UTILIZATION OF WHEAT BRAN FIBER IN CRACKERS

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submitted by **EZGİ ŞAHİN** in partial fulfillment of the requirements for the degree of **Master of Science in Food Engineering Department, Middle East Technical University** by,

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

Prof. Dr. Alev Bayındırlı ______________
Head of Department, **Food Engineering**

Assoc. Prof. Dr. Behiç Mert ______________
Supervisor, **Food Engineering Dept., METU**

Examining Committee Members:

Prof. Dr. Hami Alpas ______________
Food Engineering Dept., METU

Assoc. Prof. Dr. Behiç Mert ______________
Food Engineering Dept., METU

Prof. Dr. Aziz Tekin ______________
Food Engineering Dept., Ankara University

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

Assist. Prof. Dr. Aslı İşçi ______________
Food Engineering Dept., Ankara University

Date: September 12th, 2011

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

Name, Last name : Ezgi Şahin

Signature :

ABSTRACT

UTILIZATION OF WHEAT BRAN FIBER IN CRACKERS

ŞAHİN, Ezgi
M. Sc., Department of Food Engineering
Supervisor: Assoc. Prof. Dr. Behiç MERT

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Dietary fiber is a component in the structure of plants which is an important aspect of diet and nutrition. The demand of fiber has increased significantly, as consumers recognize its health benefits such as reduction of risk of colon cancer, cholesterol lowering affect, regulating blood glucose levels and low calorie intake. Therefore food manufacturers pay more attention to develop new products containing high fiber content. Of all the categories of food products, bakery products are the most common fiber-enriched products. In this research two different wheat bran fibers (coarse and fine fibers) that are produced by microfluidization method are utilized in one of the highly consumed bakery product “cracker”.

In this thesis study coarse and fine wheat bran fibers were utilized in different amounts with replace to wheat bran (0,15, 25, 35, 45, 55, 65, 75 g). The effects of wheat bran fiber on crackers were determined by rheological measurements of dough samples and it was found that as the amount of wheat bran fiber increases; elasticity increases as well. Textural analysis were conducted for both dough and cracker samples and these analysis demonstrated that wheat bran fiber containing dough had higher hardness values than non/less containing ones. In addition to the above analysis, HPLC analyses were done for ferulic acid determination which is a significant nutritive compound in wheat bran. It was concluded that ferulic acid amount in fiber was much higher than wheat bran.

This research demonstrated that more nutritive and much fiber containing crackers could be made by using wheat bran fiber instead of wheat bran.

Keywords: Fiber, Wheat Bran, Cracker, Rheology, Texture

ÖZ

BUĞDAY KEPEĞİ LİFİNİN KRAKERLERDE KULLANILMASI

ŞAHİN, Ezgi
Yüksek Lisans, Gıda Mühendisliği Bölümü
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Lif, bitkinin yapısında bulunan ve beslenme alışkanlıklarımız açısından önem taşıyan bir bileşendir. İnsanların, lifin kolon kanseri riskini azaltması, kolesterol düşürücü etkisi olması, kandaki şeker oranını düzenlemesi ve düşük kaloriyle sağlıklı beslenmeyi sağlaması gibi sağlık açısından yararlı etkilerini anladıkça, lifli gıdaları tüketme talepleri günden güne artmaktadır. Bu talepleri karşılamak amacıyla gıda üreticileri, yüksek lif içeren gıda ürünleri geliştirmek için çaba sarf etmektedir. Üretilen gıda ürünleri arasından en popüler olanı yüksek lif içeren unlu mamuller grubudur. Bu çalışmada, mikro-akışkanlaştırma yöntemiyle üretilen iki çeşit buğday kepeği lifi (ince ve kalın lifler) çok tüketilen unlu mamullerden biri olan kraker üzerinde denenmiştir.

Bu tez çalışmasında, ince ve kalın buğday kepeği lifleri, buğday kepeği yerine farklı miktarlarda kullanılmıştır. (0, 15, 25, 35, 45, 55, 65, 75 g). Hamur örnekleri üzerinde reolojik ölçümler yapılarak buğday kepeği lifinin krakerler üzerindeki etkileri belirlenmiş ve buğday kepeği lifi miktarı arttıkça

,elastic özelliklerin arttığı bulunmuştur. Tekstür analizleri hem hamur hem kraker için yapılmış ve bu analizler, buğday kepeği lifi içeren hamurların içermeyen ya da daha az içerenlere gore yüksek sertlik değerlerine sahip olduğunu göstermiştir. Yukarıdaki analizlerin dışında, buğday kepeğindeki önemli besleyici bileşen olan ferulik asit tayini HPLC analizleriyle yapılmıştır. Lifteki ferulik asit miktarı, buğday kepeğindekinden daha yüksek çıkmıştır.

Bu çalışma, buğday kepeği yerine buğday kepeği lifi kullanarak daha besleyici ve daha yüksek oranda lif içeren krakerler yapılabileceğini göstermiştir.

Anahtar Kelimeler: Lif, Buğday Kepeği, Kraker, Reoloji, Tekstür

To my family

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INTRODUCTION

1.1 Dietary Fiber

Fibers are generally complex carbohydrates that are mostly found in outer layer of plants. Although it is already in a part of human diet, it has been recently considered as a dietary constituent (Nelson, 2001). It was firstly described as a plant cell wall in 1953 and later on in 1973 the definition was expanded with “indigestible polysaccharides and lignin” terms (Van Der Kamp, J. W., Asp N. G., & Miller-Jones J., 2004) Recently , The American Association of Cereal Chemists (AACC) updated its definition as following; “ Dietary fiber is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation.”

1.1.1. Sources & Production of Fiber Ingredients

Fibers are available in different kinds of plant sources that can be classified as fruits, cereals, plants generally. Since the water content of fruits is higher than cereals, they consist less dietary fiber. (Cho & Dreher, 2001) Therefore the commonly known above sources is cereal grains such as wheat bran, oat bran, rye flour.

Generally cereal grains consist four different parts in their structure; hull, bran layer, endosperm, and germ although the level and contents of these may be different. Hull is placed on the external part of the grain which is made up of insoluble fibers. The next layer after the hull is bran layer in which both soluble and insoluble fibers are found. On the contrary to the outer layers endosperm and germ part of the grain are composed of starch and lipids, respectively.

The process for production of fiber from cereal grains starts with dehulling of the grain to remove hull. Then dehulled grains are flaked, grinded and bran, germ and endosperm are obtained separately. These steps are part of milling process which especially determines various types of brans, germs. Further steps may be grinding, bleaching, roasting etc. After the separation fiber content of the parts are obtained however since complete separation is difficult, some of bran, endosperm and germ can be seen in each separated part.

The fiber content of bran differs due to different type of cereal grains as shown in the figure. (Nelson, 2001)

Table 1. 1 Amount of total dietary fiber of different bran types (Nelson, 2001)

Bran Type	Total Dietary Fiber, %
Oat	16-32
Wheat	35-45
Barley	15-70
Rice	20-33

Table 1. 1 *(continued)*

Corn	~55,80-90
Soybean	~65
Rye	~25-30

Simple extraction, drying, enzyme additions are other procedures than milling for isolating fiber from different sources. Even with waste products such as hulls, almond skins, waste of fruits etc.(Cho & Dreher, 2001)

1.1.2. Physical Properties and Functions of Fibers

1.1.2.1. Water binding capacity:

Water binding capacity or holding capacity can be defined as capability of a food ingredient to capture water under some conditions. (Chen, Piva, & Labuza, 1984). Water is binded either by absorption or adsorption. Water binding capacity depends on the particle size, chemical composition and structure of fiber.(Caballero, Trugo, & Finglas, 2003) The water binding capacity is high in fiber ingredients. It also assists retardation of staling, ice crystal formation, and decreases weeping. (Cho & Dreher, 2001) Water binding capacities of some fibers are shown in the table below (Nelson, 2001)

Table 1.2 Water binding capacities of different fiber ingredients (Nelson, 2001)

Ingredient	Water Binding Capacity (g water/g materialx100)
Apple pulp	230
Rice bran	100
Wheat bran	260
Oat bran	140
Corn bran	250
Soy bran	240
Sugar beet fiber	350

1.1.2.2. Viscosity/Thickening agent

Viscosity is a resistance to flow of fluid which is rheological property. Due to the molecular weight and fiber length, the viscosity of a solution is affected directly; as molecular weight increases, viscosity increases. Thickening contribution of fibers depends on source ingredient of fiber. Plant derived fibers affect viscosity more than cereal based ones because of chemical properties.

1.1.2.3. Oil Binding Capacity

As water binding capacity fibers also have ability to bind oil because of its porosity structure rather than their affinity for oil. Since the main phenomenon is filling the porosities of fiber, if fiber contained product is interacted with water, water will place in porosities therefore the oil intake of fiber will decrease. This is important especially for bakery products. (Nelson, 2001)

1.1.2.4. Anticaking Agent

Anticaking agent is a kind of additive to avoid cake formation by which product is improved for packaging and transport. Because of this property of fiber, flowability is improved in the product. (Cho & Dreher, 2001)

1.1.2.5. Antisticking Agent

Adhereness of dough causes extrusion problems. Antisticking property of fiber decreases the stickiness of a product so that eliminate the problems during processing. (Cho & Dreher, 2001)

1.1.2.6. Mineral Binding

It can also be named as "cation-exchange capacity" because of its binding capability to cations such as calcium and zinc due to the uronic acid group in the structure of fibers. Ionic strength, pH, type of fiber and cation nature influences this ability of fiber. For instance while pectin can bind to calcium ions, wheat bran has a low capacity to bind cations.(Nelson, 2001)

1.1.2.7. Solubility

Fibers differ from each other as insoluble and soluble. Solubility of the fiber cannot be defined as the solubility of a salt in water. In other words, the amount of soluble fiber cannot be quantified. Because, it is difficult to design actual gastrointestinal conditions in a lab scale. Basically if the fraction of total dietary fiber does not dissolve in hot buffer solution, it is named as insoluble dietary fiber as in the case of wheat bran. (Caballero et al., 2003)

Branching number, having ioinizing groups, nonuniformity and internal bonding determine the solubility property of a fiber. Briefly as branching increases solubility of a fiber increases. There is inverse relationship between ionizing group and solubility. Interchain bindings attenuate the solubility because of the positional bonding. Nonuniformity and solubility increases as direct proportion.(Nelson, 2001)

1.1.3. Factors Influencing Properties of Fiber

The properties of fiber have impact on functions of fiber. This is why factors affecting fiber properties are important when dealing with fibers. Properties of fibers depend on type of source and processing mainly.

Different structural arrangement has impact on properties of fibers. For instance because of presence of carboxyl group, pectin has a property of gelation. Similarly while pectin can bind calcium due to its uronic acids part, wheat bran has low ability to bind minerals. These examples demonstrate dependence of type of source on fiber properties.

To produce and isolate fiber from different sources, various methods are used which have impact on final product. These processes include milling, bleaching, grinding, enzyme treatments, stabilization, and extrusion, drying and roasting. During milling process if the separation of bran and endosperm is not done properly, starch may mix to bran part which increases water binding capacity and viscosity due to gelation property of starch. Bleaching is conducted to remove off-colors by oxidizing; grinding affects the solubility of fiber because of lowering the particular size while increasing the contact area with water. Stabilization is for reducing rancidity by heat treatment which may cause alteration in the properties of fiber. Because of the shear forces in the extrusion process, polymer chain of fiber may be cleaved. Drying and roasting both contain heat treatment which may cause changes on the fiber property. (Nelson, 2001)

1.1.4. Importance of Fibers, Health Benefits

The origin of the evolvement of human diet is still an argumentative topic. Early humans' diet was rich in plant based foods so that fiber while, evidence of butchery depends on 2.6 million years history. However after the animal husbandry, fiber dependent habituation changed and plant based food consumption level decreased. The descent of fiber consumption had continued until Dennis Burkitt and Hugh Trowell declared the benefits of fiber on human health, especially diabetes, cardiovascular diseases and cancer.(Kendall, Esfahani, & Jenkins, 2010)

Although dietary fiber is not a major nutrient, due to its beneficial functional in gastrointestinal system, nutritionists claim that it can be considered as a nutrient. (Guo, 2009)

1.1.4.1. Coronary Heart Disease (CHD)

Throughout the world death, cardiovascular problems are the most common situation that is 17.1 million occurs in a year according to World Health Organization (WHO) research. Causes of these diseases include tobacco use, stress, and inappropriate diet mainly. Therefore there is large number of studies on prevention of CHD by changing diet and one of the subject that is focused on is link between fiber and CHD.

Fat consumption is related with CHD because of saturated fats and cholesterol mainly. Since fiber makes a person feel full, it helps to reduce fat intake. Beside that it damages the fat digestion so that excess amount of fat is removed from the body. In a study of Ellegard and Bosaeus it is proved that adding fiber to diet increases the excretion fat in 50% amount. (Van Der Kamp, J. W. et al., 2004)

According to the survey conducted on 1999, women consuming fiber rich food have a 34% lower risk of CHD than those consumes in a low amount. In the other research it is proved that if 3 g of fiber is consumed daily, it will decrease the risk of CHD mortality 27%(Van Der Kamp, J. W. et al., 2004) Due to the facts mentioned above there is a positively relation between reduction of risk of CHD and fiber consumption.

1.1.4.2. Colon Cancer

According to WHO, colon cancer is the third most common (639000 death in 2004) cancer type after lung, and stomach in the USA. The risk factors of colon cancer are predominantly age, heredity, alcohol and tobacco use, and diet.

In order to understand the relation between colorectal cancer and fiber intake, several studies conducted especially animal studies which are rather low in cost. According to Kim and Mason, the mechanism of fiber on the reduction of colon cancer is summarized as that it reduces the transit time and prevents constipation. (Young-in & Mason, 1996) It decreases the ph of fecal and eliminates carcinogens by binding to them. After fermentation to short chain fatty acid, the ph of colonic system decreases also and inhibits the growth of carcinogens. (Cho & Dreher, 2001)

Wholegrain foods as a fiber source are significant target food for reduction of risk of colon cancer.

1.1.4.3. Diabetes

Diabetes is a chronic disease related to insulin functioning in the body. A patient cannot produce enough insulin (Type 1) or cannot use insulin efficiently (Type 2) so that blood sugar level is not hold under control. These conditions have consequences on glucose metabolism in the liver and muscles. (Cho & Dreher, 2001) diabetes should be considered seriously because of its dramatically increment throughout the world. Even in America number of diabetic people is more than 16 million. (Murdock, 2002)

Fiber rich diet was recommended for diabetes in 1971 by American Diabetes Association (ADA). Before that wrong and inadequate information led to consumption of high level of fat in order not to eat carbohydrates. However according to the research high carbohydrate level food facilitate the toleration of insulin. Therefore in 1971 ADA declared and in 1979 reaffirmed that diabetes should consume same portion of carbohydrate like other people. (Cho & Dreher, 2001). After that industry tried to find a way to supply carbohydrates in a healthy way.

The glycemic index is a tool for determining of which food is appropriate for diabetes. Glycemic index (GI) is a property of a food which establishes the affect of carbohydrates on blood sugar level. Low GI demonstrates that carbohydrates are digested slowly so blood sugar level increases gradually. Therefore diabetic people should consume low GI foods in order to meet their carbohydrate need. Fibers are listed as low GI food in Food and Drug Administration. Beside that at the article of Marangoni and Poli (2007) , fiber is added to bread and biscuit and GI values are compared with control group. According to article result the GI values reduce significantly when fiber is added.(Marangoni & Poli, 2008)

1.1.4.4. Weight Control

In the last years, balanced diet trend is increasing for weight control not only for aesthetic reasons but also for reduction of risks for diabetes, cancer types, cardiovascular diseases, high blood pressure, and sleep disturbances which are the causes of obesity mainly.(Murdock, 2002)This diet includes consumption of all kind of food in proper amounts i.e energy-dense foods should not be consumed in high amounts.(Murdock, 2002)

To lose weight, calorie intake should be reduced which can be provided by whole grain or fiber consumption rather than high amount of fat or simple carbohydrates. Besides having low calorie, fiber also has an advantage of making person feel full with even a low amount.

1.1.5. Application of Fiber in Food Industry

There are several applications and studies on fortification of food products by fiber since it has various positive physiological effects on human health. However, for ease processing properties of fiber such as viscosity and solubility should be considered carefully.

Since health benefits have been declared, food uses have been increasing in the industry recently. Fiber is placed already in bakery products, ready to eat meals, dairy products, beverage industry, and meat product.

1.1.5.1. Bakery Products

Fortification of bakery products is the most common application of fiber enrichment. Breads, cookies, cakes, muffins can be listed as food products that uses the effects of fiber on rheological properties. Firstly some of the fiber ingredients may increase the water holding capacity and it affects the consistency of dough. More water may be needed and it should be determined from the loaf volume, baking conditions, finished moisture by experiments. Secondly since hydrating of wheat gluten is retarded by fibers mixing time will be longer. Insufficient gluten hydration may cause crumbs on the final product. These crumbs can be prevented by strong gluten flours or adding methylcellulose as a gluten enhancing agent. The grittiness of the final product may be a problem with high fiber content and the prevention of this problem may be the reduction of fiber size. (Nelson, 2001)

1.1.5.2. Ready to eat meals

Ready to eat (RTE) meals such as cereals are fortified especially by oat and psyllium fiber. Texture of cereals may be affected negatively and surface cracking may occur. On the other hand by fiber addition the shelf life of cereals becomes longer. (Marley, 2001)

1.1.5.3. Dairy products

Fiber use is not so common in dairy products but the applications are increasing day by day in dairy industry. It is preferred especially for reducing the fat and calorie content.

In cheese production, fiber addition facilitates the precipitation of whey properties which provides enhance in the body texture. (Nelson, 2001). Generally soluble fibers are used; however, for anticaking agent cellulose may be preferred as an insoluble fiber. In traditional cheese production it is difficult to use fibers because of high solid content and protein content dependence but it is rather easy to produce cheese spreads. (Marley, 2001) Because of the gelation and water binding capacity, viscosity of cheese alters and spreading becomes easier by fat replacement.

Fat reduction in milk and yoghurt is easier by water soluble fibers such as locust bean gum to increase creaminess and prevent syneresis. Insoluble fibers are rare in ice cream production but oats have been preferred in very small particle size in order to prevent gritty mouthfeel. (Nelson, 2001)

1.1.5.4. Beverage

As functional food popularity increases throughout the world, the usage of fiber in beverage production becomes common. Water soluble fibers are generally used as a thickening agent that increases the viscosity which means longer time in the mouth, more chance to have flavor of a beverage. Although water soluble are more common, insoluble fibers are also used in beverage industry with a shorter particle length. Other than influence on texture and flavor, water soluble fibers stabilize the system by reduction of droplet sizes. (Nelson, Amy L. 2001)

Both water soluble fibers and insoluble fibers can be used in beverage industry nowadays but the important thing is choosing appropriate fiber for desired final product. For example if beverage requirement is high viscosity with low fiber content, gum arabic should not be used since it does not increase viscosity as much as guar gum.(Nelson, 2001)

1.1.5.5. Meat Products

Fibers are preferred in meat products for different attitudes. The properties benefit from fibers in meat products are water binding capacity and texturization predominantly. Water binding capacity facilitates to maintain lubricity of a meat and leakage of water from dry product which is called purge. Beside that the shape of the product is maintained by this property and makes easy to slice the product. Texturization is a result of gel formation of water soluble fibers and helps holding of ingredients together. Choosing the suitable fiber is important for instance wheat bran is found be inappropriate for beef sloppy-joe formulas.(Nelson, 2001)

1.2. Wheat and Wheat Bran

Wheat is an important agricultural commodity which is consumed in large amount all around the world among all grains. Wheat is processed for manufacturing flour and the flour is used for making bread, pasta, biscuit products as an ingredient.

Wheat kernel structure mainly consists 3 parts; endosperm, bran and germ. The inner part is the germ which is the embryo section of the kernel. It contains protein, B-vitamins and trace minerals. The section between bran and germ is called endosperm which is the 83% of weight of kernel. It contains starch abundantly and small amount of dietary fiber. The outer part is bran like all grain structure and it is the source of dietary fiber. Wheat kernel's hull does not contain fiber as much as the other parts so independently to the type of wheat as soft, hard, red, white etc, wheat bran and germs are used for obtaining fiber.

To manufacture the wheat flour wheat milling process is conducted in which the starchy endosperm is separated from the bran and germ.(Carver, 2009)

In wheat milling process, after the type of wheat selected and blended, the wheat is cleaned from foreign materials by sieves and air blasts. After cleaning wheat is conditioned by water addition for reaching optimum milling properties in which the bran part toughens while endosperm part softens. In milling process there are series of disintegrations followed by sieving. The flakes of bran are removed by the sieves (Desrosier, 1977)

Bran amount depends on further applications such as heating, grinding. Following applications are air classification and turbomilling in which wheat germ can be clarified and 10-12% total dietary fiber can be obtained.

Wheat bran is a most important fiber source which is inexpensive and available. It is a good source of not only dietary fiber but also for other major nutrients as can be seen from the comparison of wheat and rice bran chemical composition in Table 1.3.(Caballero et al., 2003) However, it is difficult to define the wheat bran quality properties. The reason is, they depend on the wheat type, size, milling system, and thickness of bran layer. (Ellouze-Ghorbel et al., 2010)

Table 1. 3 Chemical composition of wheat and rice bran (Caballero et al., 2003)

Grams per 100g dry weight	**Wheat bran**	**Rice bran**
Protein	13-18	12-20
Fat	3-6	3-22
Ash	6-7	9-13
Total Dietary Fiber	35-58	24-29
Soluble dietary fiber	2-5	2-4
Insoluble Dietary Fiber	32-53	20-24.5
Cellulose	6-12	6-12.8
Hemicellulose	19-31	8.7-17
Lignin	2-8	3-4

Different kinds of wheat may influence the color, flavor of the final product. For instance, since hard red wheat bran has darker color than hard white wheat bran, it is preferred in bakery products, while white one is used in ready to eat products.

1.2.1. Antioxidants of Wheat and Wheat Bran

Antioxidant is a structure which inhibits the free radical formation as a result of oxidation reaction. In a food product it plays important role to extend the shelf life and improve the nutritional quality. (Arndt, Ayella, & Charles, 2008) Being an important biological activity; these reactions also protects living organisms from harmful diseases (Wang, Jin, & Ho, 1999)

In wheat grain there are different antioxidants such as tocopherols, caretonoids, lignin and phenolic acids. The aromatic secondary metabolites of phenylalanine, phenolics, have been recently considered as an important compound due to being antioxidant, anti-inflammatory, anti-mutagenic, and anti-carcinogenic properties. (Chi-Tang, Qinyun, Huang, Ke-Qin, & Robert, 1992). These phenolics are not distributed homogenized in the wheat grain structure and they are mainly concentrated on the bran layer and aleurone in a bound, free and conjugated form (Arndt et al., 2008) .According to the study of Mpfou et al the most predominant phenolic in wheat grain is ferulic acid with 49.7-64.8% of the total amount.(Mpofou, Sapirstein, & Beta, 2006) .However reported ferulic acid amount in wheat bran changes depending on the different extraction methods of phenolics, therefore, Zhou et al measured 130-144µg/g ferulic whereas Moore et al reported it as 89.4-193.9 µg/g. (Zhou, Yin, & Yu, 2005)(Moore, Liu, Zhou, & Yu, 2006)

Phenolics and antioxidants in wheat are affected by post harvesting and other production processing. By wheat milling processing phytochemicals are redistributed as shown in table 1.4. Besides the wheat flour milling, wheat based foods are subjected to heat applications such as frying, baking, and extrusion. These applications consist high temperature (100℃), in which antioxidant activity in the wheat bran decreases significantly due to oxidation, thermal degradation and Maillard reaction (Moore et al., 2006)

Table 1. 4 Phytochemicals' redistribution after wheat milling process (Moore et al., 2006)

Phytochemicals	Flour	Bran/Germ
Total Phenolics, µmol/100 g	176-195	2867-3120
Flavonoids, µmol/100 g	60-80	740-940
Total Carotenoids,µmol/100g	42-78	192-228
Hydrophilic antioxidants, µmol/g	7-16	261-545
Lipophilic antioxidants, nmol/100 g	45-65	1785-4669

Baking is the most common cooking procedure for wheat based products. The effects of baking on total phenolic content and antioxidant activity were studied by Yu et al producing whole-wheat cookies from two kind of whole-wheat flours. (Moore et al., 2006)Remarkable reduction on the concentration of ferulic acid and p-coumaric acid and total phenolic compound were seen. (Table 1.5) However, due to the Maillard reaction, the antioxidant activity increased by 13-118%.

Table 1. 5 Chemical compound amounts of cookie and dough (Moore et al., 2006)

Soft red winter wheat	Dough	Cookie
Ferulic acid, µg/g	397.65	359.22
p-coumaric acid, µg/g	13.02	11.53
Syringic acid, µg/g	6.88	6.43
Vanillic acid, µg/g	7.56	7.54
Total Phenolics, GA µg/g	843.89	696.97

1.3. Cracker

Crackers are thin and crispy bakery products generally made of unsweetened and unleavened dough. Cracker like food was firstly baked by Theodore Pearson of Newburyport in 1792 with flour and water solely. Although it was firstly named as Pearson's pilot bread, because of its longer shelf life it was used by sailors especially and called as "sea biscuit". Cracker name was developed in 1801 when Josiah Bent burnt all biscuits and heard a voice of crispiness.

Crackers contain rather fatter than other bakery products such as biscuits but less sugar. There are predominantly two types of crackers saltines and snacks which are differ from each other by leavening agent, yeast and chemicals respectively.

1.3.1. Cracker Ingredients and Their Affects on Rheology of Dough

Rheological properties of dough are an essential concept that should be understood well in bakery products. The reason is the final texture and quality of product depends on mainly rheology. Therefore fundamental mechanical properties should be explained clearly of dough.(Faridi & Faubion, 1990) Cracker dough is subjected to rheological changes during processing. Rheological properties of cracker affect not only textural characteristics of final product, but also easiness during processing. Rheological properties of cracker especially are influenced by ingredients therefore effects of them are discussed on the following topics.

1.3.1.1. Flour

Flour and its components are crucial for bakery products. It is selected due to its protein and moisture content basically because rheology of the dough is mostly affected by flour in bakery products. Hard flour is preferable for cracker. According to the study in 1977 a small reduction of moisture content of flour causes increase in firmness of dough. (Faridi, 1990). In addition to that because the water content of flour affects the amount of water as an ingredient, it should be noted during cracker production.

The flour choice in cracker making is stronger in cookie making. This kind of flour, consists approximately 10% protein. (Gabriela et al., 2003) The protein content of flour, namely gluten is an important aspect for dough rheology although leavening and gluten development is not as major as other bakery products, cakes. It is suggested in 1991 that gluten has an impact on dough rheology, the reason may be interaction with starch. According to another research of Petrofsky and Hoseney in 1995, gluten starch interaction has a relationship with optimum water content and so that rheological properties.

Other than gluten and moisture content of flour, starch damage amount and ash content of flour are also responsible for rheological properties. Starch damage may occur during milling process and it causes the increment of absorption of water because of high water holding capacity of damaged starch. Since cracker should be in a low moisture amount, low starch damaged flour should be preferred.

The fiber is not commonly found at wheat endosperm. White flour contains mostly the endosperm part while whole wheat flours consists the outer layer. The bran amount of white flour 2.78% is comparable lower than whole wheat flour 12.57% (Matz, 1992). Amount of bran determines the amount of ash content in flour. It not only affects the color of the flour but also physically damage of the gluten. (Faridi & Faubion, 1990) Therefore has an impact on rheological properties. (Faridi, Hamed 1990)

1.3.1.2. Shortening

Fat is responsible for softening and water amount determination in the batch formula. The softening affect of fat alters the consistency of dough. Dough consistency can be defined as proper softness, stickiness, elasticity and extensibility of dough. Temperature and water amount have an influence on consistency. The more amount of water cause softer dough consistency.(Manley, 2001) Water amount is affected by fat because lubricating function in the dough is affirmed when the amount of fat is high. In addition to that the mixing order is critical. The addition of fat before water may cause prevention of gluten formation since flour surfaces will be layered by fat. (Faridi & Faubion, 1990)

The texture of the dough depends on fat properties like fat crystals. Fat crystals vary due to production background of shortening namely heating process.

1.3.1.3. Water

Dough formation starts with the mixing of flour and water mainly. The ratio of water-flour depends on mainly flour properties. For instance, as the moisture content of flour decreases, water absorption will increase and vice a versa. Together with water content, bran content also influences the water amount as whole meal flours can absorb more water than white flours. (Cauvain & Young, 2001) Addition of water affects the rheological properties indirectly. The main function is to being catalyst in dough formation since high amount of it is removed during baking.(Manley, 2001) The consistency and water has an inverse relationship as increasing water, consistency will decrease. The amount of water should be enough for hydrating the flour otherwise gluten can not be fully developed. (Mirsaeedghazi, Emam-Djomeh, & Sayed, 2008)

Water functions also as a solvent for chemical agents in the formula. When chemicals are dissolved, they become available for reactions with other ingredients and increase the pH of dough especially with ammonium bicarbonate. High pH values causes weakening of gluten so that decrement in the consistency. (Manley, 2001)

1.3.1.4. Leavening Agents

In bakery products several reactions occurred during processing develops carbon dioxide in the dough which is the main leavening force. In cracker technology rather than yeast fermentation, chemical leaveners, such as sodium bicarbonate and ammonium bicarbonate, are preferred.

Being cheap, safe, relatively tasteless and odorless increases the usage of sodium bicarbonate. Besides, the pH of the sodium bicarbonate solution is comparatively lower which can be served as an advantage because of probability of undesirable colored brown spots formation at high pH regions. (Matz, 1992) In addition to that during processing over 120 °C, sodium bicarbonate does not require leavening agent in order to form carbon dioxide and the following decomposition reaction is occurred due to high temperature (W. P. Edwards, 2007)

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

Among all of these advantageous, it is difficult to control its leavening action because of its rapid rate of solution. In addition to that, although it is a dry product, the deterioration occurs easily.

Ammonium bicarbonate is generally preferred in low moisture products such as cracker, biscuits as a supplementary leavening agent. Like sodium bicarbonate, the advantage of using ammonium bicarbonate is no need for leavening agents. Decomposition starts at 40°C as in the following; (W. P. Edwards, 2007).

$$NH_4CO_3 \rightarrow NH_3 + CO_2 + H_2O$$

The carbon dioxide yield is relatively high as can be seen in the reaction above, so that ammonium bicarbonate may cause large voids in the product when added as a dry ingredient. The problem can be resolved by adding ammonium bicarbonate to the ingredients after solving it in warm water in that case the uniformity is obtained. (W. P. Edwards, 2007)

It should be given attentions to moisture content and porous content of final product while using ammonium bicarbonate. For example, If the moisture content of the product is higher than 5%, ammonia will be dissolved in water or if porous structure is not formed sufficiently, ammonia can not leave the product. The results of both situations are an undesirable ammonia taste. (Matz, 1992)

1.4. Objectives of the study

In this study, the main objective is to produce high-fiber containing cracker with acceptable sensory properties by utilization of two different particle size of wheat bran fiber, coarse and fine.

To serve for this objective, crackers containing different amount of fiber were prepared. Rheological properties of fiber containing dough samples were examined and compared with none/less fiber containing cracker dough. In addition to that coarse and fine wheat bran fiber containing dough samples were measured and compared. Both dough samples and cracker samples were analyzed using texture analyzer to determine the hardness correlation with fiber amount. In order to evaluate nutritional aspect, ferulic acid amounts of cracker samples were measured by using HPLC.

CHAPTER 2

MATERIALS AND METHODS

2.1. Materials

For cracker preparation, flour was kindly donated by Eti Company (Eskişehir, Turkey) , wheat bran obtained from Ulker Company (Ankara, Turkey), salt, shortening, sodium bicarbonate, ammonium bicarbonate were bought from local markets.

For ferulic acid determination, standard ferulic acid was provided from Sigma Chemical Co. In HPLC analysis; acetonitrile, methanol and water were used. Other chemicals were of analytical grade.

2.2. Methods

Wheat bran was used as a source to produce wheat bran fiber. By using different type of wheat bran fiber (coarse and fine) in a varying concentrations, several cracker samples were prepared. In order to determine the effects of wheat bran fiber on the quality of these, rheological and textural analyses were performed for each dough samples and cracker samples (only texture). In the base of rheological properties; flow and viscoelastic properties, textural properties; hardness, of cracker were considered and compared to each other. Besides that moisture content of crackers was analyzed**.** In addition to the physical properties of cracker samples, the nutritional aspects of different cracker samples were examined mostly due to phenol compound content, ferulic acid, which is abundantly found in bran layer of wheat grain.

2.2.1. Production of Wheat Bran Fiber

Wheat brans were processed to produce wheat bran fibers. The processing steps initiated with a softening and delignification of wheat bran by keeping it in a weak alkali solution overnight, in which pH was adjusted to 8. After the softening step, by using microfluidizer equipment, the size of softened wheat brans were reduced in two stages. (Fig 2.1)

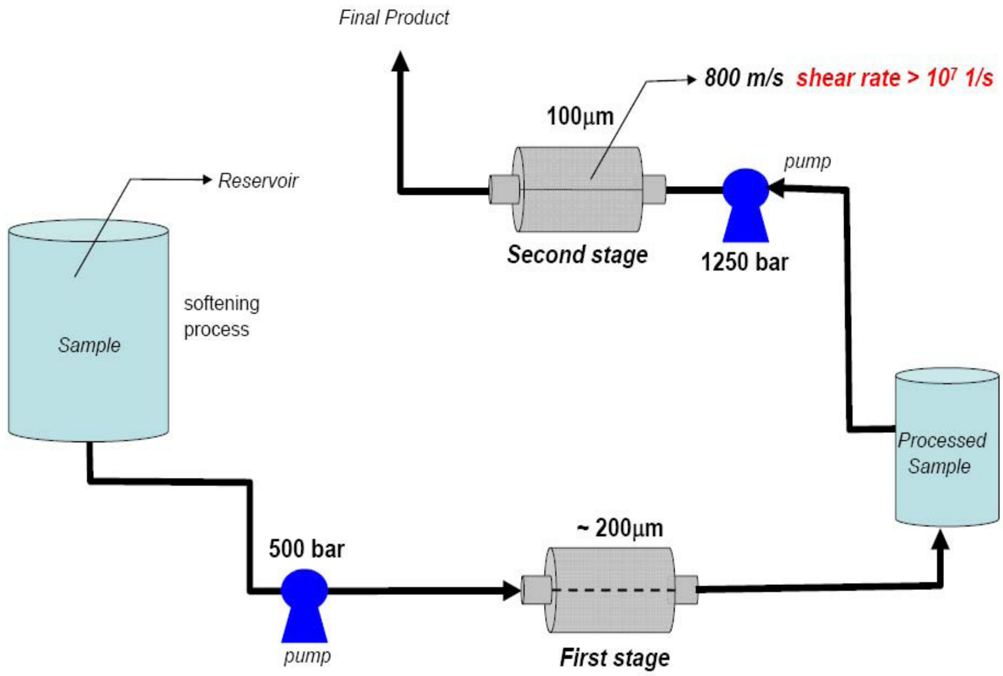

Figure 2. 1 Production of wheat bran fiber from wheat bran

In these stages the sample was pumped into two micro channels 200 µm, 100 µm respectively, by applying a high shear rate by means of high velocity up to 800 m/s. As a result of this size reduction process, micro and nano fibers were obtained from macro fibers by damaging the bonds.

Final stage was the centrifugation (6000 rpm) of wheat bran fibers. By centrifugation the moisture content of micro and nano wheat bran fibers could be set to the desired value.

By using the particle size analyzer (Malvern Mastersizer 2000) and scanning electron microscope (QUANTA 400F Field Emission SEM) from central laboratory of METU, particle size analysis and microscopic analysis of wheat bran fibers were conducted.

2.2.2. Rheological Testing

Dynamic mechanical analysis type of oscillary test was done in other words the frequency and amplitude were kept constant. In order to perform analysis, AR 2000ex model rheometer was used. Parallel plates (40 mm) were adjusted with a gap distance 1.5 mm.

2.2.3. Cracker-making Procedure

Standard wheat bran containing cracker in which wheat bran amount ~20% (w/w of wheat flour) were prepared according to the commercial formulation. The recipe was 77.5 g flour, 15 g wheat bran, 8.5 g shortening, 2 g salt, 2 g ammonium bicarbonate (NH_4CO_3) , 0.5 g sodium bicarbonate ($NaHCO_3$) and 52.5 g water. In this study wheat bran concentration, based on wheat flour amount, was adjusted and/or replaced with a coarse or fine wheat bran fiber in a different amount. In other words different cracker samples included both wheat bran and wheat bran fiber together while others included only wheat bran fibers by the guidance of above formulation. Beside the wheat bran and flour concentration, water coming from the adjusted moisture content of wheat bran fibers were taken into account while adding the water into formulation. In the following table, all the formulations that was done for 77,5 g can be seen.

Table 2. 1 Cracker formulation for 77,5 g flour containing sample

Sample No:	1	2	3	4	5	6	7	8
Flour (g)	77,5	77,5	77,5	77,5	77,5	77,5	77,5	77,5
Shortening (g)	8,25	8,25	8,25	8,25	8,25	8,25	8,25	8,25
Salt (g)	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
Amonnium bicarbonate (g)	2	2	2	2	2	2	2	2
Sodium carbonate (g)	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Water (g)	55	42,85	34,75	26,65	18,55	10,45	2,35	0
Wheat Bran Fiber (g)	0	15	25	35	45	55	65	75
Wheat Bran (g)	15	12,15	10,25	8,35	6,45	4,55	2,65	0,75

Flour, wheat bran and salt were added to the dough mixer. Leavening chemicals (sodium bicarbonate and ammonium bicarbonate) were dissolved in a water previous to the addition to the mixer to provide uniformity in the formula. Following all dry ingredients and water addition, shortening was added because if shortening is added before water, it would cover the surface of flour particles and prevent water flour interaction in other words gluten development. The dough was formed after 7-8 min mixing in slow mode. Dough was rested for 2 min. After resting, dough was sheeted and laminated to 1mm thickness and cut into rectangular mold. Then uniform holes were made at the surface of each cracker to support leavening of gas and prevent non-uniform excess rising.

The rectangular shaped crackers were placed above the porous tray to receive hot air from all parts and baked in a conventional oven (Susler, Istanbul) with a rotating tray for 9-11 min at 200℃.

2.2.4. Texture Analysis

Both the cracker dough samples and cracker samples were analyzed using a texture analyzer (The TA.XT*Plus*, England) . For dough analysis 12 g of dough samples were taken and sheeted to 1 cm in a cylindirical shape disc and placed on analyzer. The compression test for the dough was conducted with a 1 mm/sec test speed with a 60% strain rate. The final results were evaluated according to hardness of the dough.

For cracker samples with texture profile analysis, the force required for breaking the cracker was measured. In this analysis knife was used which was not sharp to break the cracker and cracker was placed on the top of the platform which has a gap distance of 2 cm.The test speed was 1mm/sec, and probe went down for 5 mm through cracker.

2.2.5. Ferulic Acid Content Analysis

Ferulic acid content were determined by the procedure decribed by Cai and Hettiarachchy et al (2003)(Cai, Hettiarachchy, & Jalaluddin, 2003). For the extraction; five hundred milligrams of samples were put into 250 ml vessels and twenty milliliters methanol was poured onto them. Cracker samples were pulvarized before this step different than the wheat bran. Refluxion was done in 95 °C water bath for 2 hours. After cooling, mixtures were filtered and liquid phases were dried by stream of nitrogen at room temperature. 1 ml of methanol was added again to dry extracts and 200 µl portions were filtered through again using 0.2 µm filter for HPLC analysis.

Hewlett-Packard was a high performance liquid chromatograph equipment with Diode array ultraviolet detector. A TSK-GEL Super-ODS colums was used. The absorbance was monitored at 254 and 238 nm.Solvent A; 0.1% trifluoroacetic acid in acetonitrile, solvent B; 0.1% trifluoroacetic acid in HPLC grade water and Solvent C; 100% methanol were mobile phases. Flow rate was adjusted to 1 ml/min and the temperature in the column was 37℃. 4 µl samples were injected for HPLC analysis. Ferulic acid (FA) content was calculated according to following equation;

$$FA\ (mg/100g) = [(aA + b)\ V_c / V_s V_t W\ ] * 100$$

where a is slope b is y-intercept, A= peak area, V_c=injencton volume for calibraton (µL), V_s = injection volume for sample (µL), V_t= volume of solvent added to sample (1mL) and W= weight of the sample (g)

CHAPTER 3

RESULTS AND DISCUSSION

3.1. Rheology of Cracker Dough

Rheological properties of dough should be explained clearly in flour containing products because of its crucial effect on the final texture and quality of product, as it is mentioned above.

Kocak (2010) studied rheology of cake dough containing different amounts of wheat bran and wheat bran fiber. As a result, fiber added cake dough, regardless of fiber and bran amount, showed shear thinning (pseudoplastic) behavior. (Kocak, 2010) For the pseudoplastic materials, the viscosity decreases as the shear applied increases. In addition to that it was resulted that bran fiber has more significant effect on yield stress than wheat bran.

Wheat bran and wheat bran fiber differs from each other due to their water holding capacity. As it can be seen from the figure 3.1, when same amount of water is added to the same amount of wheat bran and wheat bran fiber, dough formation occurs in fiber whereas excess water can be seen in wheat bran. It can be explained by the particle size difference which is seen in scanning electron microscopy (SEM) pictures of wheat bran and wheat bran fiber in figure 3.2. The major difference between two pictures is the increase in the surface area of wheat bran fiber structure which is the result of more branch formation. It leads to hold more water as in figure 3.1 and immobilize the liquid with solid. As a result of this colloid formation more complex rheological behavior is observed.

Figure 3. 1 Wheat bran (on the left) and Wheat bran fiber (on the right) containing 90% water

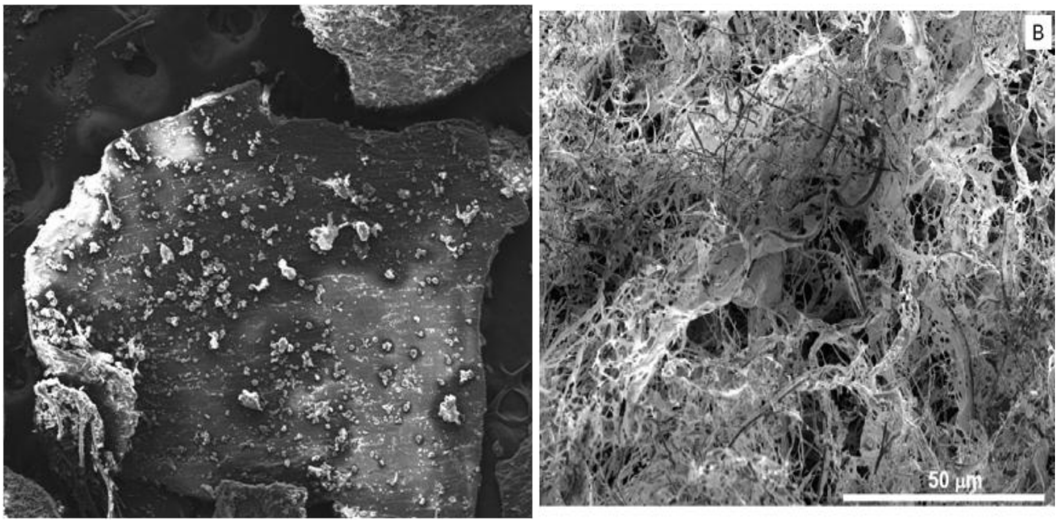

Figure 3. 2 SEM pictures of wheat bran- 500µm (on the left) and wheat bran fiber- 50µm (on the right)

3.1.1. Rheology of 77.5 g Flour Based Cracker Formulation

3.1.1.1. Rheology of 77.5 g Flour Based Cracker Formulation Produced by Coarse Fiber Gel

From oscillation test elastic modulus (G’), and viscous modulus (G’’) values were obtained for different angular frequency and strain values. G’ and G’’ are both measures of the deformation energy which are stored and consumed by the sample during the shear process ,respectively.(Mezger, 2006)

As shown in the figure 3.3, for 77.5 g flour based formulation, the explanation could be that as angular frequency increased, G’ increased for each sample. In addition to that it could be concluded that as wheat bran fiber amount increased in the dough, G’, elastic behaviour of the samples increased. Therefore, replacing wheat bran with wheat bran fiber,contributed the elasticity of fiber.

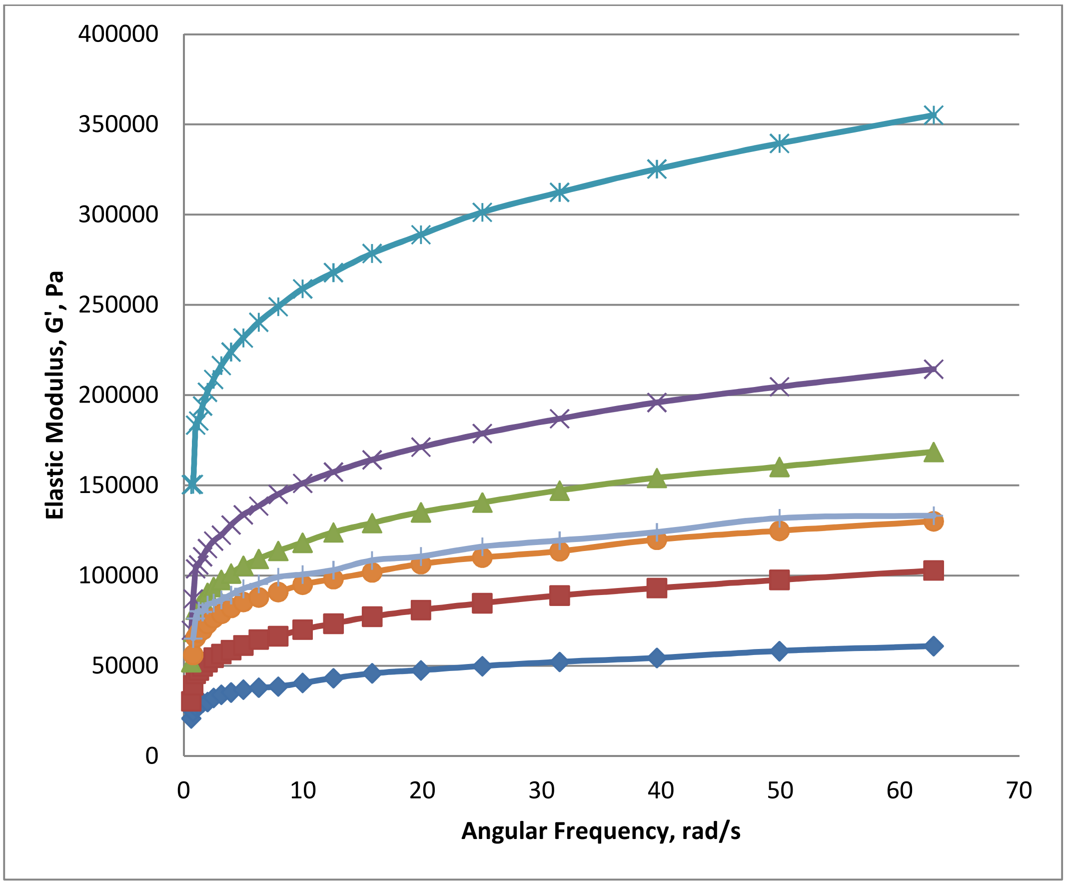

Figure 3. 3 Elastic modulus (Pa) versus angular frequency (rad/s) values of cracker dough of 77.5 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ●, 45 g coarse fiber gel)

As it is shown in the figure 3.4 , G'' also increased as wheat bran fiber increased. Because fiber contributed to viscosity of formulation.

The comparison of two figures 3.3 and 3.4 demonstrates that G' values were bigger than G'' which indicated that elastic behaviour dominated the viscous behaviour i.e dough showed the gel character.

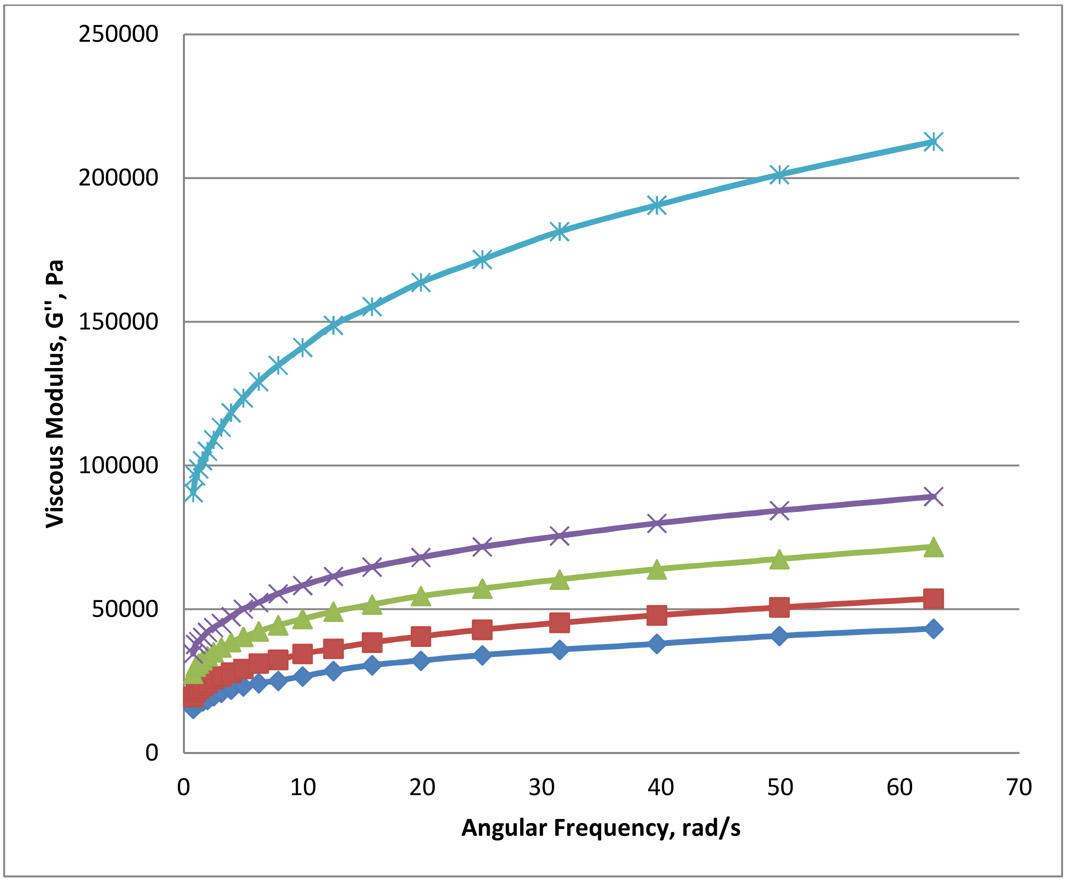

Figure 3. 4 Viscous modulus (Pa) versus angular frequency (rad/s) values of cracker dough of 77.5 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ●, 45 g coarse fiber gel)

Figure 3.5 illustrates elastic modulus vs strain which gives an idea about processability of fiber containing cracker. As it is seen, elastic modulus-strain ratio was the highest for 45 g fiber containing cracker dough which suggested that during process, applied forces would not give unrecoverable damage to that dough especially during kneeding.

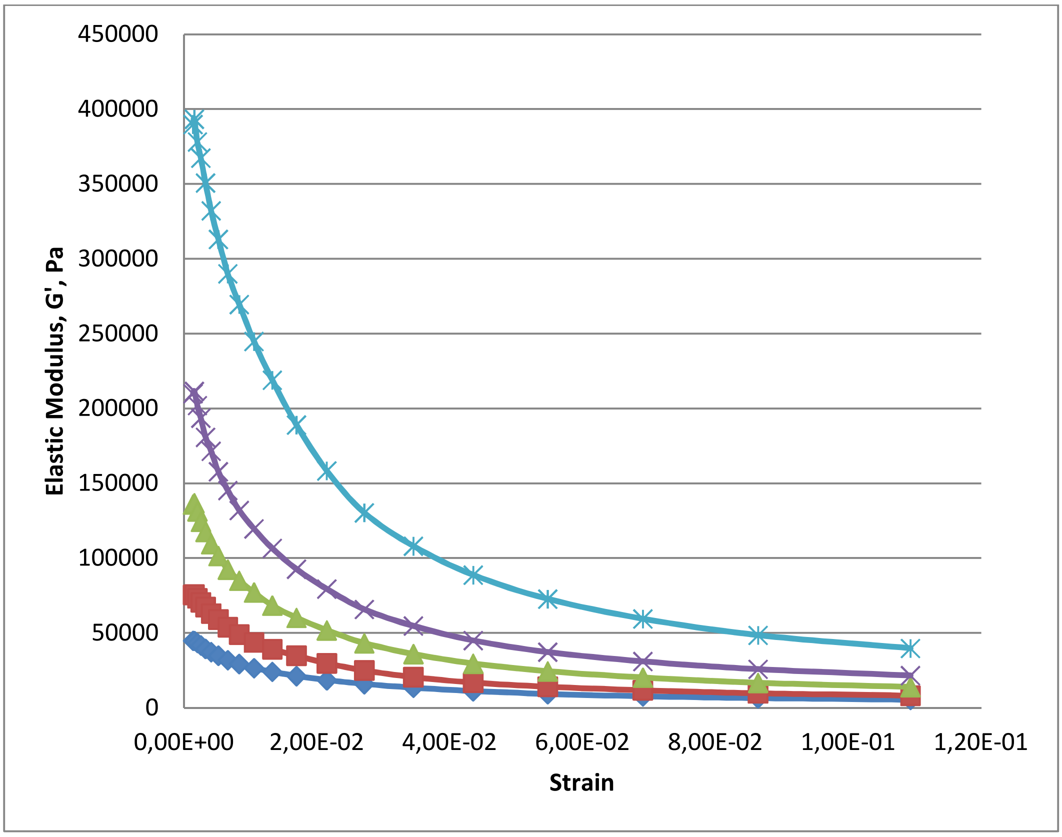

Figure 3. 5 Elastic modulus (Pa) versus strain values of cracker dough of 77.5 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ●, 45 g coarse fiber gel)

From figure 3.6, it can be obtained an opinion about processability as well. The viscosity of fiber containing dough was showing ascending behaviour, as fiber amount increased in figure 3.3. Therefore, the highest viscous modulus value was seen for high fiber containing dough in figure 3.6. These figures evidenced that more viscous and elastic dough could be used for process-facilitator.

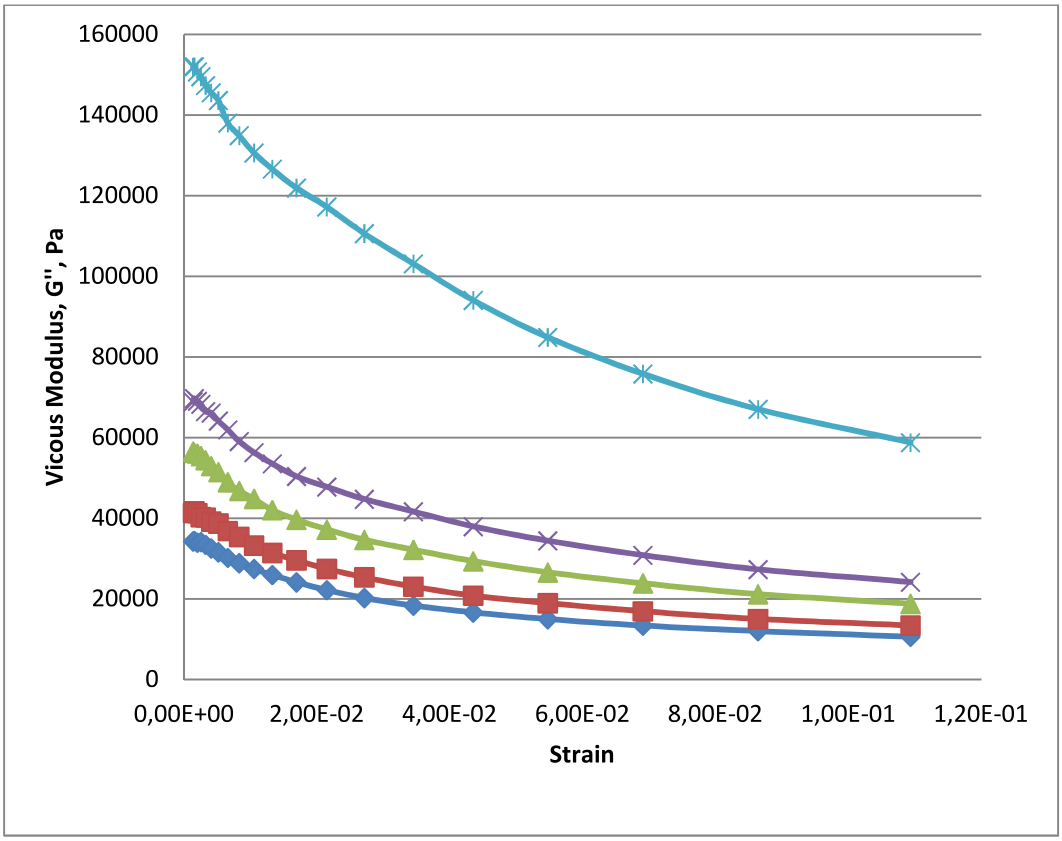

Figure 3. 6 Viscous modulus (Pa) versus strain values of cracker dough of 77.5 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ●, 45 g coarse fiber gel)

3.1.1.2. Rheology of 77.5 g Flour Based Cracker Formulation Produced by Fine Fiber Gel

In the figure 3.7 and 3.8, frequency-sweep results shows the similar behaviour with coarse fiber containing samples. For both, G' and G'' increased as the fiber gel amount in the formulation increased. In addition to that G' and G'' were positively dependent to angular frequency.

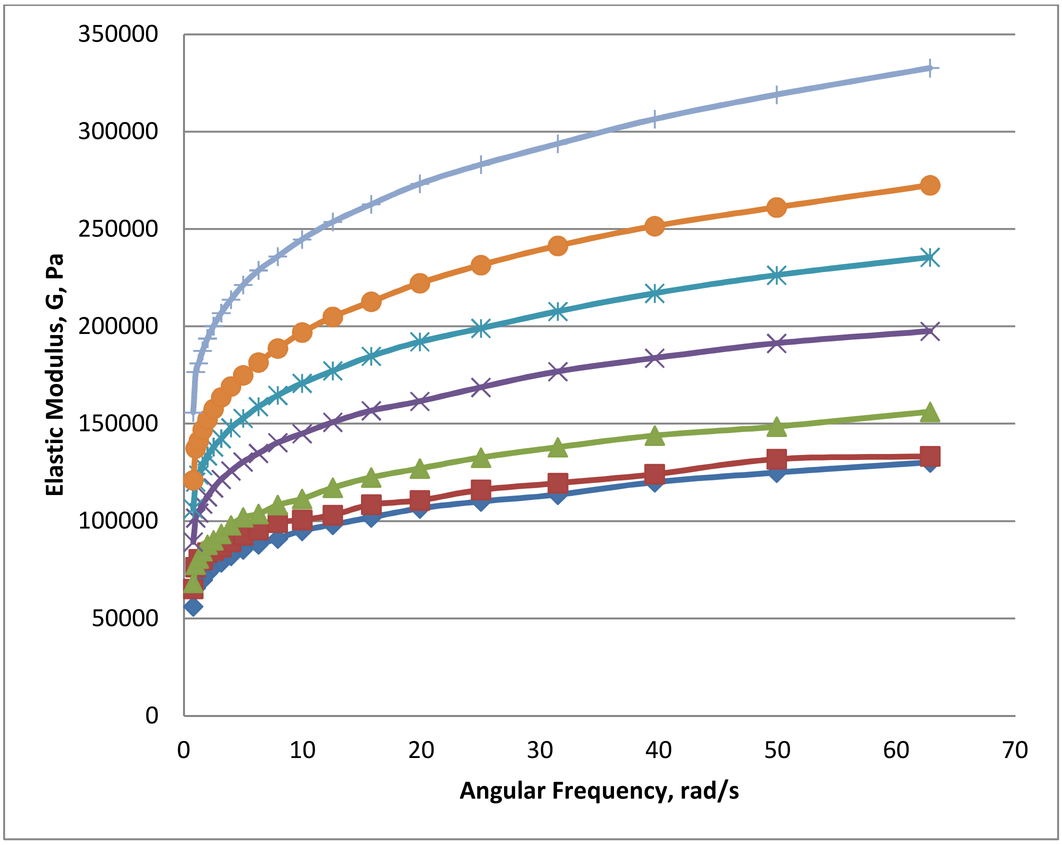

Figure 3. 7 Elastic modulus (Pa) versus angular frequency values (rad/s) of cracker dough of 77.5 g flour based formulation (♦, 15 g fine fiber gel; ■, 25 g fine fiber gel; ▲ 35 g fine fiber gel; ×, 45 g fine fiber gel; ж, 55 g fine fiber gel; ●, 65 g fine fiber gel; +, 75 g fine fiber gel)

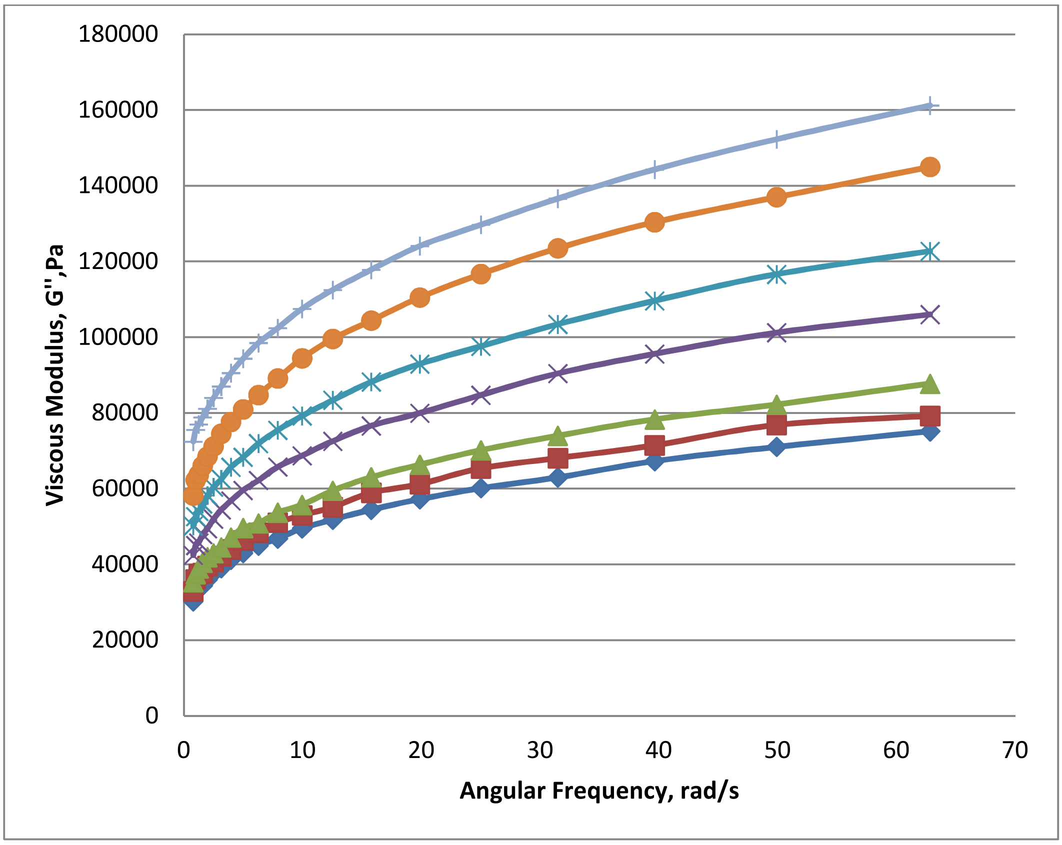

Figure 3. 8 Viscous modulus (Pa) versus angular frequency values (rad/s) of cracker dough of 77.5 g flour based formulation (♦, 15 g fine fiber gel; ■, 25 g fine fiber gel; ▲ 35 g fine fiber gel; ×, 45 g fine fiber gel; ж, 55 g fine fiber gel; ●, 65 g fine fiber gel; +, 75 g fine fiber gel)

Figure 3.9 shows the same behaviour with coarse one. It was clearly said that either fine or coarse fiber gel was used, addition of fiber eased process as compared to non-fiber containing.

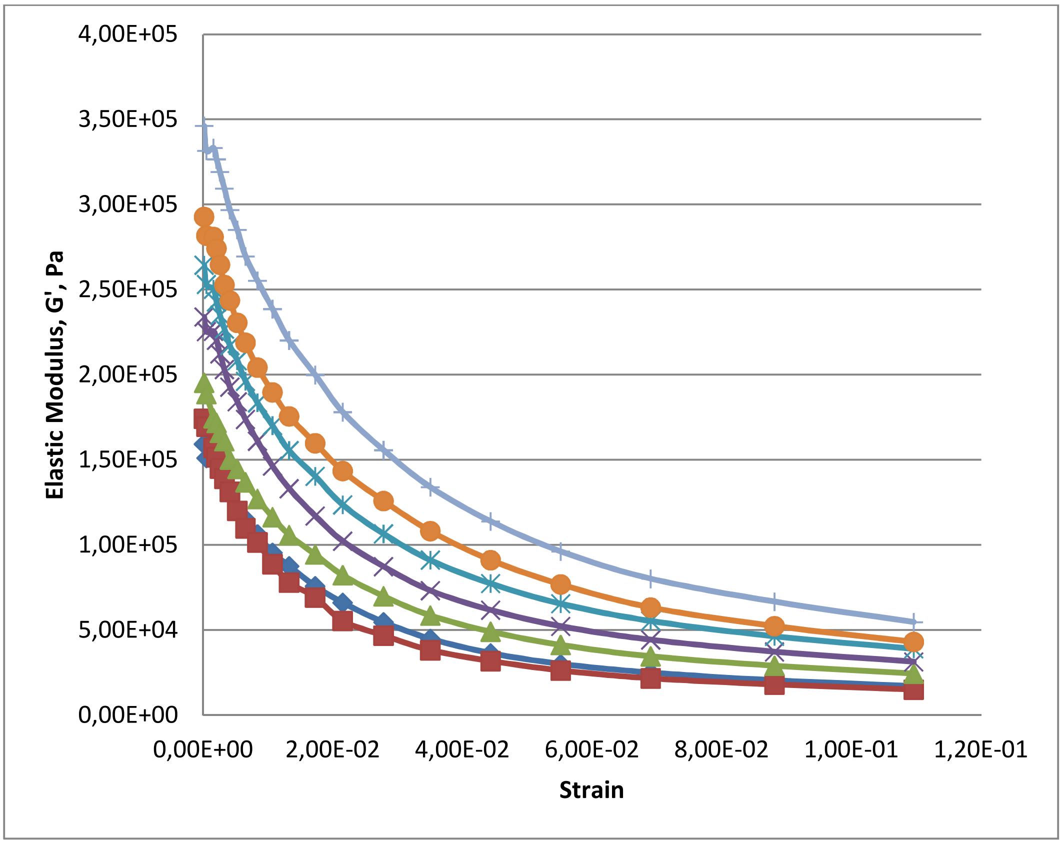

Figure 3. 9 Elastic modulus (Pa) versus strain of cracker dough of 77.5 g flour based formulation (♦, 15 g fine fiber gel; ■, 25 g fine fiber gel; ▲ 35 g fine fiber gel; ×, 45 g fine fiber gel; ж, 55 g fine fiber gel; ●, 65 g fine fiber gel; +, 75 g fine fiber gel)

The comparison of figure 3.10 and 3.6 shows that for the same amount of fiber containing cracker dough, viscous modulus was higher in coarse one. Therefore it could be commented that coarse fiber could facilitate the process even with a low amount. On the other hand, fine fiber could be added up to 75 g which still had desired processability.

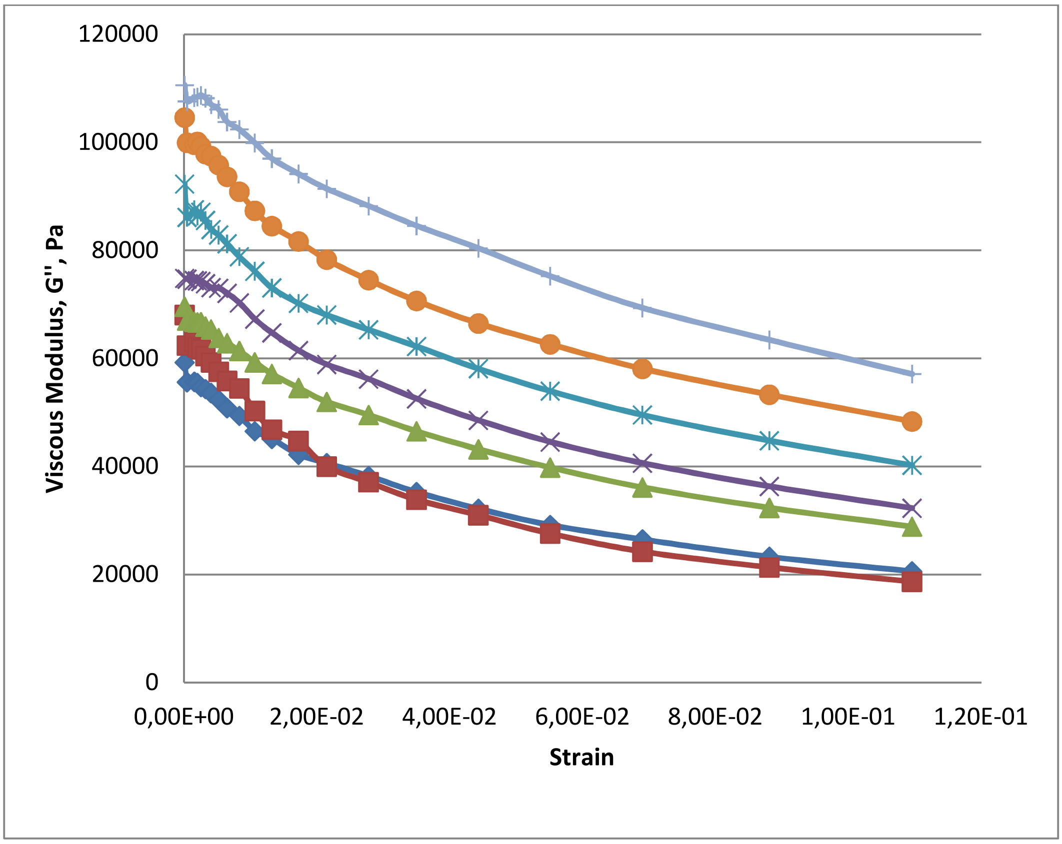

Figure 3. 10 Viscous modulus (Pa) versus strain of cracker dough of 77.5 g flour based formulation (♦, 15 g fine fiber gel; ■, 25 g fine fiber gel; ▲ 35 g fine fiber gel; ×, 45 g fine fiber gel; ж, 55 g fine fiber gel; ●, 65 g fine fiber gel; +, 75 g fine fiber gel)

3.1.2. Rheology of 70 g Flour Based Cracker Formulation

3.1.2.1. Rheology of 70 g Flour Based Cracker Formulation Produced by Coarse Fiber Gel

The following figure 3.11 demonstrates the oscillatory test results of a number of samples containing different amount of wheat bran and wheat bran fiber. From the figure it can be concluded as wheat bran fiber amount increased, viscoelastic behaviour of dough increased. It also shows that as angular frequency increased, G’ increased. On the other hand, frequency dependency was seen significantly, as wheat bran fiber amount increased.

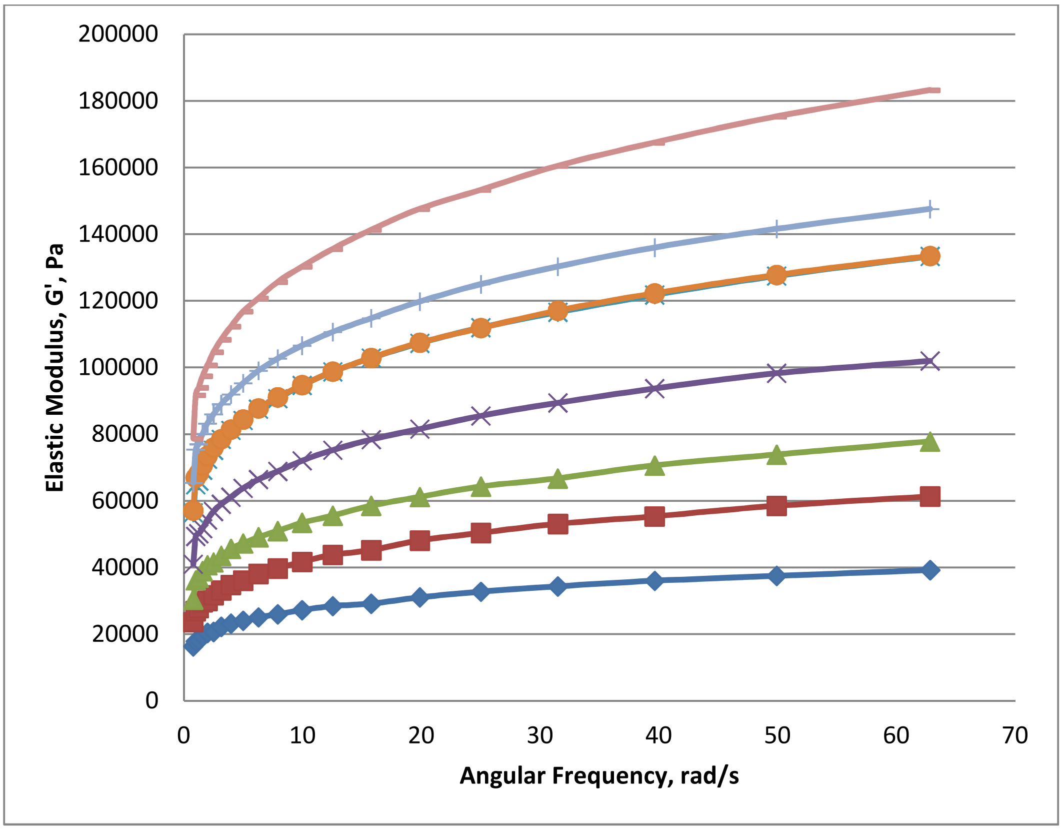

Figure 3. 11 Elastic modulus (Pa) versus angular frequency values (rad/s) of cracker dough of 70 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel;●,45 g coarse fiber gel; +,55 g coarse fiber gel; ж, 65 g coarse fiber gel; -, 75 g coarse fiber gel)

Viscous modulus vs angular frequency graph can be seen in the following figure 3.12 which shows the same behaviour with 77.5 g flour containing series, as wheat bran fiber amount increased, viscosity of the dough increased. Also for each sample, G'' increases as with the increment of angular frequency.

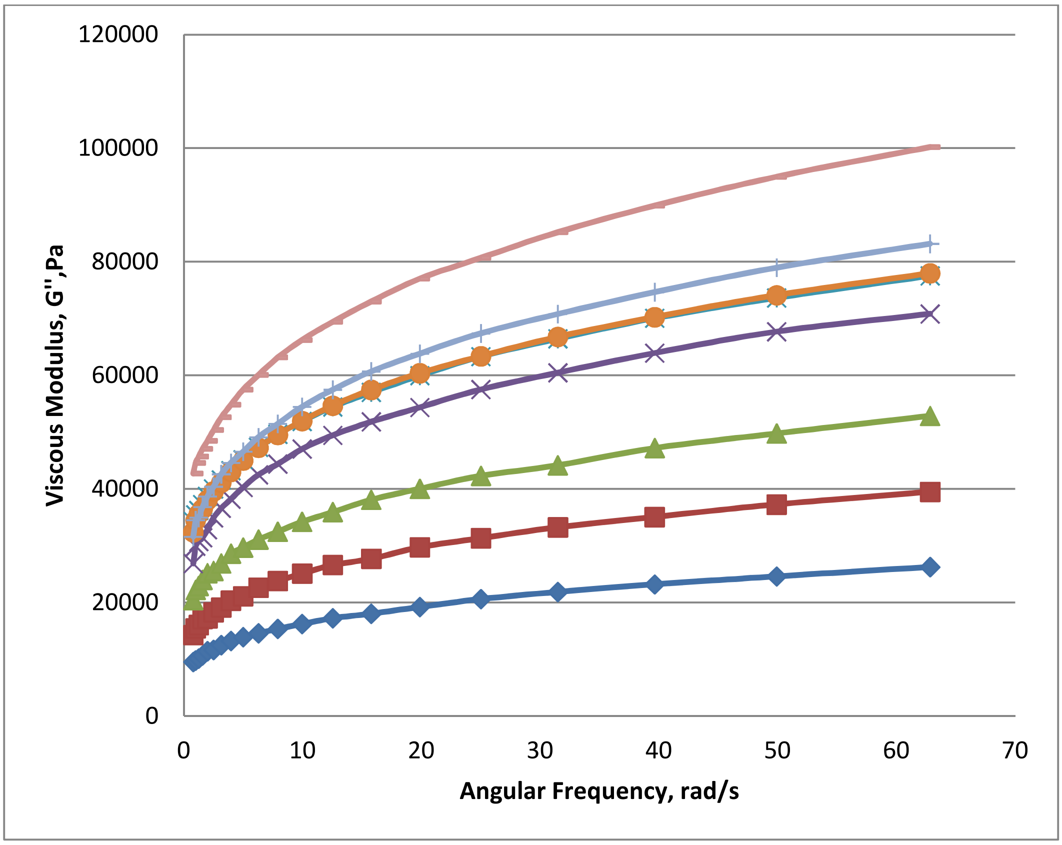

Figure 3. 12 Viscous modulus(Pa) versus angular frequency values (rad/s) of cracker dough of 70 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel;●,45 g coarse fiber gel; +,55 g coarse fiber gel; ж, 65 g coarse fiber gel; -, 75 g coarse fiber gel)

As it can be realized from figures 3.11 and 3.12, G' and G'' values of 70 g flour based formulation were lower than 77.5 g flour based formulation which indicates that gluten is the main factor for determining viscoelastic behaviour of dough.

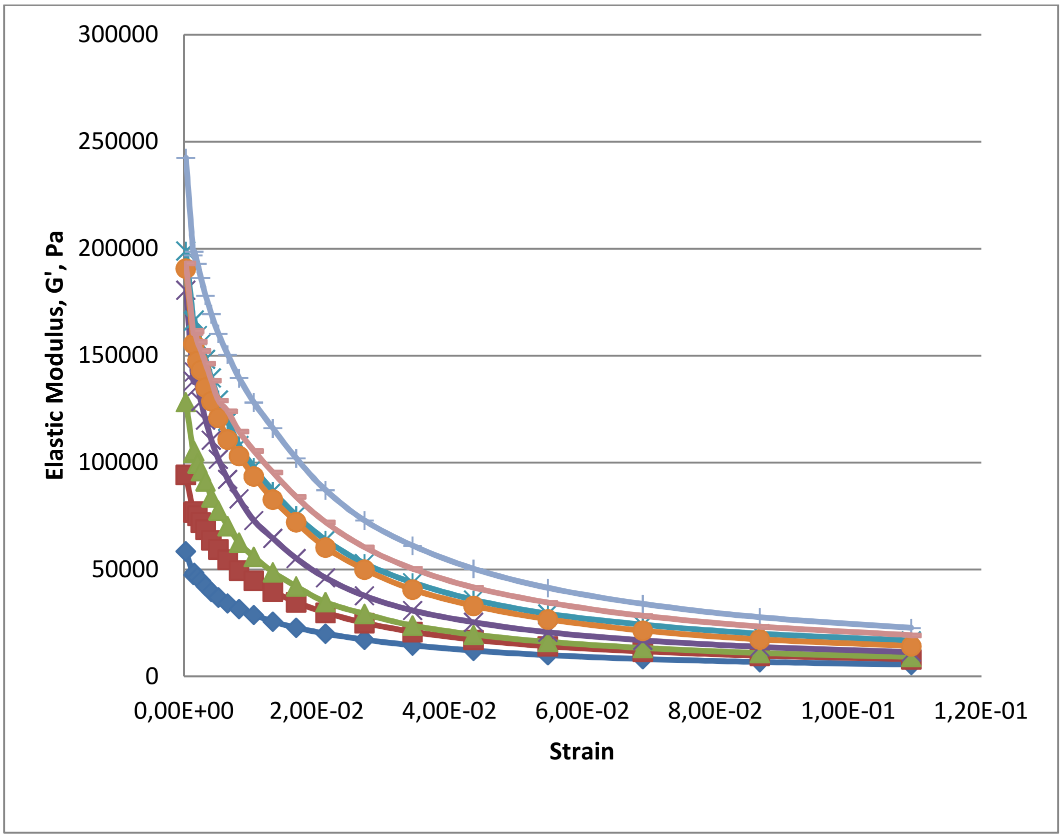

Figure 3. 13 Elastic modulus (Pa) versus strain of cracker dough of 70 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ж, 45 g coarse fiber gel; ●, 55 g coarse fiber gel; -, 65 g coarse fiber gel; +, 75 g coarse fiber gel)

Since the flour amount was lower in this dough formulation, elastic modulus and viscous modulus was found lower, as can be seen in the figures 3.13 and 3.14. However, effect of fiber addition was still the same with 77,5 g flour containing formulation which is desired.

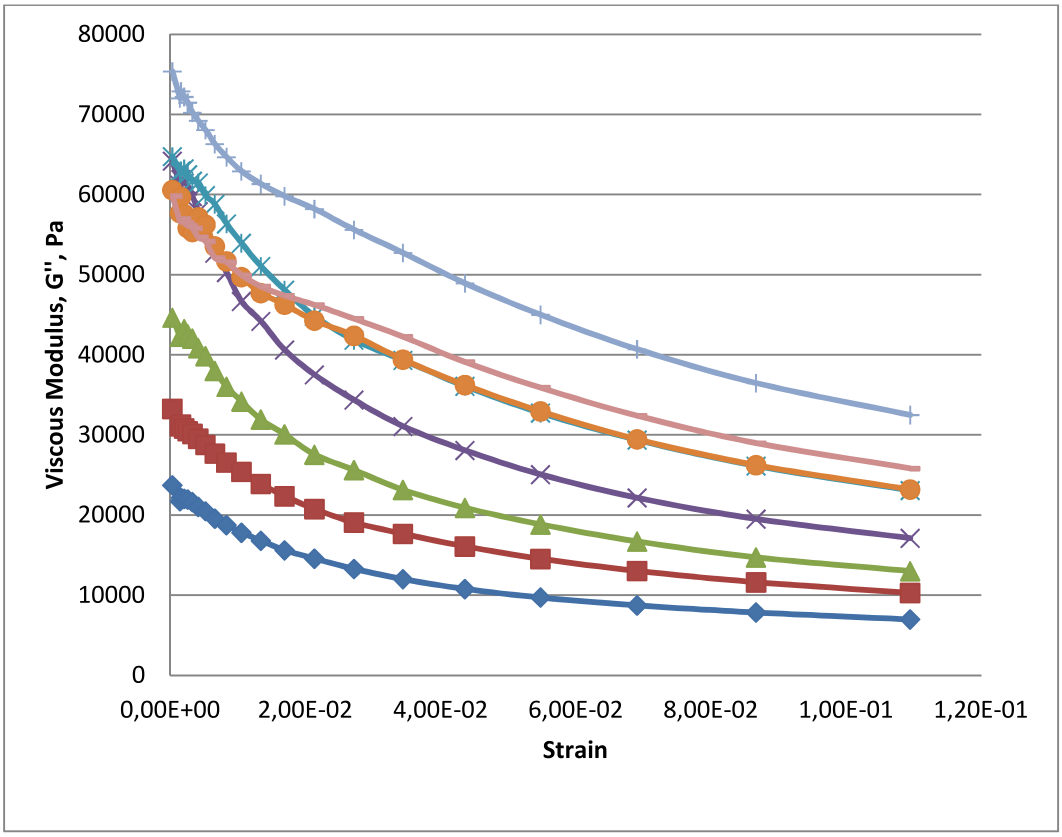

Figure 3. 14 Viscous modulus (Pa) versus strain of cracker dough of 70 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ж, 45 g coarse fiber gel; ●, 55 g coarse fiber gel; -, 65 g coarse fiber gel; +, 75 g coarse fiber gel)

3.1.3. Rheology of 60 g Flour Based Cracker Formulation

3.1.2.3 Rheology of 60 g Flour Based Cracker Formulation Produced by Coarse Fiber Gel

The oscillation tests results of 60 g flour based cracker formulation samples are shown in the following figures 3.15 and 3.16, it is again concluded that G' and G'' increases as frequency and wheat bran fiber content increase. In the figure 3.3 for the frequency value of 0.791 rad/s, G’ values is 39351 Pa while in the figure 3.15 for the same frequency value, G’ is 17730 which again indicates that flour content ,especially gluten, is mainly responsible for elasticity.

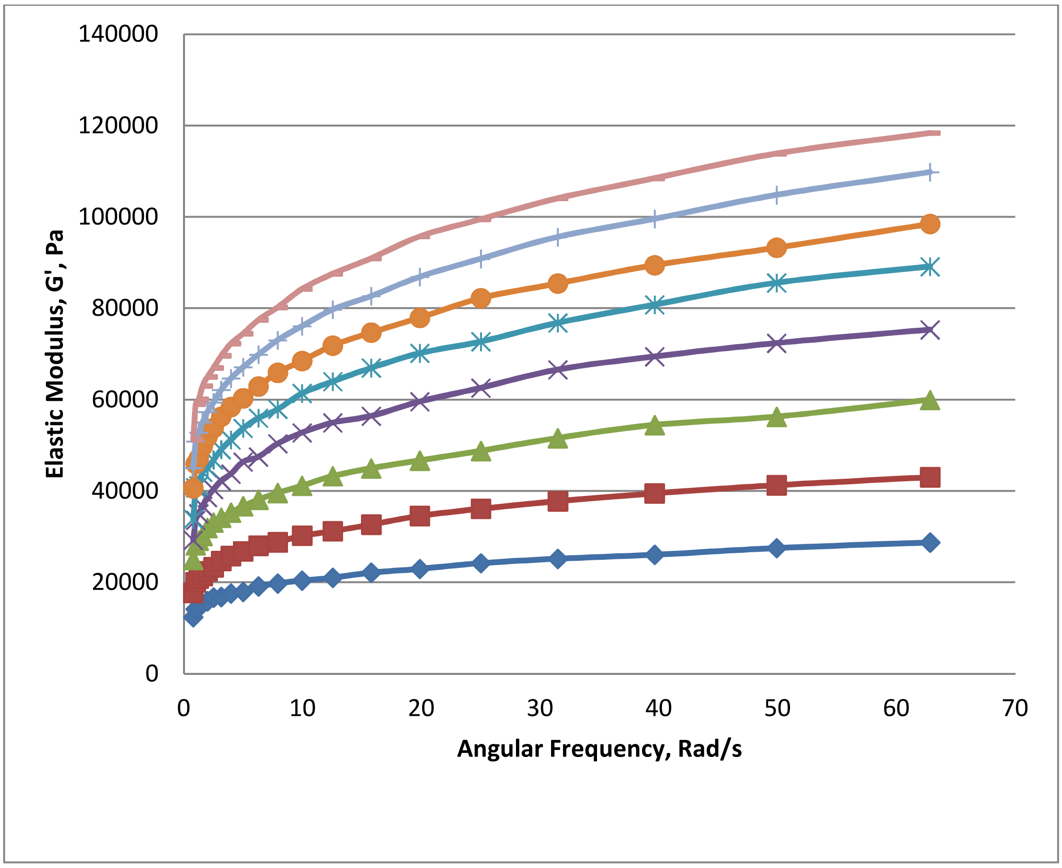

Figure 3. 15 Elastic modulus (Pa) versus strain of cracker dough of 60 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ж, 45 g coarse fiber gel; ●, 55 g coarse fiber gel; +, 65 g coarse fiber gel; -, 75 g coarse fiber gel)

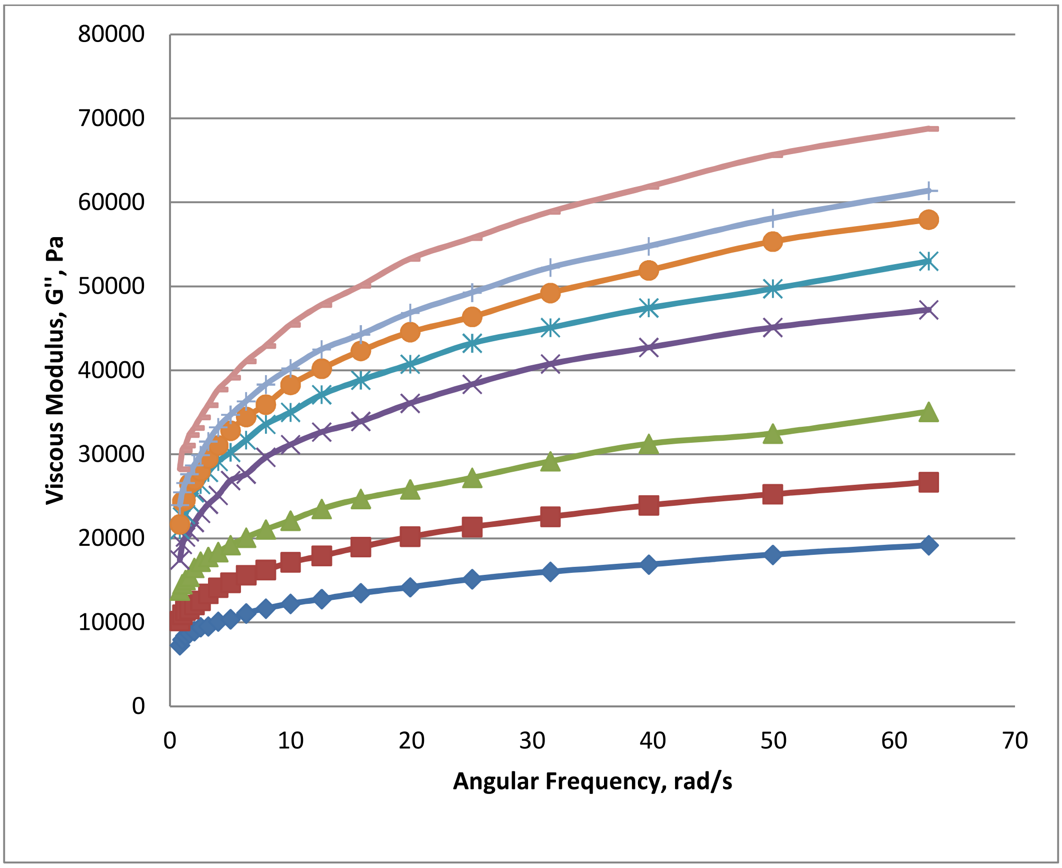

Figure 3. 16 Viscous modulus (Pa) versus angular frequency (rad/s) of cracker dough of 60 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; ж, 45 g coarse fiber gel; ●, 55 g coarse fiber gel; +, 65 g coarse fiber gel; -, 75 g coarse fiber gel)

In the figure 3.17, 60 g flour- 0 g fiber containing cracker dough has an elastic modulus approximately 40000 Pa, whereas, in the figure 3.9, 77,5 g flour-0 g fiber containing cracker dough has approximately 180000 Pa which is over four times higher than the other. It suggets that if the flour amount is decreased, more fiber should be added in order to increase the processability.

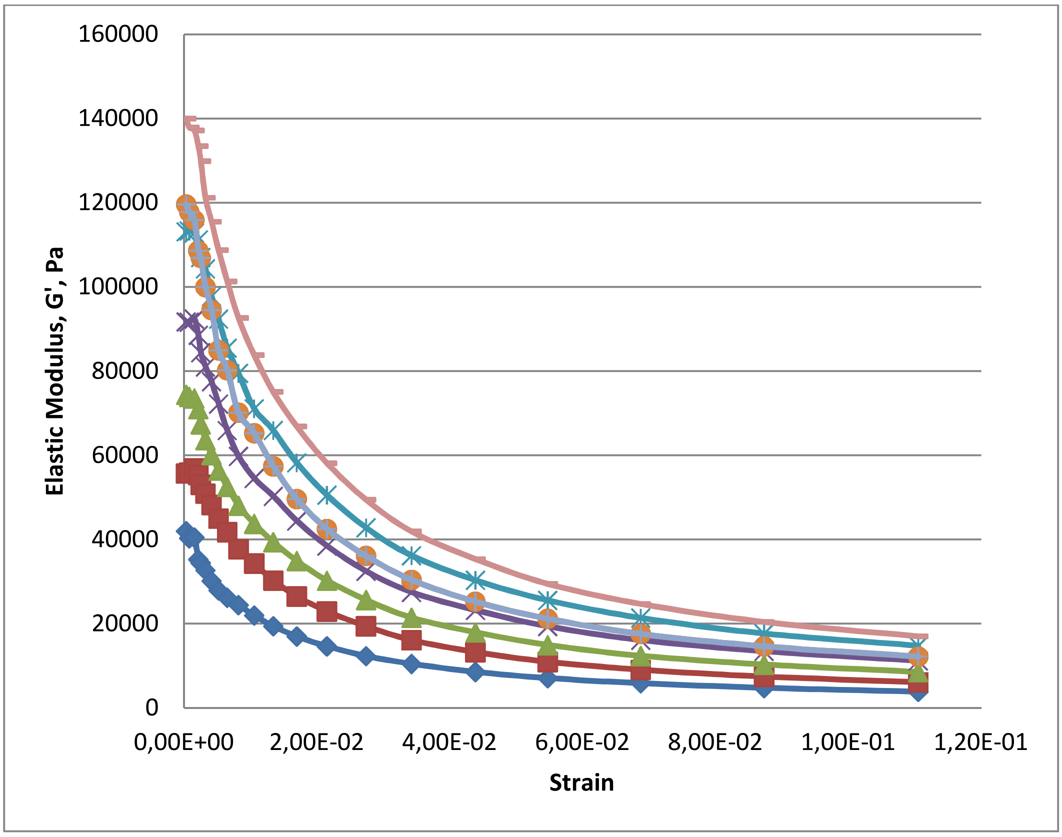

Figure 3. 17 Elastic modulus (Pa) versus strain of cracker dough of 60 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; ×, 35 g coarse fiber gel; +, 45 g coarse fiber gel; ●, 55 g coarse fiber gel; ж, 65 g coarse fiber gel; -, 75 g coarse fiber gel)

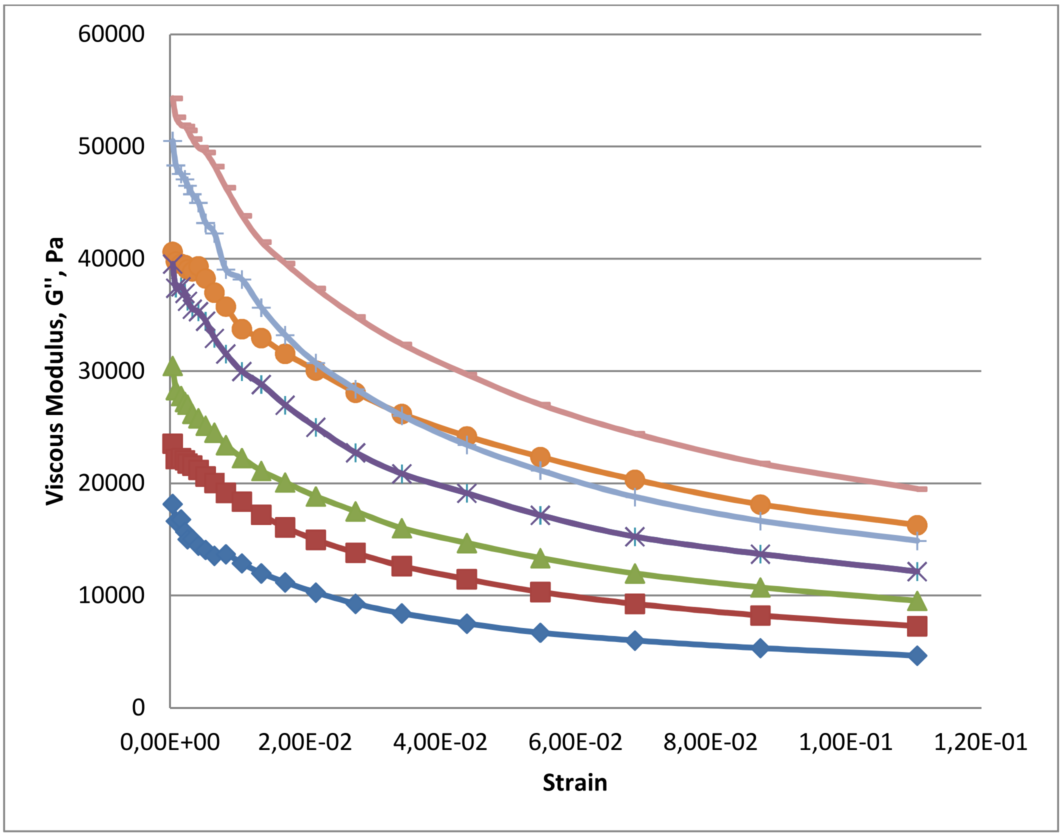

Figure 3. 18 Viscous modulus (Pa) versus strain of cracker dough of 60 g flour based formulation (♦, 0 g coarse fiber gel; ■, 15 g coarse fiber gel; ▲ 25 g coarse fiber gel; -, 35 g coarse fiber gel; ж, 45 g coarse fiber gel; ●, 55 g coarse fiber gel; +, 65 g coarse fiber gel; ×, 75 g coarse fiber gel)

3.1.3.2 Rheology of 60 g Flour Based Cracker Formulation Produced by Fine Fiber Gel

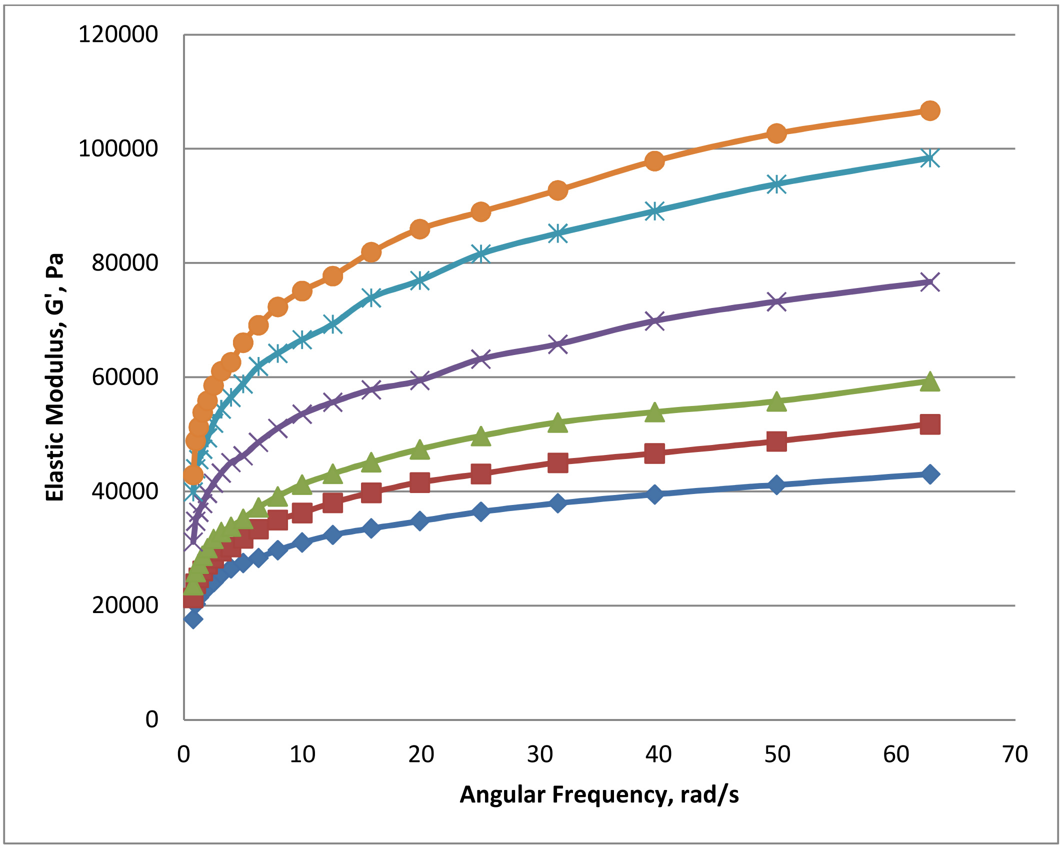

Figure 3. 19 Elastic modulus (Pa) versus angular frequency (rad/s) of cracker dough of 60 g flour based formulation (♦, 0 g fine fiber gel; ■, 15 g fine fiber gel; ▲ 25 g fine fiber gel; ×, 35 g fine fiber gel; ж, 45 g fine fiber gel; ●, 55 g fine fiber gel)

The rheological behaviour of fiber containing dough were similar regardless of flour amount or particle size of fiber. The only difference is the elastic modulus value, which is the lowest for 60 g flour containing formula in this range.

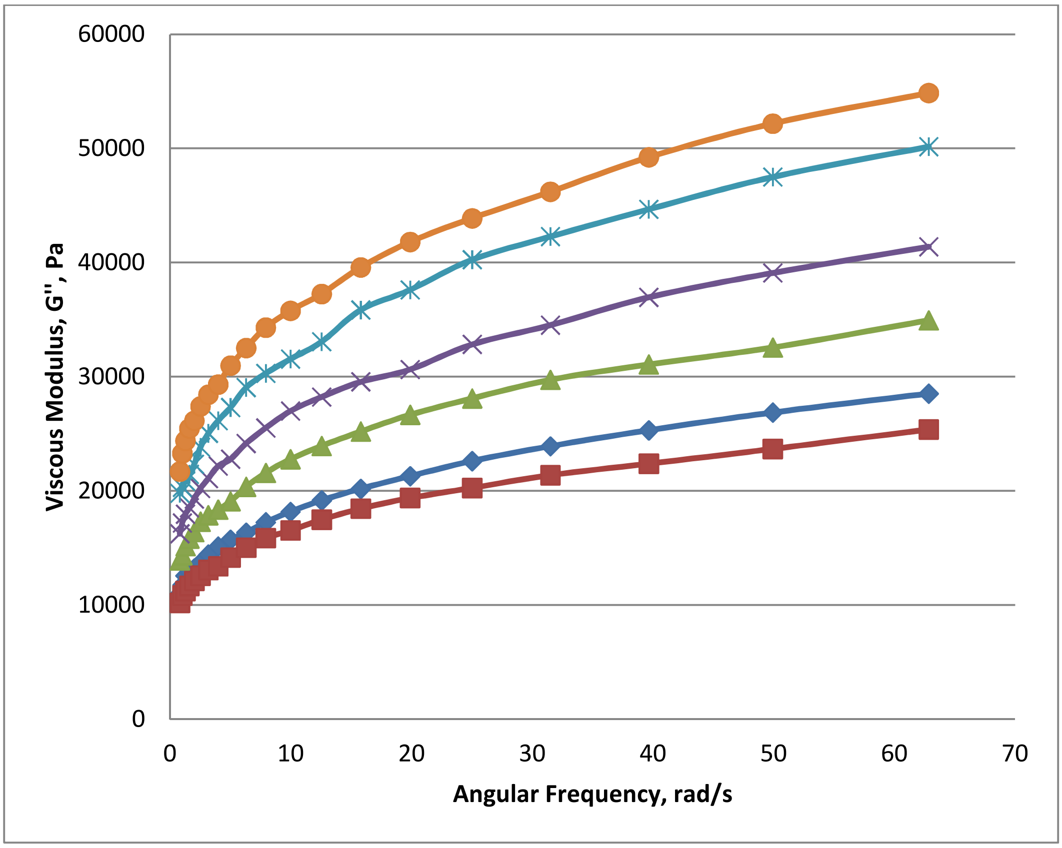

Figure 3. 20 Viscous modulus (Pa) versus angular frequency (rad/s) of cracker dough of 60 g flour based formulation (■, 0 g fine fiber gel; ♦, 15 g fine fiber gel; ▲ 25 g fine fiber gel; ×, 35 g fine fiber gel; ж, 45 g fine fiber gel; ●, 55 g fine fiber gel)

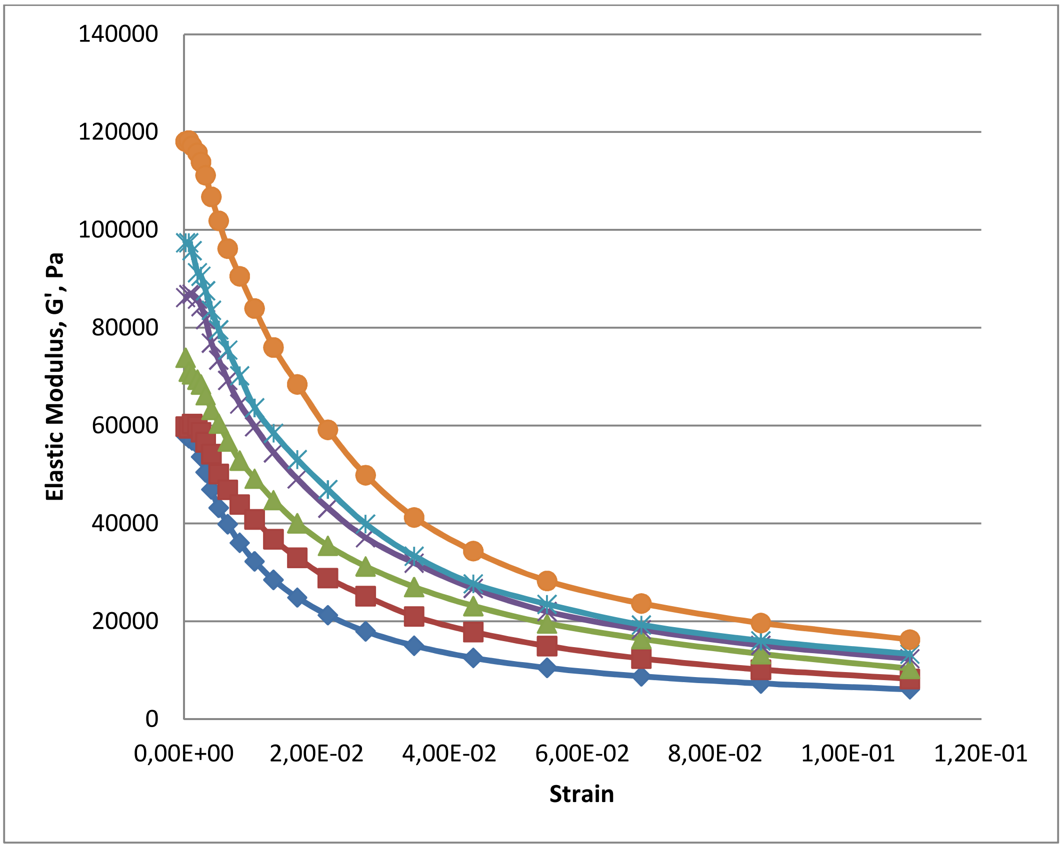

Figure 3. 21 Elastic modulus (Pa) versus strain of cracker dough of 60 g flour based formulation (♦, 0 g fine fiber gel; ■, 15 g fine fiber gel; ▲ 25 g fine fiber gel; ×, 35 g fine fiber gel; ж, 45 g fine fiber gel; ●, 55 g fine fiber gel)

Figure 3.21 and 3.22 demonstrates strain- sweep figures for 60 g flour containing fine fiber gel. In these graphs, fiber addition dependency on elastic and viscous modulus was the same with other samples. The processability could be improved by fiber addition and there was no significant difference between coarse and fine for 60 g flour. The reason could be flour amount which is more dominant than the fiber amount for this range. Therefore, if the fiber amount would increased more than 55g, it was expected to have more difference between coarse and fine values.

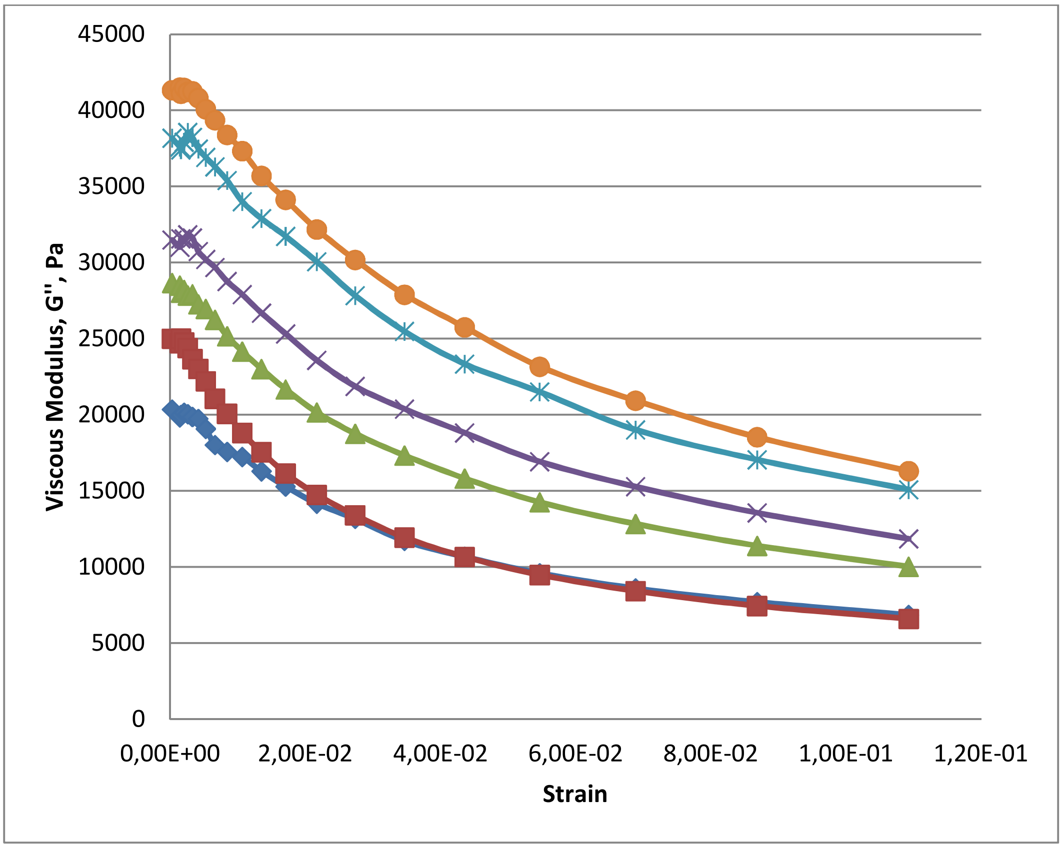

Figure 3. 22 Viscous modulus (Pa) versus strain of cracker dough of 60 g flour based formulation (♦, 0 g fine fiber gel; ■, 15 g fine fiber gel; ▲ 25 g fine fiber gel; ×, 35 g fine fiber gel; ж, 45 g fine fiber gel; ●, 55 g fine fiber gel)

3.2. Texture of Cracker

In figure 3.23 , cracker samples are shown in which coarse fiber gel was utilized in different amounts. Each row shows 77.5 g, 70 g and 60 g flour based crackers from top to bottom, respectively.

Sample numbers of a range differ also depending on moisture content. In other words, as dry content increased, dough formation was more difficult. This is why in the first row, wheat bran fiber could be added up to 45 g whereas, in others this number was 75 g and higher. Same reason holds for vice versa in which dough formation could not be occured in 60 g flour containing for first, second and third samples.

As it is explained in the figure 3.2 (see page 28), wheat bran fiber has higher water holding capacity than wheat bran. Therefore replacing wheat bran with wheat bran fiber provides to bake more fiber containing crackers.

While baking time was a significant paramater for getting more brownish colour, wheat bran fiber addition was also effective on this. In addition to that it was expected being more brownish for 60 gr flour based since more fiber was replaced with flour.

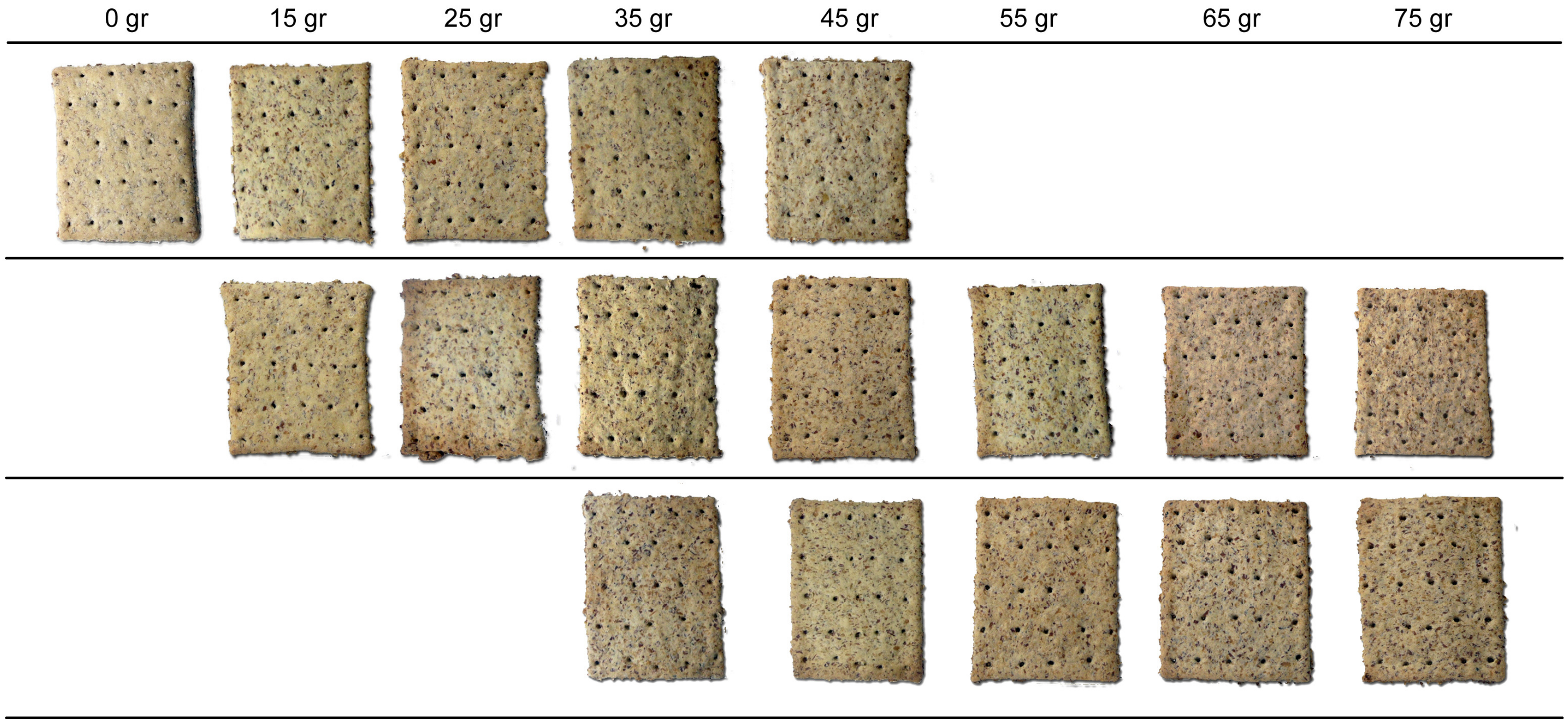

Figure 3. 23 Photographs of cracker samples in which 77.5 g(top), 70 g(middle), 60 g(bottom) coarse fiber gel utilized

Both dough and final product were measured by texture analyzer. The dough samples results are shown in the following figures 3.24, 3.25 and 3.26

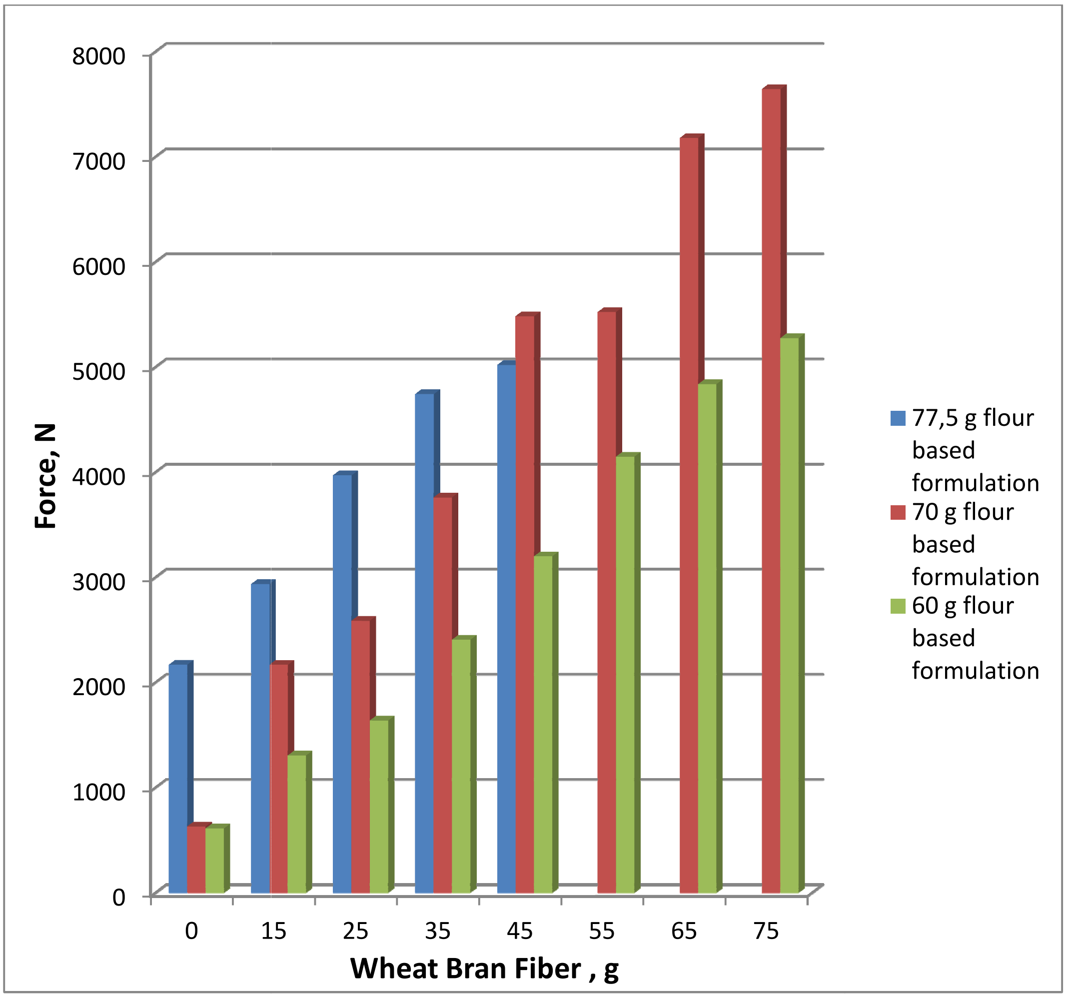

Figure 3. 24 Dough texture results of coarse fiber

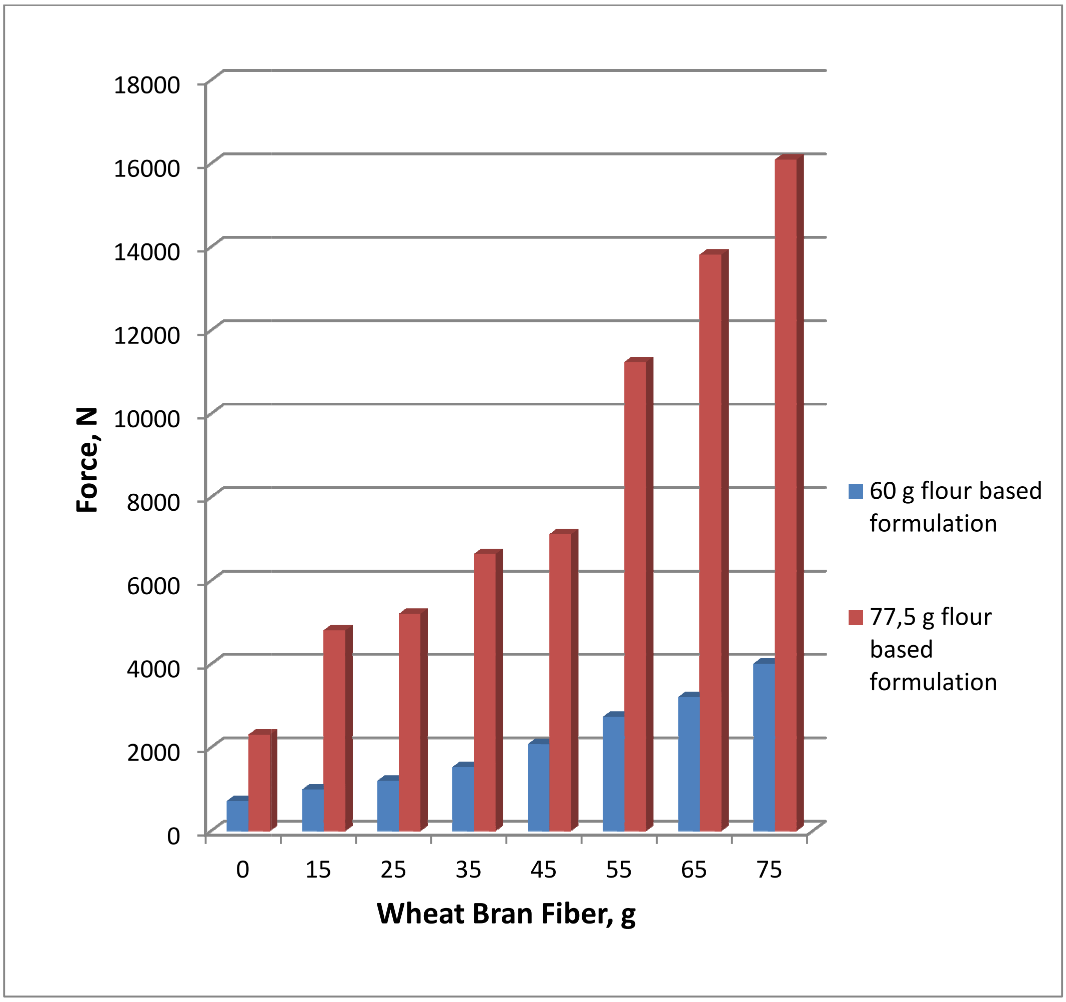

Figure 3. 25 Dough texture results for fine fiber

In the above figures 3.24 and 3.25, hardness of different dough samples containing different amounts of wheat bran fiber (0 g,15 g ,25 g ,35 g ,45 g ,55 g ,65 g ,75 g) is shown as a texture analysis results. From the figures it can be concluded for both coarse and fine wheat bran fiber that as the wheat bran fiber amount increased, hardness of the dough increased. In addition to that in the figures, it is clear that the required force for the dough samples differed significantly depending on a flour amount which demonstrated that flour dominated the textural properties of the cracker dough.

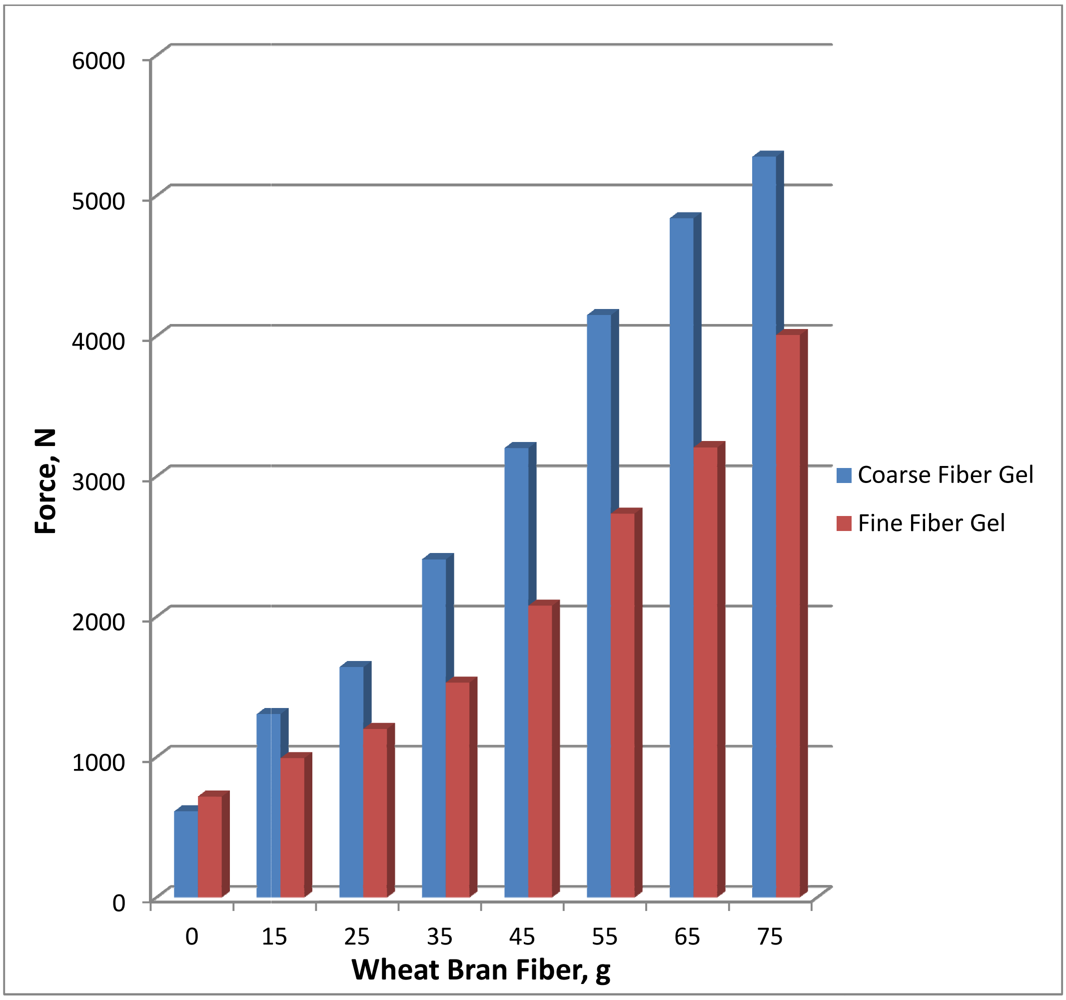

Figure 3. 26 Dough texture comparison of the formulations with coarse and fine wheat bran fiber

Figure 3.26 compares coarse and fine wheat bran fiber effects on dough texture. As it can be seen, differences between the force values of coarse and fine fiber gel became significant as the fiber gel amount increased and coarse one dominated textural property.

The following figure 3.27 shows the textural results of final product, crackers. In the figure there are some details that should be considered. The first point is that there is no whole range of eight crackers for every kind of samples. This is because of the correlation between wheat bran fiber and flour amount. For instance, in 77.5 g flour based formulation in which the flour amount was the highest, water holding capacity was lowest, therefore, no dough formation was seen after fifth sample. The second point is, although there is a direct relation with increase in fiber content and force required, there may be seen minor decreasing in the figure. The reason is that force value also depends on the moisture content of cracker.

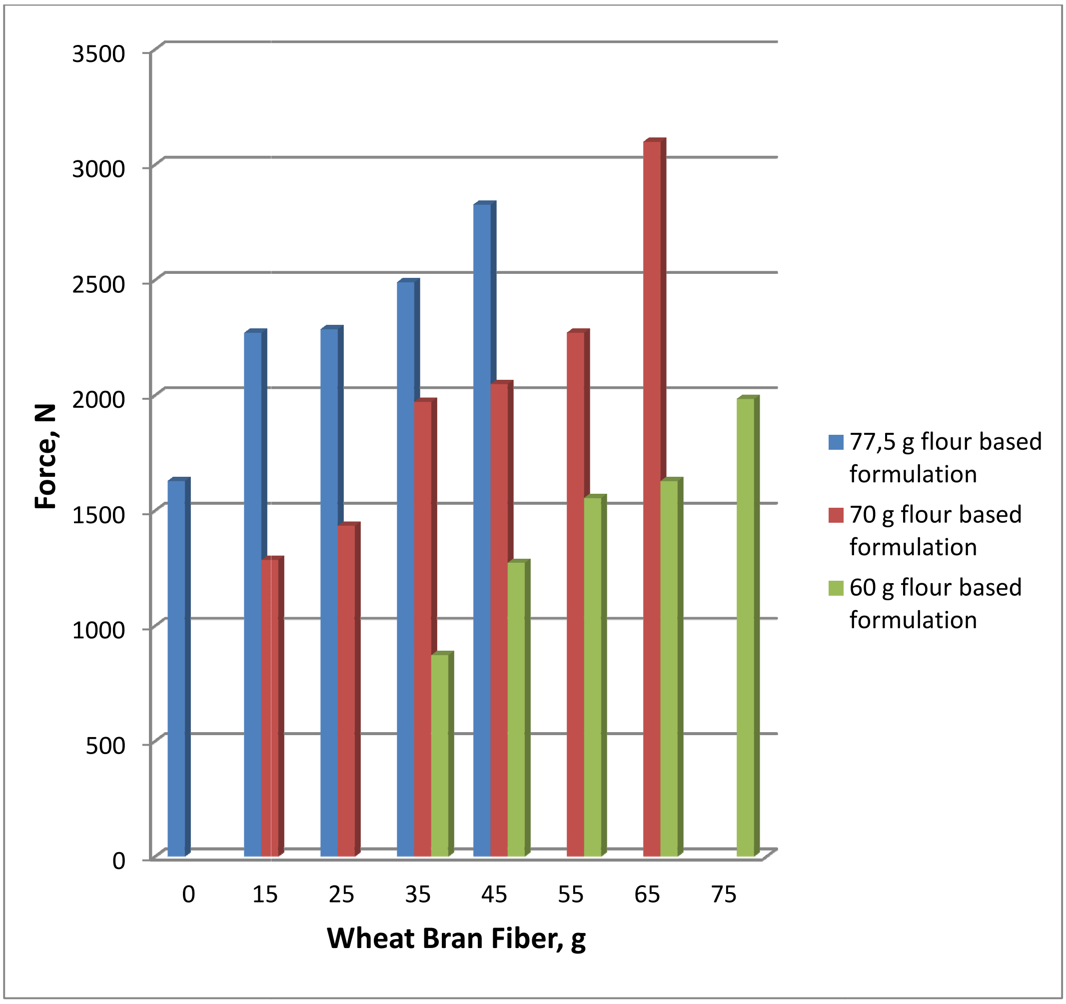

Figure 3. 27 Cracker texture results of different formulations

3.3. Ferulic Acid Analysis Results

Ferulic acid content was determined by HPLC analysis. HPLC chromatograms of wheat bran and wheat bran fiber are shown in figures 3.28 and 3.29, respectively. The peak of the pattern between 30-40 minutes demonstrates the ferulic acid which is shown with an arrow. As it can be seen from the chromatograms, ferulic acid content dramatically increased when wheat bran was converted to wheat bran fiber structure. This can be explained by surface area availability of wheat bran fiber.

In fig 3.30 the reason of the reduction of the peak as compared to figure 3.29, as it was mentioned in the introduction part, was the effect of heat process during baking, however it still remained in higher values which was desirable for this kind of cracker and which gave an opportunity to improve functionality of cracker.

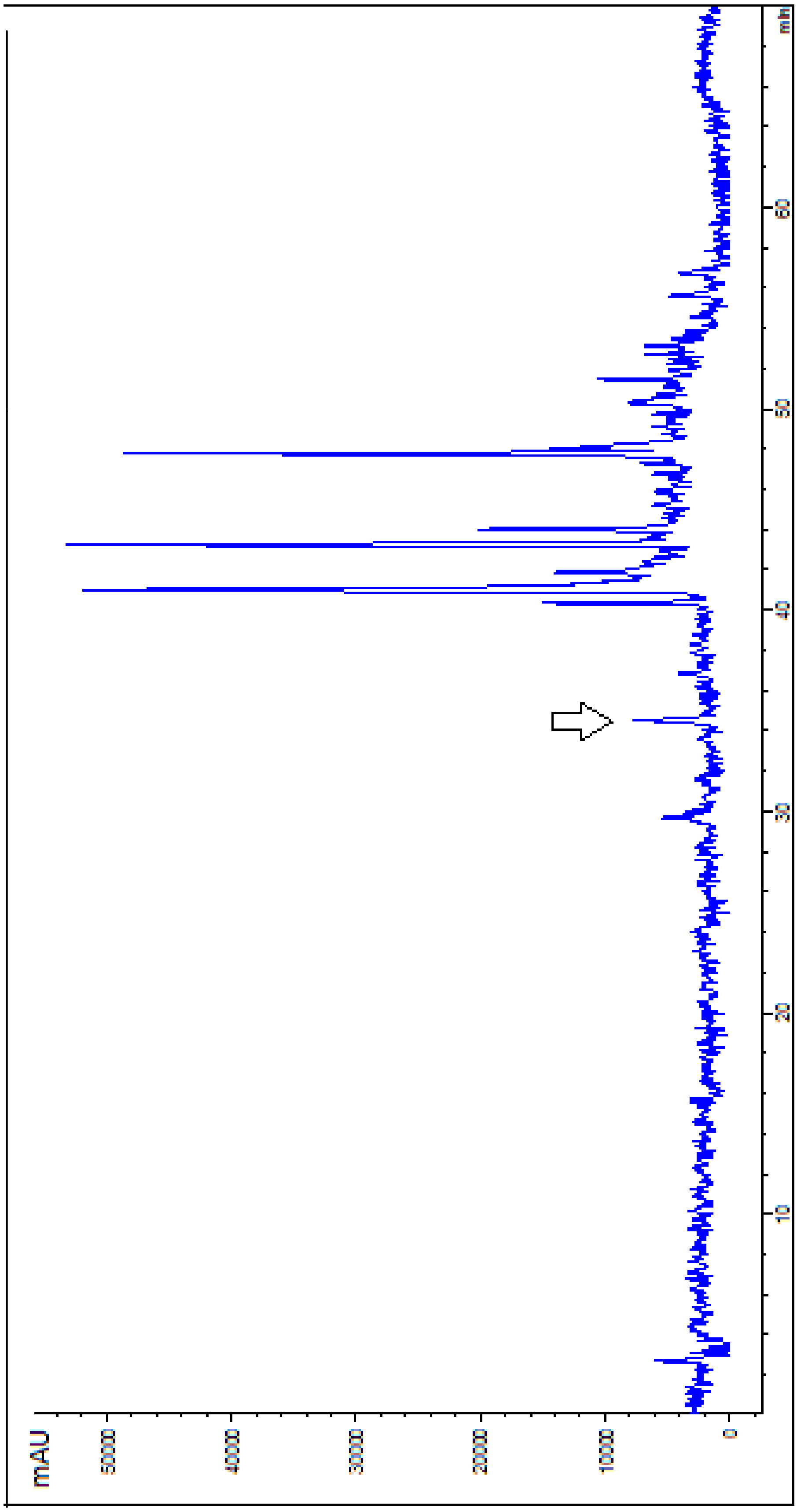

Figure 3. 28 HPLC Chromatogram of ferulic acid from wheat bran

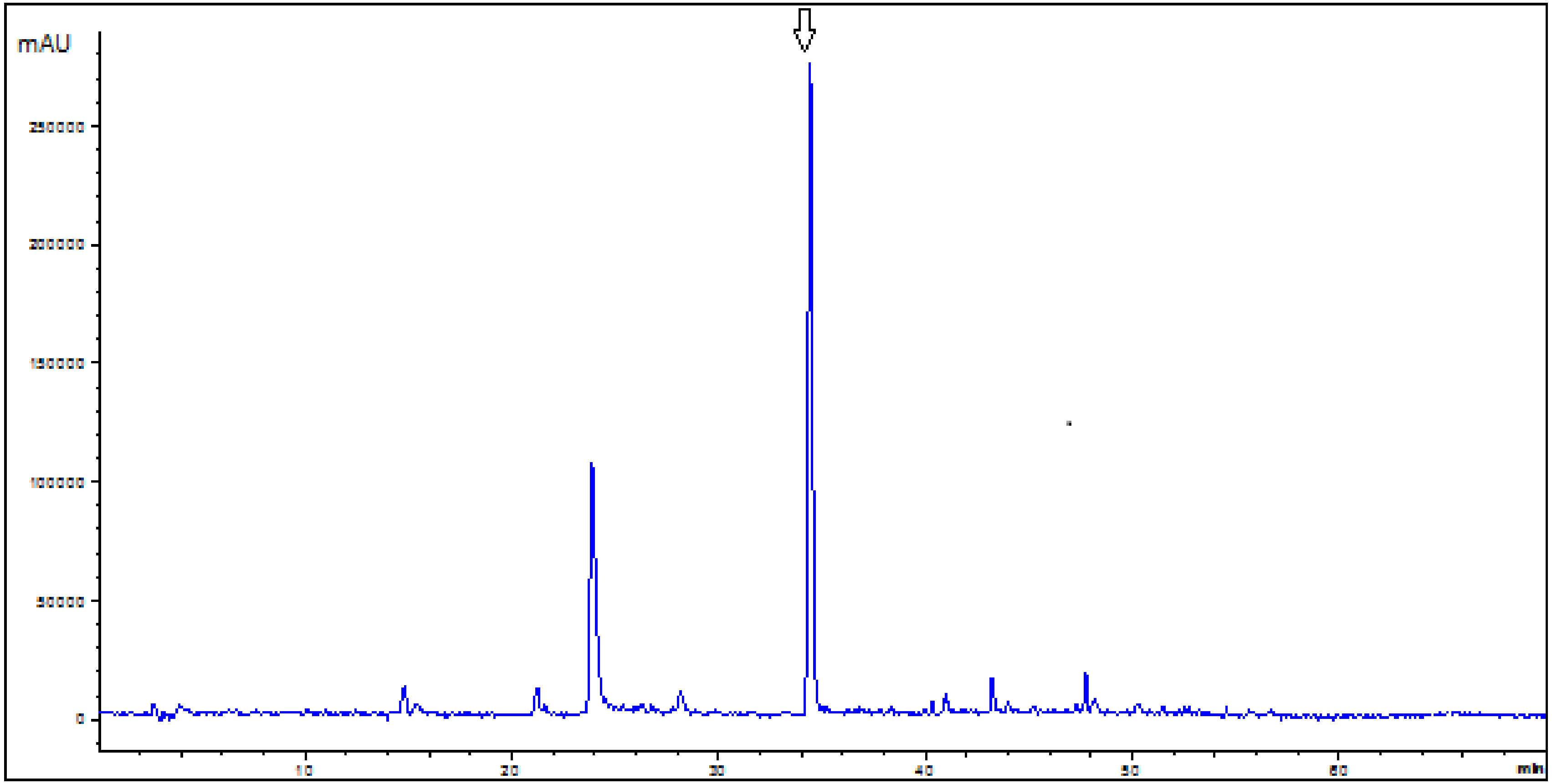

Figure 3. 29 Chromatogram of ferulic acid from wheat bran fiber

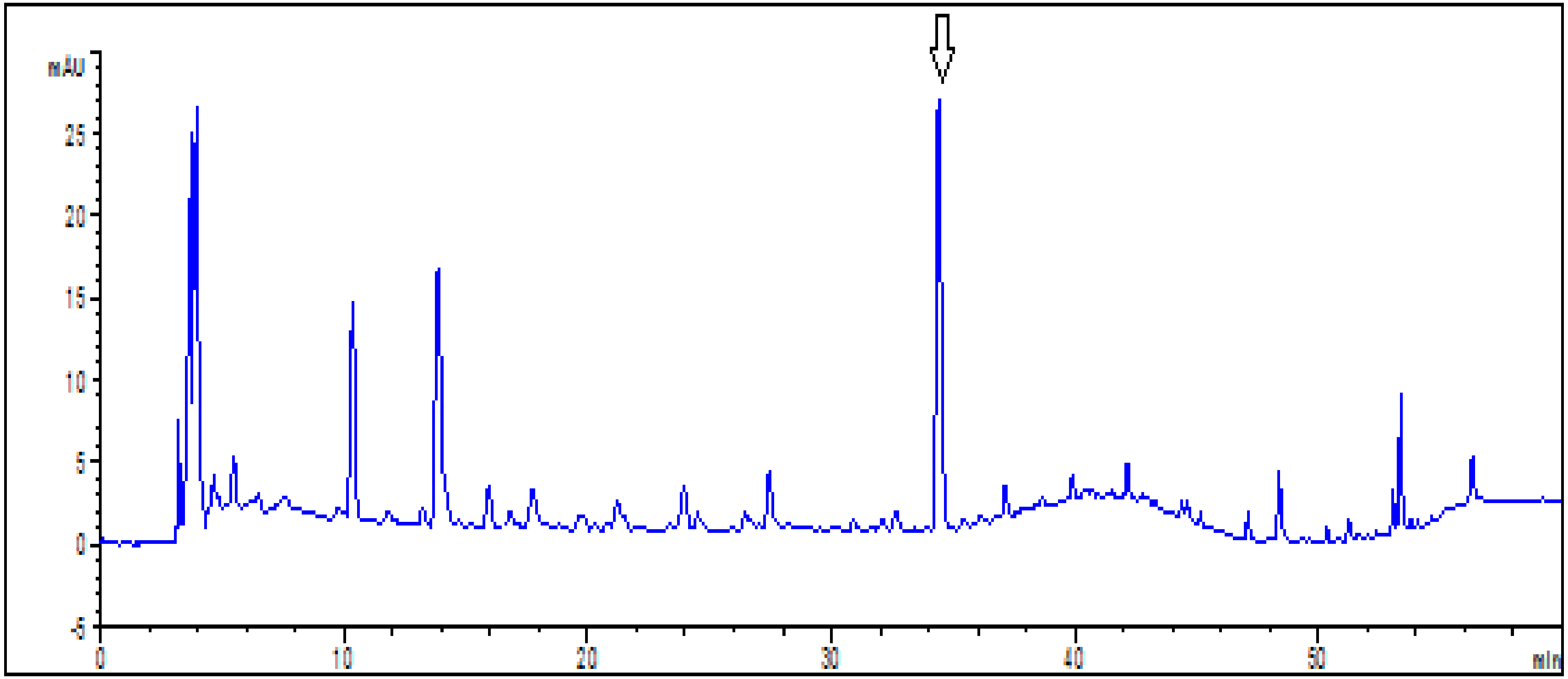

Figure 3. 30 Chromatogram of ferulic acid from wheat bran fiber containing cracker

Ferulic acid content is also measured in the range of coarse and fine fiber containing crackers. In fig 3.31, as it is expected, first columns are nearly the same since crackers contains the same amount of wheat bran. For second and third column fine fiber containing crackers have higher amount of ferulic than coarse ones. It can be explained by the same reason of having a higher ferulic acid of fiber than wheat bran. Both for coarse fiber containing and fine fiber containing cracker, ferulic acid content increases as fiber amount increases in the formulation.

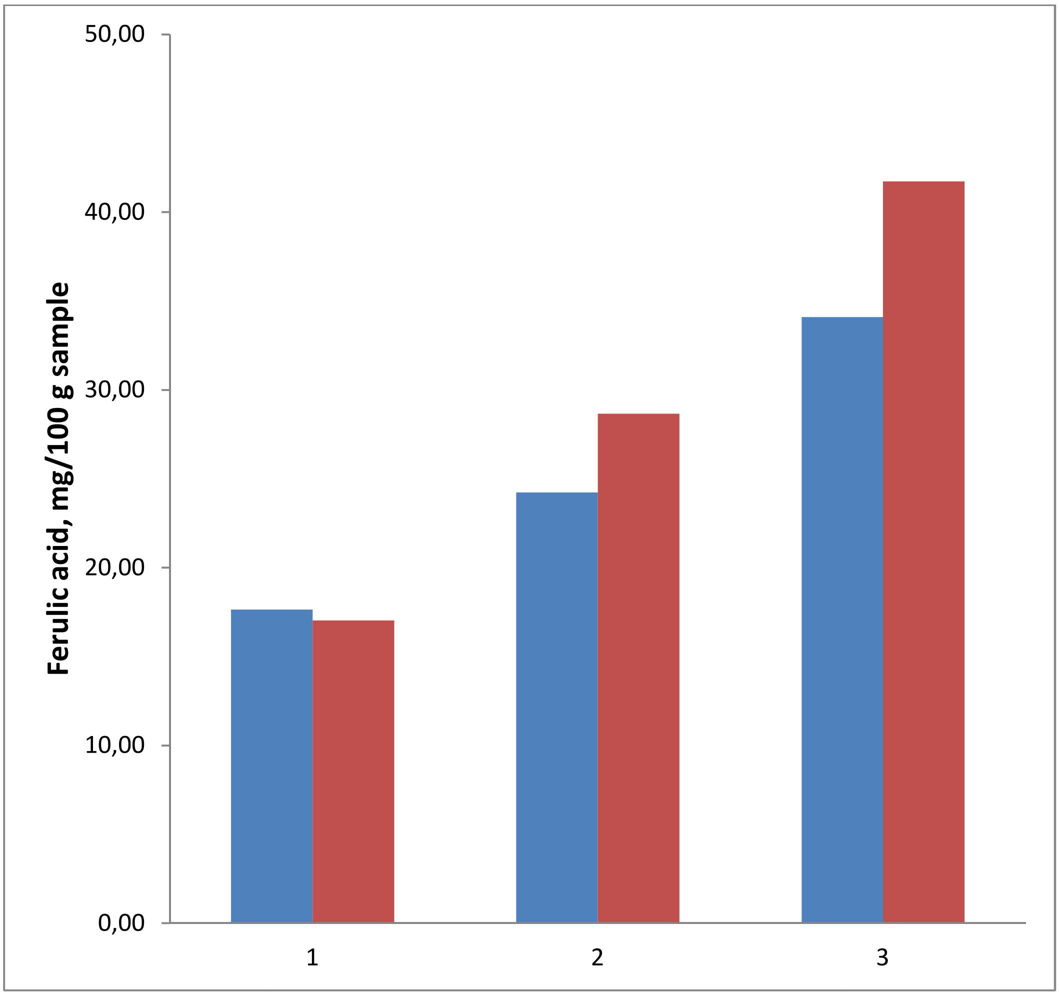

Figure 3. 31 Ferulic acid contents of cracker samples 0 g, 25 g, 45 g fiber containing, respectively ■ Coarse fiber containing crackers , ■ Fine fiber containing crackers

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

In this study it can be concluded that fiber addition to cracker dough affects the dough and final product quality. From the rheological perspective, elasticity increases as amount of wheat bran fiber usage increases. Having coarse and fine structure also differs the elasticity.

From texture analysis, it is clear that hardness of dough increases with replacing wheat bran with wheat bran fiber. Flour amount in the dough sample is significant for hardness value this is why as flour content decreases, hardness decreases; although it still shows the same behaviour for wheat bran fiber. The comparison of coarse and fine wheat bran fiber demonstrates that cracker with fine wheat bran fiber is harder than cracker with coarse one due to higher water absorption.

By HPLC analysis, ferulic acid concentration in wheat bran fiber and in fiber utilized cracker is found dramatically higher than the wheat bran and wheat bran utilized cracker. This also explains that as fiber content increases, ferulic acid concentration increases.

As a result of this study, since dietary fiber has outstanding beneficial effects on human health, more nutritive and healthier crackers can be produced without affecting quality parameters negatively. By using rheological and textural behaviour data, more flour can be replaced with wheat bran fiber which also reduces the calorie with especially starch intake. Therefore, more increment of fiber content can be done from current which is 15% (w/w) as a future work.

Phenolic content of fiber has also a positive contribution on nutritional excellence of cracker. As well as the ferulic acid concentration, the bioavailability of ferulic acid has a major importance on its effectiveness. Therefore bioavailability of ferulic acid in wheat bran fiber and fiber containing product may be studied as a future work.

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