SE Fit	Residual	St Resid	
17	1.26371	2.37973	0.18182	-1.11602	-3.54	R
19	1.40287	2.37973	0.18182	-0.97686	-3.10	R
20	3.89112	2.37973	0.18182	1.51139	4.80	R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c75mf	12	3.962	A
c75	12	3.217	B
c50mf	12	2.075	C
c50	12	1.944	C D
c25mf	12	1.692	C D
c25	12	1.597	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin percentage	N	Mean	Grouping
0.300	24	2.755	A
0.225	24	2.489	B
0.150	24	2.001	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin percentage	N	Mean	Grouping
c75mf	0.300	4	4.313	A
c75	0.300	4	3.834	A
c75mf	0.150	4	3.808	A
c75mf	0.225	4	3.766	A
c75	0.225	4	3.713	A
c50mf	0.300	4	2.380	B
c50	0.300	4	2.325	B
c50mf	0.225	4	2.246	B
c75	0.150	4	2.105	B
c50	0.225	4	1.992	B

```
c25mf   0.300       4  1.868    B
c25     0.300       4  1.809    B
c25mf   0.225       4  1.714    B
c50mf   0.150       4  1.599    B
c50     0.150       4  1.515    B
c25     0.225       4  1.501    B
c25mf   0.150       4  1.495    B
c25     0.150       4  1.481    B

Means that do not share a letter are significantly different.
```

Table B.4 Results of Tuckey's mean comparison test for weight loss of baked cake samples

General Linear Model: weight loss versus sample, inulin%

```
Factor   Type   Levels  Values
sample   fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%  fixed       3  0.150, 0.225, 0.300


Analysis of Variance for weight loss, using Adjusted SS for Tests

Source          DF    Seq SS   Adj SS   Adj MS         F      P
sample           5    7.0354   7.0354   1.4071    529.86  0.000
inulin%          2   90.0800  90.0800  45.0400  16960.67  0.000
sample*inulin%  10    5.2442   5.2442   0.5244    197.48  0.000
Error           18    0.0478   0.0478   0.0027
Total           35  102.4074


S = 0.0515321   R-Sq = 99.95%   R-Sq(adj) = 99.91%


Grouping Information Using Tukey Method and 95.0% Confidence

sample  N    Mean  Grouping
c25     6  10.805  A
c25mf   6  10.798  A
c75     6  10.788  A
c50     6  10.222    B
c50mf   6   9.907      C
c75mf   6   9.747        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

inulin%   N    Mean  Grouping
0.150    12  12.172  A
0.225    12  10.638    B
0.300    12   8.323      C
Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

sample  inulin%  N    Mean  Grouping
c25mf   0.150    2  12.980  A
c75     0.150    2  12.575    B
```

c50	0.150	2	12.215	C
c25	0.150	2	12.070	C D
c50mf	0.150	2	11.930	D E
c75	0.225	2	11.780	E
c75mf	0.150	2	11.260	F
c25	0.225	2	11.250	F
c25mf	0.225	2	10.940	G
c50	0.225	2	10.370	H
c50mf	0.225	2	9.880	I
c75mf	0.225	2	9.610	J
c25	0.300	2	9.095	K
c25mf	0.300	2	8.475	L
c75mf	0.300	2	8.370	L
c50	0.300	2	8.080	M
c75	0.300	2	8.010	M
c50mf	0.300	2	7.910	M

Means that do not share a letter are significantly different.

Table B.5 Results of Tuckey's mean comparison test for total color change of baked cake samples

General Linear Model: color versus sample, inulin%

Factor	Type	Levels	Values
sample	fixed	6	c25, c25mf, c50, c50mf, c75, c75mf
inulin%	fixed	3	0.150, 0.225, 0.300

Analysis of Variance for color, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
sample	5	160.342	160.342	32.068	86.93	0.000
inulin%	2	832.496	832.496	416.248	1128.38	0.000
sample*inulin%	10	18.971	18.971	1.897	5.14	0.001
Error	18	6.640	6.640	0.369		
Total	35	1018.449				

S = 0.607362   R-Sq = 99.35%   R-Sq(adj) = 98.73%

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c50mf	6	38.17	A
c25mf	6	37.10	A B
c75mf	6	37.03	B
c75	6	34.43	C
c50	6	33.73	C
c25	6	32.27	D

Means that do not share a letter are significantly different.
Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.300	12	42.23	A
0.225	12	32.55	B
0.150	12	31.58	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c75mf	0.300	2	44.70	A
c50mf	0.300	2	44.30	A
c25mf	0.300	2	42.40	A B
c75	0.300	2	41.60	B C
c50	0.300	2	40.60	B C
c25	0.300	2	39.80	C
c50mf	0.225	2	36.70	D
c25mf	0.150	2	34.50	D E
c25mf	0.225	2	34.40	D E
c75mf	0.225	2	33.50	E F
c50mf	0.150	2	33.50	E F
c75mf	0.150	2	32.90	E F G
c75	0.225	2	31.30	F G H
c50	0.225	2	30.50	G H I
c75	0.150	2	30.40	H I
c50	0.150	2	30.10	H I
c25	0.225	2	28.90	H I
c25	0.150	2	28.10	I

Means that do not share a letter are significantly different.

Table B.6 Results of Tuckey's mean comparison test for adhesiveness of baked cake samples stored for 2 days

General Linear Model: adhesiveness versus sample, inulin%

Factor	Type	Levels	Values
sample	fixed	6	c25, c25mf, c50, c50mf, c75, c75mf
inulin%	fixed	3	0.150, 0.225, 0.300

Analysis of Variance for adhesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
sample	5	0.183909	0.183909	0.036782	8.06	0.000
inulin%	2	0.102083	0.102083	0.051042	11.19	0.000
sample*inulin%	10	0.060378	0.060378	0.006038	1.32	0.242
Error	54	0.246410	0.246410	0.004563		
Total	71	0.592780				

S = 0.0675510   R-Sq = 58.43%   R-Sq(adj) = 45.35%

Unusual Observations for adhesiveness

Obs	adhesiveness	Fit	SE Fit	Residual	St Resid	
22	-0.261510	-0.380400	0.033776	0.118890	2.03	R
33	-0.395090	-0.277517	0.033776	-0.117573	-2.01	R
41	-0.315750	-0.181975	0.033776	-0.133775	-2.29	R
59	-0.343300	-0.187797	0.033776	-0.155503	-2.66	R

```
R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95.0% Confidence

sample   N     Mean  Grouping
c50     12  -0.1449  A
c25mf   12  -0.1639  A
c50mf   12  -0.1774  A B
c25     12  -0.1790  A B
c75     12  -0.2583    B C
c75mf   12  -0.2815      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

inulin%   N     Mean  Grouping
0.150    24  -0.1512  A
0.225    24  -0.2089    B
0.300    24  -0.2424    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

sample  inulin%  N     Mean  Grouping
c50     0.150    4  -0.0755  A
c25mf   0.150    4  -0.1302  A B
c50mf   0.150    4  -0.1376  A B C
c25     0.225    4  -0.1635  A B C
c25mf   0.225    4  -0.1700  A B C
c50     0.225    4  -0.1762  A B C
c25     0.300    4  -0.1773  A B C
c75mf   0.150    4  -0.1800  A B C
c50mf   0.225    4  -0.1820  A B C
c50     0.300    4  -0.1829  A B C
c75     0.150    4  -0.1878  A B C
c25mf   0.300    4  -0.1917  A B C
c25     0.150    4  -0.1962  A B C
c50mf   0.300    4  -0.2126  A B C D
c75     0.225    4  -0.2775    B C D
c75mf   0.225    4  -0.2840    B C D
c75     0.300    4  -0.3095      C D
c75mf   0.300    4  -0.3804        D

Means that do not share a letter are significantly different.
```

Table B.7 Results of Tuckey's mean comparison test for cohesiveness of baked cake samples stored for 2 days

General Linear Model: cohesiveness versus sample, inulin%

```
Factor   Type   Levels  Values
```

sample	fixed	6	c25, c25mf, c50, c50mf, c75, c75mf
inulin%	fixed	3	0.150, 0.225, 0.300

Analysis of Variance for cohesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
sample	5	0.0648089	0.0648089	0.0129618	64.86	0.000
inulin%	2	0.0345442	0.0345442	0.0172721	86.43	0.000
sample*inulin%	10	0.0411749	0.0411749	0.0041175	20.60	0.000
Error	54	0.0107912	0.0107912	0.0001998		
Total	71	0.1513192				

S = 0.0141364   R-Sq = 92.87%   R-Sq(adj) = 90.62%

Unusual Observations for cohesiveness

Obs	cohesiveness	Fit	SE Fit	Residual	St Resid
4	0.184760	0.152848	0.007068	0.031913	2.61 R
49	0.145824	0.175221	0.007068	-0.029398	-2.40 R
56	0.174594	0.206942	0.007068	-0.032348	-2.64 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c25	12	0.15889	A
c50mf	12	0.15572	A
c25mf	12	0.15150	A
c50	12	0.15084	A
c75	12	0.11194	B
c75mf	12	0.07713	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.150	24	0.15083	A
0.300	24	0.14880	A
0.225	24	0.10338	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c50	0.150	4	0.20694	A
c25mf	0.300	4	0.20562	A
c50mf	0.300	4	0.20339	A
c25	0.150	4	0.17522	A B
c50mf	0.150	4	0.16312	B
c25	0.300	4	0.15285	B C
c25	0.225	4	0.14859	B C
c25mf	0.150	4	0.14545	B C
c75	0.150	4	0.14447	B C
c50	0.300	4	0.12376	C D
c75	0.300	4	0.12276	C D
c50	0.225	4	0.12183	C D

c25mf	0.225	4	0.10343	D E
c50mf	0.225	4	0.10065	D E
c75mf	0.300	4	0.08444	E
c75mf	0.225	4	0.07720	E
c75mf	0.150	4	0.06975	E
c75	0.225	4	0.06860	E

Means that do not share a letter are significantly different.

Table B.8 Results of Tuckey's mean comparison test for hardness of baked cake samples stored for 2 days

General Linear Model: hardness versus sample, inulin%

Factor	Type	Levels	Values
sample	fixed	6	c25, c25mf, c50, c50mf, c75, c75mf
inulin%	fixed	3	0.150, 0.225, 0.300

Analysis of Variance for hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
sample	5	82.0183	82.0183	16.4037	114.78	0.000
inulin%	2	11.6243	11.6243	5.8122	40.67	0.000
sample*inulin%	10	26.7308	26.7308	2.6731	18.70	0.000
Error	54	7.7174	7.7174	0.1429		
Total	71	128.0908				

S = 0.378042   R-Sq = 93.98%   R-Sq(adj) = 92.08%

Unusual Observations for hardness

Obs	hardness	Fit	SE Fit	Residual	St Resid
8	2.38167	3.22200	0.18902	-0.84033	-2.57 R
40	4.24253	3.40949	0.18902	0.83304	2.54 R

R denotes an observation with a large standardized residual.
Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c75	12	5.323	A
c75mf	12	4.661	B
c25mf	12	3.189	C
c50	12	2.695	D
c25	12	2.688	D
c50mf	12	2.626	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.300	24	3.982	A
0.225	24	3.604	B
0.150	24	3.006	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

```
sample  inulin%  N   Mean  Grouping
c75     0.300    4  6.804  A
c75mf   0.300    4  5.713    B
c75     0.225    4  5.032    B C
c75mf   0.225    4  4.240      C D
c75     0.150    4  4.134      C D E
c75mf   0.150    4  4.031        D E
c25mf   0.150    4  3.447        D E F
c25mf   0.225    4  3.409        D E F
c50     0.225    4  3.316        D E F
c50mf   0.300    4  3.310        D E F
c50     0.300    4  3.222          E F
c25     0.150    4  3.161          E F
c50mf   0.225    4  2.853            F G
c25     0.225    4  2.771            F G
c25mf   0.300    4  2.711            F G
c25     0.300    4  2.132              G H
c50mf   0.150    4  1.716                H
c50     0.150    4  1.546                H
```

Means that do not share a letter are significantly different.

Table B.9 Results of Tuckey's mean comparison test for adhesiveness of baked cake samples stored for 4 days

General Linear Model: adhesiveness versus sample, inulin%

```
Factor   Type   Levels  Values
sample   fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%  fixed       3  0.150, 0.225, 0.300
```

Analysis of Variance for adhesiveness, using Adjusted SS for Tests

```
Source          DF   Seq SS   Adj SS   Adj MS      F      P
sample           5  0.11476  0.11476  0.02295   2.19  0.068
inulin%          2  0.47092  0.47092  0.23546  22.51  0.000
sample*inulin%  10  0.08416  0.08416  0.00842   0.80  0.625
Error           54  0.56498  0.56498  0.01046
Total           71  1.23482
```

S = 0.102287   R-Sq = 54.25%   R-Sq(adj) = 39.84%

Unusual Observations for adhesiveness

```
Obs  adhesiveness        Fit    SE Fit   Residual  St Resid
  9     -0.247150  -0.426480  0.051143   0.179330      2.02 R
 39     -0.569310  -0.312243  0.051143  -0.257067     -2.90 R
 50     -0.402990  -0.191345  0.051143  -0.211645     -2.39 R
 63     -0.443410  -0.242055  0.051143  -0.201355     -2.27 R
```

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c50	12	-0.2279	A
c25	12	-0.2581	A
c25mf	12	-0.2986	A
c50mf	12	-0.3132	A
c75	12	-0.3174	A
c75mf	12	-0.3485	A

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.150	24	-0.1831	A
0.225	24	-0.3248	B
0.300	24	-0.3739	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c50	0.150	4	-0.0694	A
c75	0.150	4	-0.1490	A B
c25	0.150	4	-0.1913	A B C
c75mf	0.150	4	-0.2167	A B C
c50mf	0.150	4	-0.2303	A B C
c25mf	0.150	4	-0.2421	A B C
c25	0.225	4	-0.2515	A B C
c50	0.225	4	-0.2564	A B C
c25mf	0.225	4	-0.3122	A B C
c25	0.300	4	-0.3314	A B C
c25mf	0.300	4	-0.3414	B C
c50mf	0.300	4	-0.3530	B C
c50mf	0.225	4	-0.3564	B C
c50	0.300	4	-0.3579	B C
c75	0.225	4	-0.3766	B C
c75mf	0.225	4	-0.3957	B C
c75	0.300	4	-0.4265	C
c75mf	0.300	4	-0.4331	C

Means that do not share a letter are significantly different.

Table B.10 Results of Tuckey's mean comparison test for cohesiveness of baked cake samples stored for 4 days

General Linear Model: adhesiveness versus sample, inulin%

Factor	Type	Levels	Values
sample	fixed	6	c25, c25mf, c50, c50mf, c75, c75mf
inulin%	fixed	3	0.150, 0.225, 0.300

Analysis of Variance for adhesiveness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
sample	5	0.11476	0.11476	0.02295	2.19	0.068
inulin%	2	0.47092	0.47092	0.23546	22.51	0.000
sample*inulin%	10	0.08416	0.08416	0.00842	0.80	0.625
Error	54	0.56498	0.56498	0.01046		
Total	71	1.23482				

S = 0.102287   R-Sq = 54.25%   R-Sq(adj) = 39.84%

Unusual Observations for adhesiveness

Obs	adhesiveness	Fit	SE Fit	Residual	St Resid	
9	-0.247150	-0.426480	0.051143	0.179330	2.02	R
39	-0.569310	-0.312243	0.051143	-0.257067	-2.90	R
50	-0.402990	-0.191345	0.051143	-0.211645	-2.39	R
63	-0.443410	-0.242055	0.051143	-0.201355	-2.27	R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c50	12	-0.2279	A
c25	12	-0.2581	A
c25mf	12	-0.2986	A
c50mf	12	-0.3132	A
c75	12	-0.3174	A
c75mf	12	-0.3485	A

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.150	24	-0.1831	A
0.225	24	-0.3248	B
0.300	24	-0.3739	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c50	0.150	4	-0.0694	A
c75	0.150	4	-0.1490	A B
c25	0.150	4	-0.1913	A B C
c75mf	0.150	4	-0.2167	A B C
c50mf	0.150	4	-0.2303	A B C
c25mf	0.150	4	-0.2421	A B C
c25	0.225	4	-0.2515	A B C
c50	0.225	4	-0.2564	A B C
c25mf	0.225	4	-0.3122	A B C
c25	0.300	4	-0.3314	A B C
c25mf	0.300	4	-0.3414	B C
c50mf	0.300	4	-0.3530	B C
c50mf	0.225	4	-0.3564	B C
c50	0.300	4	-0.3579	B C
c75	0.225	4	-0.3766	B C

```
c75mf   0.225    4  -0.3957    B C
c75     0.300    4  -0.4265      C
c75mf   0.300    4  -0.4331      C

Means that do not share a letter are significantly different.
```

Table B.11 Results of Tuckey's mean comparison test for hardness of baked cake samples stored for 4 days

General Linear Model: hardness versus sample, inulin%

```
Factor             Type   Levels  Values
sample             fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin percentage  fixed       3  0.150, 0.225, 0.300


Analysis of Variance for hardness, using Adjusted SS for Tests

Source                     DF   Seq SS   Adj SS  Adj MS       F      P
sample                      5  168.480  168.480  33.696  249.85  0.000
inulin%                     2   33.639   33.639  16.820  124.72  0.000
sample*inulin%             10   50.870   50.870   5.087   37.72  0.000
Error                      54    7.283    7.283   0.135
Total                      71  260.272


S = 0.367238   R-Sq = 97.20%   R-Sq(adj) = 96.32%


Unusual Observations for hardness
Obs  hardness      Fit   SE Fit  Residual  St Resid
  2   3.57286  2.77909  0.18362   0.79377      2.50 R
 35   5.80777  6.77245  0.18362  -0.96468     -3.03 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95.0% Confidence

sample   N   Mean  Grouping
c75     12  6.947  A
c75mf   12  5.901    B
c50     12  4.853      C
c50mf   12  3.352        D
c25mf   12  3.176        D E
c25     12  2.799          E

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

Inulin%     N   Mean  Grouping
0.300      24  5.313  A
0.225      24  4.559    B
0.150      24  3.642      C
```

```
Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

sample  inulin%     N   Mean  Grouping
c75     0.300       4  8.532  A
c50     0.300       4  7.569    B
c75     0.225       4  6.772    B C
c75mf   0.300       4  6.446      C D
c75mf   0.150       4  6.040      C D E
c75     0.150       4  5.536        D E F
c75mf   0.225       4  5.218          E F
c50     0.225       4  4.758            F G
c50mf   0.225       4  3.959              G H
c25mf   0.225       4  3.798                H I
c50mf   0.300       4  3.358                H I J
c25mf   0.300       4  3.195                H I J
c25     0.225       4  2.848                  I J K
c25     0.300       4  2.779                    J K
c25     0.150       4  2.770                    J K
c50mf   0.150       4  2.738                    J K
c25mf   0.150       4  2.535                    J K
c50     0.150       4  2.231                      K

Means that do not share a letter are significantly different.
```

Table B.12 Results of Tuckey's mean comparison test for cohesiveness of baked cake samples stored for 2 and 4 days

General Linear Model: cohesiveness versus sample, inulin%, storage time

```
Factor        Type   Levels  Values
sample        fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%       fixed       3  0.150, 0.225, 0.300
storage time  fixed       3  0, 2, 4


Analysis of Variance for cohesiveness, using Adjusted SS for Tests

Source                 DF    Seq SS    Adj SS    Adj MS       F      P
sample                  5  0.110195  0.110195  0.022039   55.49  0.000
inulin%                 2  0.055397  0.055397  0.027699   69.74  0.000
storage time            2  0.222419  0.222419  0.111209  280.01  0.000
sample*inulin%         10  0.033225  0.033225  0.003322    8.37  0.000
sample*storage time    10  0.015672  0.015672  0.001567    3.95  0.000
inulin%*storage time    4  0.009047  0.009047  0.002262    5.70  0.000
Error                 182  0.072283  0.072283  0.000397
Total                 215  0.518238


S = 0.0199288   R-Sq = 86.05%   R-Sq(adj) = 83.52%


Unusual Observations for cohesiveness

Obs  cohesiveness       Fit    SE Fit   Residual  St Resid
  1      0.133273  0.181857  0.007907  -0.048584     -2.66 R
  3      0.142395  0.181857  0.007907  -0.039463     -2.16 R
```

5	0.102526	0.158167	0.007907	-0.055640	-3.04 R
14	0.210901	0.174109	0.007907	0.036791	2.01 R
16	0.217799	0.174109	0.007907	0.043690	2.39 R
17	0.212700	0.170703	0.007907	0.041997	2.30 R
75	0.132956	0.087582	0.007907	0.045374	2.48 R
76	0.131491	0.087582	0.007907	0.043909	2.40 R
81	0.093281	0.044377	0.007907	0.048904	2.67 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c50	36	0.11462	A
c25	36	0.10698	A B
c50mf	36	0.10297	A B
c25mf	36	0.09647	B
c75	36	0.06489	C
c75mf	36	0.05359	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.150	72	0.10598	A
0.300	72	0.09572	B
0.225	72	0.06806	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

storage time	N	Mean	Grouping
0	72	0.13434	A
2	72	0.07576	B
4	72	0.05966	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c50	0.150	12	0.15898	A
c50mf	0.150	12	0.12622	B
c25	0.300	12	0.12129	B
c50	0.300	12	0.11328	B C
c25mf	0.300	12	0.11042	B C
c50mf	0.300	12	0.10929	B C D
c25	0.150	12	0.10907	B C D
c25mf	0.150	12	0.10798	B C D
c25	0.225	12	0.09058	C D E
c75	0.150	12	0.08146	D E F
c50mf	0.225	12	0.07341	E F G
c50	0.225	12	0.07160	E F G
c25mf	0.225	12	0.07101	E F G
c75	0.300	12	0.06745	E F G
c75mf	0.225	12	0.05601	F G
c75mf	0.300	12	0.05260	G
c75mf	0.150	12	0.05215	G
c75	0.225	12	0.04576	G

Means that do not share a letter are significantly different.

```
Grouping Information Using Tukey Method and 95.0% Confidence

        storage
sample  time      N     Mean  Grouping
c25     0        12  0.15889  A
c50mf   0        12  0.15572  A
c25mf   0        12  0.15150  A
c50     0        12  0.15084  A
c75     0        12  0.11194    B
c50     2        12  0.10297    B C
c50mf   2        12  0.09126    B C
c50     4        12  0.09004    B C D
c25     2        12  0.08260      C D E
c25     4        12  0.07944      C D E F
c25mf   2        12  0.07761      C D E F G
c75mf   0        12  0.07713      C D E F G
c50mf   4        12  0.06194        D E F G H
c25mf   4        12  0.06029          E F G H I
c75     2        12  0.05114            F G H I
c75mf   2        12  0.04900              G H I
c75mf   4        12  0.03462                H I
c75     4        12  0.03159                  I

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95.0% Confidence

         storage
inulin%  time      N     Mean  Grouping
0.150    0        24  0.15083  A
0.300    0        24  0.14880  A
0.225    0        24  0.10338    B
0.150    2        24  0.09814    B
0.300    2        24  0.07224      C
0.150    4        24  0.06896      C
0.300    4        24  0.06612      C
0.225    2        24  0.05691      C D
0.225    4        24  0.04388        D

Means that do not share a letter are significantly different.
```

Table B.13 Results of Tuckey's mean comparison test for adhesiveness of baked cake samples stored for 2 and 4 days

General Linear Model: adhesiveness versus sample, inulin%, storage time

```
Factor        Type   Levels  Values
sample        fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%       fixed       3  0.150, 0.225, 0.300
storage time  fixed       3  0, 2, 4


Analysis of Variance for adhesiveness, using Adjusted SS for Tests
Source                 DF    Seq SS    Adj SS    Adj MS      F      P
sample                  5  0.446951  0.446951  0.089390  13.37  0.000
inulin%                 2  0.870351  0.870351  0.435175  65.09  0.000
```

storage time	2	0.707996	0.707996	0.353998	52.95	0.000
sample*inulin%	10	0.175000	0.175000	0.017500	2.62	0.005
sample*storage time	10	0.043015	0.043015	0.004301	0.64	0.775
inulin%*storage time	4	0.078263	0.078263	0.019566	2.93	0.022
Error	182	1.216724	1.216724	0.006685		
Total	215	3.538300				

S = 0.0817637   R-Sq = 65.61%   R-Sq(adj) = 59.38%

Unusual Observations for adhesiveness

Obs	adhesiveness	Fit	SE Fit	Residual	St Resid	
10	-0.100341	-0.303078	0.032439	0.202738	2.70	R
23	-0.117400	-0.347263	0.032439	0.229863	3.06	R
24	-0.525240	-0.347263	0.032439	-0.177977	-2.37	R
33	-0.479260	-0.271031	0.032439	-0.208229	-2.77	R
131	-0.343300	-0.155953	0.032439	-0.187347	-2.50	R
153	-0.247150	-0.421053	0.032439	0.173903	2.32	R
156	-0.573310	-0.421053	0.032439	-0.152257	-2.03	R
179	-0.530030	-0.377175	0.032439	-0.152855	-2.04	R
180	-0.209690	-0.377175	0.032439	0.167485	2.23	R
181	-0.136760	-0.319254	0.032439	0.182494	2.43	R
183	-0.569310	-0.319254	0.032439	-0.250056	-3.33	R
190	-0.547660	-0.377780	0.032439	-0.169880	-2.26	R
194	-0.402990	-0.186652	0.032439	-0.216338	-2.88	R
207	-0.443410	-0.227202	0.032439	-0.216208	-2.88	R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	N	Mean	Grouping
c50	36	-0.1588	A
c25	36	-0.1809	A
c25mf	36	-0.1981	A
c50mf	36	-0.2128	A B
c75	36	-0.2621	B C
c75mf	36	-0.2899	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	N	Mean	Grouping
0.150	72	-0.1303	A
0.225	72	-0.2405	B
0.300	72	-0.2805	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

storage time	N	Mean	Grouping
0	72	-0.1566	A
2	72	-0.2008	B
4	72	-0.2939	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c50	0.150	12	-0.0514	A
c75	0.150	12	-0.1227	A B
c25	0.150	12	-0.1335	A B C
c25mf	0.150	12	-0.1508	A B C
c50mf	0.150	12	-0.1579	A B C
c75mf	0.150	12	-0.1658	A B C
c25	0.225	12	-0.1826	B C
c50	0.225	12	-0.1882	B C
c25mf	0.225	12	-0.2114	B C D
c25	0.300	12	-0.2266	B C D
c25mf	0.300	12	-0.2322	B C D E
c50mf	0.225	12	-0.2348	B C D E
c50	0.300	12	-0.2370	B C D E
c50mf	0.300	12	-0.2455	C D E
c75mf	0.225	12	-0.3117	D E F
c75	0.225	12	-0.3145	D E F
c75	0.300	12	-0.3492	E F
c75mf	0.300	12	-0.3922	F

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	storage time	N	Mean	Grouping
c50	0	12	-0.1038	A
c25	0	12	-0.1055	A
c25mf	0	12	-0.1319	A B
c50	2	12	-0.1449	A B C
c50mf	0	12	-0.1477	A B C
c25mf	2	12	-0.1639	A B C D
c50mf	2	12	-0.1774	A B C D
c25	2	12	-0.1790	A B C D
c75	0	12	-0.2108	A B C D E
c50	4	12	-0.2279	B C D E
c75mf	0	12	-0.2398	B C D E F
c25	4	12	-0.2581	C D E F
c75	2	12	-0.2583	C D E F
c75mf	2	12	-0.2815	D E F
c25mf	4	12	-0.2986	E F
c50mf	4	12	-0.3132	E F
c75	4	12	-0.3174	E F
c75mf	4	12	-0.3485	F

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	storage time	N	Mean	Grouping
0.150	0	24	-0.0567	A
0.150	2	24	-0.1512	B
0.150	4	24	-0.1831	B C
0.225	0	24	-0.1879	B C
0.225	2	24	-0.2089	B C
0.300	0	24	-0.2251	B C
0.300	2	24	-0.2424	C
0.225	4	24	-0.3248	D
0.300	4	24	-0.3739	D

Means that do not share a letter are significantly different.

Table B.14 Results of Tuckey's mean comparison test for hardness of baked cake samples stored for 2 and 4 days

General Linear Model: hardness versus sample, inulin%, storage time

```
Factor        Type   Levels  Values
sample        fixed       6  c25, c25mf, c50, c50mf, c75, c75mf
inulin%       fixed       3  0.150, 0.225, 0.300
storage time  fixed       3  0, 2, 4


Analysis of Variance for hardness, using Adjusted SS for Tests

Source                  DF   Seq SS   Adj SS  Adj MS       F      P
sample                   5  262.789  262.789  52.558  173.04  0.000
inulin%                  2   46.780   46.780  23.390   77.01  0.000
storage time             2  157.456  157.456  78.728  259.20  0.000
sample*inulin%          10   48.903   48.903   4.890   16.10  0.000
sample*storage time     10   42.506   42.506   4.251   13.99  0.000
inulin%*storage time     4    5.507    5.507   1.377    4.53  0.002
Error                  182   55.280   55.280   0.304
Total                  215  619.220


S = 0.551121   R-Sq = 91.07%   R-Sq(adj) = 89.45%


Unusual Observations for hardness

Obs  hardness      Fit   SE Fit  Residual  St Resid
  8   1.85847  2.95923  0.21866  -1.10076     -2.18 R
 20   3.89112  2.21338  0.21866   1.67774      3.32 R
 56   1.74982  0.73059  0.21866   1.01923      2.01 R
 80   2.38167  3.82112  0.21866  -1.43945     -2.85 R
 89   3.95642  2.87604  0.21866   1.08038      2.14 R
149   7.62122  6.33644  0.21866   1.28478      2.54 R
150   7.51764  6.33644  0.21866   1.18120      2.33 R
151   7.62122  6.33644  0.21866   1.28478      2.54 R
152   7.51764  6.33644  0.21866   1.18120      2.33 R
179   5.80777  6.94363  0.21866  -1.13586     -2.25 R
199   2.04667  3.19041  0.21866  -1.14374     -2.26 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95.0% Confidence

sample   N   Mean  Grouping
c75     36  5.162  A
c75mf   36  4.842  A
c50     36  3.164    B
c25mf   36  2.686      C
c50mf   36  2.684      C
c25     36  2.361      C
Means that do not share a letter are significantly different.
Grouping Information Using Tukey Method and 95.0% Confidence

inulin%   N   Mean  Grouping
0.300    72  4.017  A
0.225    72  3.550    B
0.150    72  2.883      C
```

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

storage time	N	Mean	Grouping
4	72	4.505	A
2	72	3.530	B
0	72	2.415	C

Means that do not share a letter are significantly different.
Grouping Information Using Tukey Method and 95.0% Confidence

sample	inulin%	N	Mean	Grouping
c75	0.300	12	6.390	A
c75mf	0.300	12	5.491	B
c75	0.225	12	5.172	B C
c75mf	0.150	12	4.626	C D
c75mf	0.225	12	4.408	C D
c50	0.300	12	4.372	D
c75	0.150	12	3.925	D E
c50	0.225	12	3.355	E F
c50mf	0.225	12	3.020	F G
c50mf	0.300	12	3.016	F G
c25mf	0.225	12	2.974	F G
c25mf	0.300	12	2.591	F G H
c25mf	0.150	12	2.493	G H I
c25	0.150	12	2.471	G H I
c25	0.225	12	2.373	G H I
c25	0.300	12	2.240	G H I
c50mf	0.150	12	2.018	H I
c50	0.150	12	1.764	I

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

sample	storage time	N	Mean	Grouping
c75	4	12	6.947	A
c75mf	4	12	5.901	B
c75	2	12	5.323	B C
c50	4	12	4.853	C
c75mf	2	12	4.661	C D
c75mf	0	12	3.962	D E
c50mf	4	12	3.352	E F
c75	0	12	3.217	E F
c25mf	2	12	3.189	E F
c25mf	4	12	3.176	E F
c25	4	12	2.799	F G
c50	2	12	2.695	F G H
c25	2	12	2.688	F G H
c50mf	2	12	2.626	F G H
c50mf	0	12	2.075	G H I
c50	0	12	1.944	H I
c25mf	0	12	1.692	I
c25	0	12	1.597	I

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

inulin%	storage time	N	Mean	Grouping
0.300	4	24	5.313	A
0.225	4	24	4.559	B
0.300	2	24	3.982	C
0.150	4	24	3.642	C
0.225	2	24	3.604	C
0.150	2	24	3.006	D
0.300	0	24	2.755	D E
0.225	0	24	2.489	E F
0.150	0	24	2.001	F

Means that do not share a letter are significantly different.