PRODUCING MICRO AND NANO FIBERS HAVING HIGH WATER HOLDING CAPACITY FROM TOMATO AND WHEAT WASTE PRODUCTS AND USING THEM IN MODEL FOODS

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ABSTRACT

PRODUCING MICRO AND NANO FIBERS HAVING HIGH WATER HOLDING CAPACITY FROM TOMATO AND WHEAT WASTE PRODUCTS AND USING THEM IN MODEL FOODS

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The main objective of this study was to investigate the fibers and their effects and availability in ketchup (tomato fiber) and cake (wheat bran fiber) production.

In order to this, rheological properties of ketchups with tomato fiber, and cake (100, 80, 60 g flour formulations) with wheat bran fiber in different concentrations were investigated. Tomato powder in ketchup and wheat bran in cake was used for comparison. The samples studied had pseudoplastic behavior having a definite yield stress with a good fit for the Herschel-Bulkley model. The viscosity and yield stress values increased as the percentage of fiber increased. Moreover the samples were found to be more elastic than viscous (G'>G''). Both G' and G'' values increased with oscillatory frequency, percentage of fiber, and in cake samples decreased as the amount of flour decreased.

Stability measurements of ketchups studied were done by using Lumisizer. The microstructure of tomato powder, wheat bran and fibers were investigated under SEM. It was seen that the fibers had branched, long and thin structure while the other two had lumy and thick structure. The pressure used, resulted in this structure with increased surface area and finally increased water holding capacity in fibers.

Moreover, texture of cakes prepared was all investigated in terms of volume, outer surface, hardness, cohesiveness and gumminess.

Finally it was found to be possible to produce healthier ketchups and cakes with fiber in a good quality by decreasing the other undesired ingredients.

Keywords: Fiber, Tomato pulp, Wheat bran, Rheology, Texture

ÖZ

DOMATES POSA ATIKLARINDAN YÜKSEK SU TUTMA KAPASİTESİNE SAHİP MİKRO VE NANO LİFLERİNİN ÜRETİLMESİ VE MODEL GIDA ÜRÜNLERİNDE KULLANILMASI

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Bu çalışmada domates posası ve buğday kepeği kullanılarak mikro ve nano boyutlarda lifler üretilmiş ve model gıda olarak seçilen ketçap ve kek ürünlerinde kullanılmışlardır. Lif üretim tekniği olarak yeni teknoloji olan mikroakışkanlandırıcı seçilmiştir. Üretilen liflerin fonksiyonel özelliklerinin anlaşılması amacıyla ketçapta domates tozu, kekte ise buğday kepeği kullanılmıştır. Çalışılan örneklerin belirli bir akış gerilimlerinin olduğu ve Herschel-Bulkley modeline uyduğu belirlenmiştir. Viskozite ve akış gerilim değerleri lif yüzdesi arttıkça paralel olarak artmış ve örneklerin viskoz olmaktan çok elastik özelliklere sahip olduğu bulunmuştur (G’>G’’). Her iki G’ and G’’ değerleri artan salınım frekansıyla ve lif yüzdesiyle birlikte artmış, kek örneklerinde ise unun azalmasıyla birlikte azalmıştır. Lumisizer cihazı kullanılarak yapılan çalışmalarda ketçapın kararlılık ölçümleri yapılmıştır.

Domates tozu, buğday kepeği ve liflerin mikroyapıları taramalı elektron mikroskobu kullanılarak incelenmiştir. Liflerin dallı, uzun, ince yapıları varken toz ve kepek örneklerinin topaklı ve kalın bir yapısının olduğu gözlenmiştir. Liflerin üretiminde kullanılan yüksek basınç genişletilmiş yüzey alanı ve sonuçta artırılmış su tutma kapasitesiyle bu yapıya neden olmuştur.

Çalışma süresince hazırlanan kek örnekleri ise tekstür ve içyapı bakımından incelenmiş, kullanılan kepek liflerinin tekstür ve yapıya son derece olumlu etkileri olduğu gözlenmiştir.

Sonuç olarak daha sağlıklı ketçap ve keklerin, bazı istenmeyen hammaddeler azaltılarak kaliteli bir şekilde bu çalışma sırasında üretilen mikro ve nano lifler ile üretilebilineceği bulunmuştur.

Anahtar sözcükler: Lif, Domates posası, Buğday kepeği, Reoloji, Tekstür

To My Family

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DF	Dietary Fiber
G’	Elastic Modulus
G’’	Viscose Modulus
HPMC	Hydroxypropyl methylcellulose
HPP	High-pressure processing at ambient temperature
LBG	Locust bean gum
PME	Pectinmethylesterase
RDA	Recommended daily allowance
SEM	Scanning Electron Microscope
TPA	Texture Profile Analysis
n	Flow behavior index

CHAPTER 1

INTRODUCTION

1.1 Tomato

1.1.1 General Information

Tomato is one of the most widely grown fruit, originated from South America. For both the fresh fruit market and the processed food industries, its importance is high all over the world.

Tomato belongs to the *Solanaceae* family that includes potatoes, peppers, tobacco and many other plants (Uçkun, 2007). *Lycopersicon esculentum* (lycopersicon = wolf peach, esculentum = edible) is the species name that the tomato belongs but there is alternative names such as *Solanum lycopersicum*, or *Lycopersicon lycopersicum* (Silva et al.,2008). Different names are the result of the controversy about the genus of the tomato. The genus *Solanum* with the name of *Solanum Lycopersicon* is the first one that it placed, but then it was placed in the genus *lycopersicon* with the name *Lycopersicon esculentum* (http://www.growtomatoes.com). Moreover, *Lycopersicon lycopersicum* was derived as a combination of previous two names. Although there is close genetic similarity between tomato and potato (Silva et al., 2008), structures are different for two of them, so the tomato placed in different genus.

Wild-type tomato is believed to have originated in western South America, is native especially in Peru and the Galapagos Islands (http://www.growtomatoes.com/historical_background.htm), but being first domesticated in Mexico (Serrano et al., 2008). Spanish explorers introduced the tomato into Europe (Serrano et al., 2008) during the 16th century. At first times, instead of eating, people raised it because of its beautiful flowers (Serrano et al., 2008), except in Italy and Spain (http://www.growtomatoes.com/historical_background.htm). The fruit was thought to be poisonous. It became popular in Europe as an edible fruit from the 18th century (Serrano et al., 2008) as indicated by its presence in several recipes, and from Europe it was passed back into America in this century (http://www.growtomatoes.com/historical_background.htm). By the end of the 19th century, consumption and processing of the tomato were common all over Europe and North America. It was introduced from Europe to southern and eastern Asia, Africa and the Middle East.

Today tomato is one of the most important crops worldwide (Sahin and Ozdemir, 2004, Koocheki et al., 2009, Hernandez et al., 2008, Consonni et al., 2009, and Vercet et al., 2002). Popularity of tomato; has been increasing day by day because of its versatility of use (Silva et al., 2008) in a fresh or processed form (Marcotte et al., 2001, Consonni et al, 2009) and because of its high health and nutritional contributions to humans (Zhang et al., 2008). It is marketed as a processed product such as paste, ketchup (Sahin and Ozdemir, 2004; Koocheki et al., 2009; Vercet et al., 2002), juice, sauce, or in a canned, dried or frozen form. Both tomato and tomato products are rich sources of lycopene, vitamin C and A, calcium, iron, β-carotene, lutein, lectin, and a variety of phenolic compounds such as flavonoids and phenolic acids. They are rich in folates, potassium, fiber, and protein, but low in sodium, cholesterol and saturated fat (http://www.nutritiondata.com/facts/vegetables-and-vegetable products/2682/2).

1.1.2 Nutritional Value and Health Benefits of Tomato

Tomato cultivated and consumed in a large number of countries throughout the world. It is really a popular fruit all over the world. Tomato and tomato products are important not only because of the large amount consumed, but also because of their high health and nutritional contributions to humans.

Tomatoes are rich in food components necessary for the normal growth of human such as carotenoids (lycopene), vitamin C, vitamin E and dietary fiber (Alam et al., 2009). They are composed of 93–95 % water. The remaining constituents include 5–7 % inorganic compounds, organic acids (citric and malic), sugars (glucose, fructose, and sucrose), solids insoluble in alcohol (proteins, cellulose, pectin, polysaccharides), carotenoids and lipids (Silva et al., 2008).

Carotenoids are important to humans because of their nutraceutic property (Silva et al., 2008) and lycopene is major the carotenoid for tomato and tomato based products. It is responsible for the red colour of the fruit (Silva et al., 2008; Davis et al., 2003). It is found in a restricted number of vegetables, but the tomato is the main source of it (Silva et al., 2008). It constitues 80-90 % of the total carotenoid of tomato fruit (Zhang et al., 2008, Serrano et al., 2008, Inbaraj et al., 2008).

Lycopene is insoluble in water, but since it is hydrophilic it is soluble in alcolic substances and oil. Therefore it is absorbed in higher portions when consumed with, for example, olive oil (http://tomatoesweb.com). The level of it changes according to the different species of tomatoes, increasing as the redness is increased (http://tomatoesweb.com), varies as a function of time of harvest, geographic location and plant genotype (Silva et al., 2008). It is reported in the literature that the content of lycopene is usually higher in tomatoes which are processed than the content of raw ones since lycopene releases from the matrix as the tomato is processed and becomes more accessible for extraction (Benner et al., 2007), resulting in increased bioavailability of lycopene (Benner et al., 2007; Davis et al., 2003). This results with the improved sensory properties; redder colour, and improved health benefits (Benner et al., 2007). It is the reason why the ketchups are better source of lycopene than raw tomatoes which is uncooked (http://tomatoesweb.com).

Antioxidants are substances with lots of health benefits such as lowering the aging and reducing some types of cancers by lowering the DNA damage. Lycopene is currently the most potent carotenoid singlet oxygen antioxidant known; the antioxidant power of it is nearly a hundred times higher than the power of Vitamin E which is really a powerful antioxidant soluble in fat. According to the studies done, lycopene has an important place in reducing the diseases such as some types of cancers (http://tomatoesweb.com, Zhang et al., 2008), cardiovascular disease (http://tomatoesweb.com, Inbaraj et al., 2008), diabetes, osteoporosis, and male infertility (http://tomatoesweb.com).

The β-carotene pigment is responsible for the yellowish color (Silva et al., 2008) and represents 5-10 % (Serrano et al., 2008) of the total carotenoid content of the tomato fruit. The content of β-carotene determines the activity of vitamin A (Charanjit et al., 2008), which has been cited as important in the prevention of coronary diseases and cancer. The concentration of β-carotene varies considerably among species, cultivators or lineages (Silva et al., 2008). Other carotenoids in tomato constitute small amounts of phytone, phytofluene, α-carotene, γ-carotene, neurosporene, and lutein (Charanjit et al., 2008).

Besides vitamin A, the most important vitamins in the constitution of the tomato fruit are vitamin B_1 (thiamine), B_2 (riboflavin), B_3 (pantothenic acid), B_6, niacin, folic acid, biotin, C (ascorbic acid) and E (α-tocopherol) (Silva et al., 2008).

Several studies have reported the importance of vitamin C and A in the human diet, cited mainly for its antioxidant activity (Silva et al., 2008, http://tomatoesweb.com). The studies have shown that both Vitamin A and C reduce the risk of cancers, reduce the risk factors for diabetes and atherosclerosis, increase DNA mutation rates and save DNA cell from damage (http://tomatoesweb.com).

In addition to all above-mentioned constituents of tomato, it can also be said that tomato is rich in dietary fiber providing so it is effective in reducing “bad" cholesterol levels, some types of cancer and regulating levels of blood sugar (http://tomatoesweb.com).

Moreover, tomato is a rich source of potassium (Silva et al., 2008). Potassium is important in the control of the osmotic pressure of the blood, kidney function and control of heart muscle concentrations (Silva et al., 2008).

Tomatoes have also been associated with low content of calories, fats and sodium. The calorie content of tomato is only 20 calories in 100g and this is easily absorbed by the body making the tomato favorable for the obese people. Since it is rich in most of the essential minerals and vitamins, and fills the stomach without adding calories to the body, it is recommended by experts in weight loss programs.

1.1.3 World Tomato Production

Tomato is the second most important vegetable crop next to potato (Moreno et al., 2008). In the late 1880s, tomatoes were grown in 171 countries (Serrano et al., 2008). According to the 2006 data (from FAOSTAT and EUROSTAT), the total production of tomatoes worldwide was over 123 million metric tons with the main producers being China, the United States and Turkey. In Europe, the total production was more than 17 million tons. The most important producer countries are those within the Mediterranean Sea: Italy, followed by Spain and Greece (11%) (Serrano et al., 2008). In 2007, 33.6 million tons of tomato are produced in China; 14.2 in United States of America; 9.9 in Turkey; 8.6 in India; 7.6 in Egypt; and 6 million tons in Italy (FAOSTAT, 2009). In 2008, 125 million tons of tomatoes were produced in the world (http://en.wikipedia.org/wiki/Tomato).

1.1.3.1 Tomato Industry in China

China is the largest producer of tomato with accounting for about one quarter of the global output (http://en.wikipedia.org/wiki/Tomato). The majority of China's tomatoes for processing are used for paste. China does not stay stable by continuing the increase of the production of tomato, tomato process capacity and as a results tomato export. As an example for this large capacity the forecast done for 2009 tomato production can be given as it was 39.5 million tons (Anonymous, 2009).

1.1.3.2 Tomato Industry in U.S.A.

Tomatoes are the America's most important commercial vegetable, both in yearly weight consumed (Souza et al., 2008; Moreno et al., 2008) and annual yield (Moreno et al., 2008), aside from the potato. Tomatoes are the most widely used canned vegetables in the United States. California produces 90 % of the U.S. supply of processing tomatoes and 35 % of the world's supply (http://en.wikipedia.org/wiki/Tomato).

1.1.3.3 Tomato Industry in Turkey

Since ecological and geographical conditions are suitable, it is widely grown in Turkey throughout the year in big quantities (Sarısaclı, 2009). Its production continues to increase. Greenhouse production is often used in winter months for fresh consumption (Sarısaclı, 2009). Tomatoes are exported both as fresh and processed forms such as dried, frozen, and as tomato paste, ketchup, tomato can, tomato juice and sauce from Turkey (Uckun, 2007). Turkey mainly exports to Eastern Europe and Russia. When the total exportation data of tomatoes in the first 5 months of 2009 are compared with the same period of the year before, it is realized that the total export raised up to 20% and reached 335,000 tons (Anonymous, 2009).

Tomato processing has an important place in food industry. Each year nearly 3 million tons of overall production is processed afterwards (Sarısaclı, 2009). There are more than 60 types of tomato varieties that are suitable for the processing (Sarısaclı, 2009).

The dominant traditional processing line in Turkey is tomato paste, with the production capacity of over 650 000 tons / year (Sarısaclı, 2009). In the tomato paste production Republic of China ranks first and then USA and Italy comes and in the fourth place Turkey follows (Sarısaclı, 2009).

In Turkey there is over 70 plants processing tomato, most of which located in Bursa and Marmara region. Tomato paste is one of the most important products among processed fruits and vegetables exports that are exported. Turkey has an important place in the world in terms of tomato paste exportation; it is in the third place in the world trade of tomato paste (105 thousand tons in 2008) following Republic of China and Italy. In the year 2008 Turkish tomato paste export reached the highest value 150 578 367 $. Turkish exports the tomato paste all over the world; Iraq, Saudi Arabia, Russian Federation, Japan, Sudan, Oman, Georgia, Algeria, Germany and Kuwait are the principal markets for Turkish tomato paste. Every year the number of the countries continues to increase which shows how the tomato paste of Turkey has a good quality (Sarısaclı, 2009).

In addition to the tomato paste, canned whole tomatoes (peeled, diced and etc.) exportation also has an important place in Turkey. Their exports were 9 thousand tons in 1991 and rose to its highest level in 2007 to 24 thousand tons and reached the highest export value 22.854.63 $ in 2008 (Sarısaclı, 2009).

1.1.4 Industrial Tomato Products

Tomatoes are important for worldwide agriculture, in terms of production and economic value, and tomato production is among the more industrialized in the world. The tomatoes that are produced mostly consumed in the processed form (more than 80 %) such as paste, juice, puree, sauces (Souza et al., 2008, Moreno et al., 2008), ketchup, and soups (Moreno et al., 2008).

Tomato processing is an important industry as the fresh tomatoes are processed to concentrate for use as juice, puree, paste, pizza sauce, ketchup, and the like (Al-Wandowi et al., 1985). Because of the economic impact, tomato concentrates have been the subject of many rheological studies (Al-Wandowi et al., 1985).

1.1.4.1 Tomato Paste

Tomato paste is among the most important product for the processed tomatoes. Every year really a large percentage of the tomatoes produced are used for the tomato paste production. Tomato paste is subsequently used as an ingredient in many food products such as soups, sauces (Smith, 2009; Valencia et al., 2004) and ketchup (Valencia et al., 2004; Bayod et al., 2007).

Tomato paste is a tomato product that is produced as the tomato pulp is concentrated after the skins and seeds are removed. It contains not less than 24% (w/w) natural tomato soluble solids (Moreno et al., 2008; Valencia et al., 2004; Smith, 2009; Bayod et al., 2007).

Tomato paste is produced from the concentration of ripened and healthy fruit pulp through an adequate technological process, with the addition of 1 to 3 % of sodium chloride. It is low in calories and total fat. It is also referred to as “tomato mass” or “tomato concentrate”. It is a product, easily found in any supermarket, used all over the world in sauces, pastas, lasagnas, pizzas or other dishes (Souza et al., 2008). It is usually canned to avoid the addition of preservatives and therefore a natural and safe product (Souza et al., 2008).

1.1.4.2 Tomato Ketchup

Tomato ketchup is a tomato product that is produced from hot (sometimes cold) extracted tomatoes or directly from tomato pastes, purees and concentrates (Sahin and Ozdemir, 2004; Koocheki et al., 2009). It is spiced and heterogeneous product and contains at least 12 percent tomato solids (Sharoba et al., 2005).

The consumption of tomato ketchup is high among the other tomato products. A large percentage of the tomatoes processed are used in the tomato ketchup production. There are lots of tomato products in the market, some are traditional such as tomato paste, some are new products such as tomato juices and among the all, and the tomato ketchup have a really high share in the market.

Zonis (2007) described the manufacture of tomato ketchup as follows;
The selection of tomatoes superior in color and flavor is the beginning of the process. After the harvesting process then the grading, sorting, washing and chopping of the tomatoes comes (Benner et al., 2007). Scaling process; precooking tomatoes in stainless steel vats, is the following process. After these processes tomatoes become preserved and eliminated from the bacteria. Cyclones separate stems, skins or any seeds from the precooked tomato pulp. Then the screen filtering of the pulp is done. Heating process begins after the pulp that is filtered is pumped into the cooking vessels. There it is heated to boiling. This cooking process takes between 30-45 minutes. During cooking any ingredients that constitute the ketchup such as spices, sweeteners, salt, vinegar or any other flavorings are added. The time of adding varies according to the form of ingredients; for example if the ingredient is volatile such as spice oils, it is added later. During cooking process the mixing process also continues with the help of mechanical stirring blades. The temperature during this heating process is important for the taste of the final product; it should be not too high to prevent the final product from overcooked taste. After the cooking process has finished, again the filtering is done in order to have a smoother consistency. Since the excess air in the product can result in the darkening of the final product or it can result in bacteria development in the product, it is removed from the ketchup. Then at the temperature of at least 190°F, the filling process is done by the help of filling machines. After the bottling and sealing of the containers is finished, they are cooled to prevent the product being overcooked (stack burning condition).

Benner et al., (2007) described the ketchup manufacturing as follows;
After harvesting tomatoes they go to paste factories and there the washing and sorting process follows. The red and the ripe ones are selected for the processes. Tomatoes are sliced if needed depending on the process plant. Then the hot break treatment for 1 min at temperature in the interval of 90–95 ˚C is done. By this process a paste required for the ketchup is obtained. It results with a high viscosity paste as a result of the enzyme inactivation during the hot break process. Next the screening process comes in which seeds and peels are separated from the tomato pulp and the juice is squeezed. Then the concentration comes with the help of evaporator. After the concentration of the paste, packaging of it in aseptic bags and transportation to the production sites where the other ingredients are added into the paste come. Then heating and de-aerating of the mixture of paste is occurred and finally the ketchup production ends with filling and packing of the mixture.

On the other hand Mccarthy et al., (2008) described the manufacture of tomato by directly using tomato paste instead of beginning from the raw tomatoes. Tomato paste which have °Brix in the range of 23-33 is the beginning constituent of the ketchup. Water is added to the tomato paste in order to dilute it, and adjust the soluble solid level. It is adjusted to the level of 16–19 °Brix. Then the cooking process is occurred at 200°F (93°C). The other ingredients (such as salt, vinegar, sugar, spices) are added again during this process. Finally the bottling of the product is achieved.

1.1.4.3 Canned Tomato

Canned tomatoes are tomatoes that are sealed into a can after having been processed by heat. Tomatoes with a more firm outer peel and pectin layer are used for processing (Wikipedia). Nearly 156 kg of canned tomato are produced from 100kg of fresh tomato (http://www.dalama.bel.tr/sayfa.asp?idx=47).

Canned tomatoes are available in several different forms; they are usually peeled, but can also be canned without peeling, they can be in a whole or in a diced form. Moreover they can be packed in juice or purée (http://www.dalama.bel.tr/sayfa.asp?idx=47).

1.1.4.4 Tomato Juice

Tomato juice is the juice obtained from the tomatoes which are crushed and then subjected to skin and seed removing process (Moreno et al., 2008). The heating process is important for the juice industry for safely consumption so the pasteurization or sterilization is applied before the whole process is ended. Salt is the only ingredient used in the tomato juice production, the content of the salt should not be more than % 1.5 (http://www.dalama.bel.tr/sayfa.asp?idx=47).

1.1.4.5 Tomato Puree

Tomato puree is a product which is in between the tomato juice and tomato ketchup in terms of properties. The consistency of is higher than the tomato juice while it is lower than the ketchup’s. It is really useful in kitchen since tomato juice and tomato ketchup can be instantly prepared by adding water and by mixing spices to it.

1.1.4.6 Frozen Tomato

Tomato skin is generally peeled and chopped (or in a whole form) and then put in containers. Following this process, precooking is done before quick freezing. Nearly 92kg of frozen tomato is obtained from 100 kg of tomatoes (http://www.dalama.bel.tr/sayfa.asp?idx=47).

1.1.4.7 Dried Tomato

The interest to the dried tomato is increasing day by day since it has a various usage place such as snacks, pizza toppings, and other savoury dishes (Camargo et al., 2004). However at the same time the process of drying is not wanted to be used as it has unfavorable effects on the final product quality. It is not an efficient process in a product with high water moisture content. Therefore it is not very suitable process for the tomato which has the moisture content of 93–95%. 18–22 % moisture content is needed for complete-drying, and 25-35 % is needed for partial drying.

The drying process is achieved after the tomatoes are cut, by leaving them under sun or using the drying by convection. However alternative treatments such as osmotic dehydration, spray drying, antioxidant application and the addition of tomato concentrate are used (Camargo et al., 2004).

1.1.5 Rheology of Tomato Ketchup

The rheological knowledge about fluid and semisolid foodstuffs is crucial to understand and design the flow processes in quality control, in stability measurements and in storage and also to understand and design the texture (Sahin and Ozdemir, 2004; Koocheki et al., 2009). It is important from both engineering and consumer viewpoints. Food processing equipments such as pipes, filters, pumps, evaporators, mixers, heat exchangers and sterilizers can only be designed and optimized with accurate and reliable rheological information (Koocheki et al., 2009).

Moreover the rheology is important since it is also necessary to ensure the product acceptability because the consistency is a crucial property for a product to be sold (Sahin and Ozdemir, 2004). The products with improper rheological properties for example with unsuitable consistency will be sold at a lower price or will not even be sold.

There are lots of studies done up to now about the rheological properties and behavior of tomato products. All these studies conducted showed that there is not a one factor affecting the rheology. All the properties about the raw material such as variety and maturity (agronomic parameters) affect the viscosity of tomato products. Moreover compositional parameters such as acidity, pectic content and soluble solids and processing parameters such as heating and screening are the important parameters that have a role in the viscosity; in the rheology of the tomato products (Bayod et al., 2008, Bayod et al., 2007).

Tomato products shows shear thinning behaviour with a yield stress. There are different models that can be used to define the rheological properties of tomato products (Smith, 2009; Bayod et al., 2007) under steady shear; for example, the power law equation or, when a yield stress is accounted for, the Bingham plastic, Herschel–Bulkley, Casson (Bayod et al., 2007) and Ostwald de Waele (Smith, 2009) models. However, the datas obtained shows variation as a result of different experimental conditions. Therefore it is difficult to obtain a general description about the rheology of tomato products (Bayod et al., 2007).

Like with the other tomato products tomato ketchup is studied within time and different models are suggested. The viscous properties of it have been traditionally described by a power-law model (Ostwald de Waele) or by models (Casson and Herschel-Bulkley) involving a yield stress value as a fitting parameter (Valencia et al., 2004). Pectic content in the ketchup has an important effect on the values for the yield stress.

The rheology of some commercial Egyptian and German ketchups are investigated by Sharoba et al. (2005) in steady and dynamic shear (In the dynamic test, at a determined frequency the stress changes sinusoidally with time. To investigate the food structure, oscillation is an ideal nondestructive method for measuring structural formation changes). They found that tomato ketchups are semi-solid, non-Newtonian fluids with a definite yield stress. The obtained steady flow curves were fitted best with the Herschel–Bulkley model. Moreover they found that while some tomato ketchups exhibit thixotropic properties some exhibit rheopectic properties. They stated that ketchups showed weak gel-like structure. The values for G^1 (elastic modulus) were found to be higher than the values of G^{11} (viscose modulus), and both values increased as the oscillatory frequency increased.

Effect of tomato paste processing on the linear viscoelastic properties of ketchup was studied by Valencia et al. (2004). They reported that the properties such as water-insoluble solid (WIS) content, mean volume diameter, and tomato variety effects the viscoelasticity of the tomato ketchup. They found that an increase in the tomato paste breaking temperature generally yields higher values of the linear viscoelastic properties of the corresponding tomato ketchup samples because of larger tomato paste WIS content.

The effect of different hydrocolloids on the rheological properties of tomato ketchup was studied by Koocheki et al. (2009). They reported that all the ketchup samples studied showed non-Newtonian, pseudoplastic behavior at different levels of hydrocolloids and at different temperatures. The Power-law and Herschel-Buckley are the models that were successfully fit to the data of shear stress versus shear rate.

Varela et al., (2003) investigated the effects of xanthan gum and guar gum and also the effect of native corn starch on the rheology of tomato ketchup. They investigated the effects of them in some important properties such as serum separation and consistency of ketchup. They found that the Herschel-Bulkley is the suitable model to fit the experimental flow curves.

The studies generally showed that the tomato ketchup is time-independent fluid. Some suggested that the kectchup can be described by pseudoplastic behavior but some characterized it as a thixotropic fluid (Varela et al., 2003).

1.1.5.1 Tomato Ketchup versus Viscosity

Sensory characteristics play an important role for consumers on the buying behavior. The most important sensorial characteristic is the sight. It is properties that can be viewed and is the indicator of the quality. It includes the consistency of the product. Consistency plays a major role in the initial acceptability of a product, to be successfully marketing. Color takes the first place in the initial measure of the quality of the product and then consistency comes (Claybon and Barringer, 2002).

Consistency refers the viscosity in the tomato products. It is the ability of solid part keep in suspension during the shelf life of the product (Kuo-Chiang Hsu, 2008). The product with a low consistency will result in two phases as pulp and serum that is the syneresis will actualize as a result of the inability of retaining the solid part in suspension (Krebbers et al., 2003).

Consistency so viscosity is one of the major quality attributes that need to be taken into account in order to have a good quality. It is important for the consumer acceptability (Valencia et al., 2003). The viscosity is defined in the standards of The United States' for semi solid products as the ability of the product to hold the liquid part in suspension (Tehrani and Ghandi, 2007). It affects the intensity of the flavour and it determines to a great extent the overall feel in the mouth (Sharoba et al., 2005).

For the processors viewpoint, since the viscosity is a determining factor for yield and quality, it has economic implications. When the consistency (viscosity) of the product is high, then the amount that is needed to attain a certain level of quality is low (Claybon and Barringer, 2002). This means that the increase in consistency means reduction in product cost.

It is important for many foods such as tomato ketchup to be able to flow when an external force is applied and to save the shape when there is not any force that is applied (Varela et al., 2003). Furthermore, viscosity is important since, it must be consistent with the processing equipments such as pipes, filters, pumps, evaporators, heat exchangers, sterilizes, and mixers (Sharoba et al., 2005). It has importance in the handling, storage, processing and transportation (Sharoba et al., 2005) of the product.

Since the manufacturers have different formulas for the commercial ketchup, it might have an extremely variable composition. Different formulas are the result of the ingredients used in different quantities and different flavorings used.

However these differences make it harder to establish the analytical parameters on which quality depends (Sharoba et al., 2005). Nevertheless there should be an acceptable range for the flow behavior of the product. Several parameters such as raw material quality and conditions for processing play an important role in the flow behavior of tomato ketchup. Therefore it is important to have a raw material with a satisfactory quality and to control and adjust the processing variables continuously to have a final product (ketchup) with a constant and desirable quality (Bayod et al., 2008).

The syrup and the tomato fiber are the constituents of the tomato ketchup. The properties of the syrup, the ratio of syrup and tomato fiber are the principal factors that determine the consistency/viscosity of ketchup. The viscosity of the liquid and the proportion of insoluble tomato fiber present largely determine the thickness or body of the product. The variety and maturity of the tomatoes, the method of pulp preparation (hot break, cold break), the final pH of the finished products (Varela et al., 2003), enzymatic degradations, pulp network, pectin/protein interaction, homogenization process and concentration (Sahin and Ozdemir, 2007; Koocheki et al., 2009) are the other factors that affects the body.

Consistency is of great importance, as consumers want their ketchup to be the same, bottle after bottle (Zonis, 2007). Thick products are preferred by the consumers. Therefore nowadays thickeners are used in the tomato ketchup processing. To have a thick product, the manufacturers use tomato pulp powder (Farahnaky et al. 2008), potato or corn starches, modified starches or various hydrocolloids such as guar gum, carboxymethylcellulose, traganth gum, locust been gum, and xanthan gum (Panovska, et al. , 2009; Sahin and Ozdemir 2004).

1.1.5.2 Effect of Temperature on Ketchup Rheology

The viscosity is a function of temperature; when the temperature increases, there occurs an increase in intermolecular distances and the viscosity decreases (Sharoba et al., 2005).

Koocheki et al. (2009) studied on the rheological properties of ketchup as a function of temperature. They found in general that both consistency coefficients and yield point were significantly affected by temperature. They observed a decrease in consistency coefficients with the increase in temperature indicating a decrease in appearent viscosity at higher temperatures. Moreover they observed that ketchups tended to have higher pseudoplasticity at higher temperatures.

The relationship between effective viscosity and temperature for different brand ketchups was examined by Sharoba et al. (2005) and it was shown that effective viscosity values decreased as the temperature was increased. The effect of temperature on the viscosity was described with Arrhenius-type equation by Sharoba et al. (2005) and Koocheki et al. (2009).

Moreover break step (hot or cold break) commonly used in the production ketchup and also in other tomato products are also indicative of the importance temperature. The tomatoes chopped are heated quickly to the temperatures of 60–77 ˚C for cold break and at least to 90˚ C for hot break (Chong et al., 2009). Hot break is used to produce products with high viscosity (Benner et al. , 2007, Kuo-Chiang Hsu, 2008) such as ketchup and tomato sauce; on the other hand, the cold break method is used to produce products with lower viscosity values, such as juices (Chong et al. , 2009; Kuo-Chiang Hsu, 2008). In cold break process the aim is to preserve the natural color and fresh flavor of the tomato; whereas, in hot break inactivating enzymes important to viscosity is the main objective. Hot break inactivates two enzymes, particularly endopolygalacturonase (EPG) and pectinmethylesterase (PME) (Kuo-Chiang Hsu, 2008). This contributes to the breakdown of pectin which is a polysaccharide found in the primary cell walls and middle lamella of higher plants (Chong et al. , 2009).

1.1.5.3 Effect of Hydrocolloids on Ketchup Rheology

The consistency of tomato ketchup can be improved by adding polysaccharides such as hydrocolloids and they increase the viscosity and reduce the serum loss of tomato ketchups (Sahin and Ozdemir, 2007, Koocheki et al., 2009).

Koocheki et al. (2009) studied on the rheological properties of ketchup as a function of different hydrocolloids namely guar, xanthan and CMC gum and found that the addition of hydrocolloids increased the appearent viscosity and yield point of the ketchup. They stated in general that both consistency coefficients and yield point were significantly affected by type and concentration of hydrocolloids.

Similarly Sahin and Ozdemir (2004) investigated the effects of xanthan gum, guar gum, tragacanth gum, carboxy methyl cellulose, and locust bean gum and found that all hydrocolloids increased the consistency of the ketchup. All decreased the fluidity of the ketchups. Moreover fluidity increased as the concentration of hydrocolloids increased.

1.1.5.4 Effect of Pressure on Ketchup Rheology

It was found by some studies that processing in high pressure improves viscosity and color properties when compared with their conventional heat-processing counterparts (Kuo-Chiang Hsu, 2008).

Homogenizers (changes the particle size), have been used extensively in the processing of tomato products such as tomato ketchups, sauces, and juices with the aim of obtaining products with increased viscosity, reduced separation, improved texture, more uniform color and increased yield (http://www.freepatentsonline.com/5965190.html). Using high pressure, the method of high shear homogenization of ketchups (also other tomato products) results with a increased viscosity without significant loss of other important product characteristics, such as color, liquid retention, texture, etc. (http://www.freepatentsonline.com/5965190.html).

Pectin is the component that plays an important role in the preparation of tomato dispersions. This polysaccharide is naturally found and it dissolves in water forming a jelly-like material. Obviously, this material will produce an increase in viscosity and reduction in separation by tying up any remaining free water. Since the homogenization provides uniform and complete solubilization of the pectin, both of the effects mentioned above (increase in viscosity, reduction in separation) will be succeed.

Moreover tomato PME, enzyme that takes place in the breakdown of pectins is a heat-labile enzyme. Unfortunately it is stabilized against thermal denaturation at ambient pressure. When the pressure is increased above atmosphere (up to 500–600MPa) (Kuo-Chiang Hsu, 2008), it becomes active to take place in pectin breakdown.

Homogenization provides benefit to all grades of ketchup, since in the formulation an increase of 10–14% in the yield of the solids (insoluble and soluble) can be achieved by increasing the percentage of tomato solids. In other words, ketchup homogenized at a pressure of 2500–3000 psi will have a

Bostwick (Bostwick Consistometer is the standard device used to measure viscosity in the industry for sauces and ketchup, essentially measures the distance in centimeters that the product will take in a 30 seconds time) equal to that of unhomogenized ketchup containing 1.10 to 1.14 times as much tomato solid (http://www.apv.com/pdf/technicalinfo/PB_Tomato_Products7_2008.pdf).

Thakur et al., (1995) investigated how homogenization pressure affects the consistency of tomato juice and found that when tomato juice was homogenized under pressure at room temperature, the consistency increased and the serum separation decreased.

Krebbers et al., (2003) investigated the how the viscosity is affected by combined high-pressure thermal treatments and they stated that at ambient temperature high pressure processing resulted with improved viscosity and color compared to heat pasteurization. They claimed that the adverse quality effects of hot-break step (in hot break there is a loss in quality in terms of color, flavor, and nutritional value) can be avoided by high-pressure processing.

1.1.6 Tomato Waste Product

Important amounts of tomato are consumed in the form of processed products such as tomato paste, paste, puree, ketchup, and salsa (http://www.actahort.org/members/showpdf?session=19980). In tomato processing plants, mixture of peel and seeds are left as a waste after processing. The volume of this waste is huge and goes unutilized due to lack of adequate technology; representing around the 4% of fruit weight (http://www.actahort.org/members/showpdf?session=19980).

During the last decade, an increase of tomato derivatives manufacture has been observed and this results in higher quantities of tomato wastes (Manzanos et al., 2006).

If the waste remaining is not used, it will increase the disposal problem (Farahnaky et al., 2008) and also will be a risk for the environment. Currently it is used mainly for animal feeding, with no economical benefits for the industry.

Tomato waste has an excellent chemical composition, contain highly valuable active compounds (Farahnaky et al., 2008). According to the authors, fiber is the major compound of tomato waste; 59.03% (other values: total sugars: 25.73%, protein: 19.27%, pectin: 7.55%, total fat: 5.85% and mineral content: 3.92%) (http://www.actahort.org/members/showpdf?session=19980).

Moreover, tomato waste can be used to obtain different compounds having high economical and nutritional values such as fiber, oil, or antioxidants (http://www.actahort.org/members/showpdf?session=19980). There are studies about it showing that valuable materials such as carotenoids and lycopene have been extracted from tomato waste (Farahnaky et al., 2008). Moreover seed protein and oil are among the valuable materials that have been extracted from the tomato waste (Farahnaky et al., 2008).

Based on the valuable chemical composition of tomato waste, it can be used as functional food in human nutrition. There are various factors that make tomato waste suitable for the use in food industry as an ingredient. One of the main reasons is the increase in interest of consumers for use of natural ingredients in the food products. The other significant reason is that tomato waste has really important functional and physical properties. It has been claimed that it has high water holding absorption capacity since it includes a large amount of polysaccharides in its content such as fiber. Moreover it can be used instead of other hydrocolloids in tomato-based products as a thickener as a natural food additive.

The reuse of the waste can beneficial to both producers and consumers and also to the environment. Millions of tons of tomatoes are destroyed, and large amounts of tomatoes processed are considered as waste every year. Instead of simply wasting this material, it will be possible to benefit from this waste by conversion of such wastes into valuable products and save the environment from pollution.

1.2 Hydrocolloids

1.2.1 What is hydrocolloid

The term ‘hydrocolloids’ (or gums) refers to a range of polysaccharides (with the exception of gelatin; since gelatin is a protein) which consists of long chain, hydrophilic, high molecular weight molecules (Hoefler, 2004). Currently they are used widely in industry to perform various functions such as gelling and thickening aqueous solutions, stabilizing emulsions, foams, and dispersions, the controlled release of flavours, and inhibiting ice and sugar crystal formation etc. (Philips and Williams, 2000). They are most commonly used in food industry; nowadays there is an increased demand for them. They are used in low concentrations (generally not higher than 1 %) however they can show significant changes on the textural and organoleptic properties of food products (Philips and Williams, 2000).

1.2.2 Sources of hydrocolloids

Origin of the commercially important hydrocolloids is given in Table 1.1

Table 1.1 Source of commercially important hydrocolloids

BOTANICAL • Trees cellulose • Tree gum exudates gum arabic, gum karaya, gum ghatti, gum tragacanth • Plants starch, pectin, cellulose • Seeds guar gum, locust bean gum, tara gum, tamarind gum • Tubers konjac manan
ALGAL • Red seaweeds Agar, carrageenan • Brown seaweeds Alginate
MICROBIAL Xanthan gum, curdlan, dextran, gellan gum, cellulose
ANIMAL Gelatin, caseinate, whey protein, chitosan
Source: Williams, P.A., Philips G.O., 2000, Introduction to food hydrocolloids, p. 1.

Most of the hydrocolloids are found naturally, but some such as carboxymethyl cellulose (CMC) are obtained after some chemical modifications.

1.2.3 Some Important Properties of Hydrocolloids

Chemical or physical structures of hydrocolloids show variation; while some, such as pectin and cellulose, have linear structure, some have branched molecules. Some are soluble in cold water while some only in hot water. Some, such as cellulose, are not digestible.

Most of the hydrocolloids have side units (mostly sugar units, or sometimes carboxyl groups, sulfate groups or methyl ether group) which influence the properties of the hydrocolloid. Water molecules are oriented around hydroxyl groups of sugar units (and around anionic groups presenting on some gums) and moves around with the gum molecule to some extent leading to volume increasing and swelling (Figure 1.1). Some gum (namely thickeners) molecules exhibit little interaction with each other, moving with their layer of organized water following them. Some gum (namely the gelling agents) molecules make interactions with each other, using various types of bonds, forming a three-dimensional network called a gel (Hoefler, 2004).

1.2.4 Gum Combinations

Generally (but not always) combining two different thickening gums -result in a synergistic effect- leads to a higher viscosity than expected that is the viscosity of the solution will be higher than the solution prepared with only one of them as a result of increased random collisions between different molecules. On the other hand the case is generally different when a thickening agent is combined with a gelling gum that is viscosity will be lower than the expected because of the fixed nature of a gel network. Instead of collisions thickening agent will be imprisoned in the gel network (Hoefler, 2004).

1.2.5 Functions and Food Applications of Hydrocolloids

Functions and applications of commonly used hydrocolloids are summarized in table 1.2.

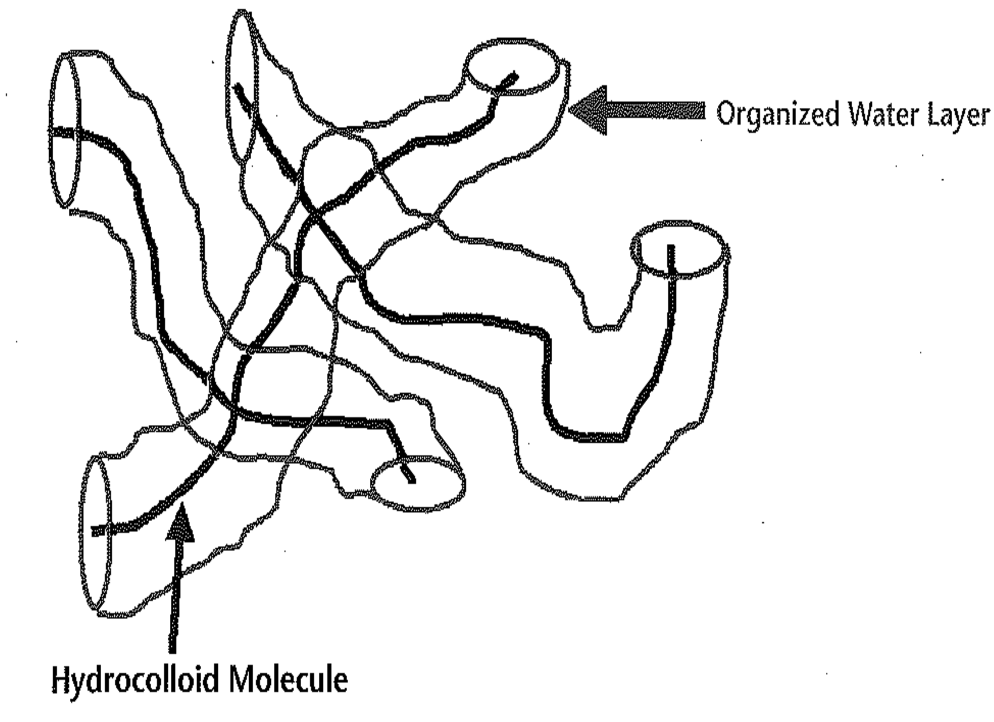

Figure 1.1 Hydrocolloid molecules surrounded by organized water (taken from Hoefler, 2004)

Table 1.2 Functions and applications of commonly used hydrocolloids

Hydrocolloids: Functions and Food Applications

Hydrocoloid	Function	Application
Guar and locust bean gums	Stabilizer, water retention	Dairy, ice cream, desserts, bakery
Carrageenans	Stabilizer, thickener, gelation	Ice cream, meat products, dressings, instant puddings
Agars	Gelation	Dairy, confectionery, meat products
Gum arabic	Stabilizer, thickener, emulsifier,encapsulating agent	Confectionery, bakery, beverages, sauces
Gum tragacanth	Stabilizer, thickener, emulsifier	Dairy, dressings, confectionery, sauces
Pectins	Gelatin, thickener, stabilizer	Jams, preserves, beverages, confectionery, dairy
Alginates	Stabilizer, gelation	Ice cream, instant puddings, beverages
Xanthan gum	Stabilizer, thickener	Dressings, beverages, dairy, bakery
Carboxymethyl-cellulose	Stabilizer, thickener, water retention	Ice cream, batters, syrups, cake mixes, meats
Methyl cellulose	Gelatin, stabilizer, water retention	Fat reducer, bakery
Modified starches	Stabilizers, emulsifiers	Bakery, soups, confectionery

Source: Stephen A.M., Phillips, G.O., Williams P.A., 2006, Food Polysaccharides and Their Applications, p.8

1.2.6 Important Hydrocolloids Used In Food Industry

1.2.6.1 Xanthan Gum

1.2.6.1.1 Source

Xanthan Gum is a extracellular polysaccharide produced from the bacterium *Xanthomonas campestris*, a single-cell organism found on the leaves of the *Brassica* vegetables such as cabbage (Philips and Williams, 2000; Stephen et al., 2006).

1.2.6.1.2 Structure

Xanthan gum has a linear (1→4) linked β-D-glucose backbone (like cellulose), but every second glucose unit is attached to a trisaccharide at C-3, consisting a glucuronic acid residue linked (1→4) to a terminal mannose unit and (1→2) to a second mannose that connects to the backbone.

Approximately 50 % of the terminal mannose residues are pyruvated and the nonterminal residues are usually substituted at the C-6 position with an acetal group (Figure 1.2) (Philips and Williams,2000).

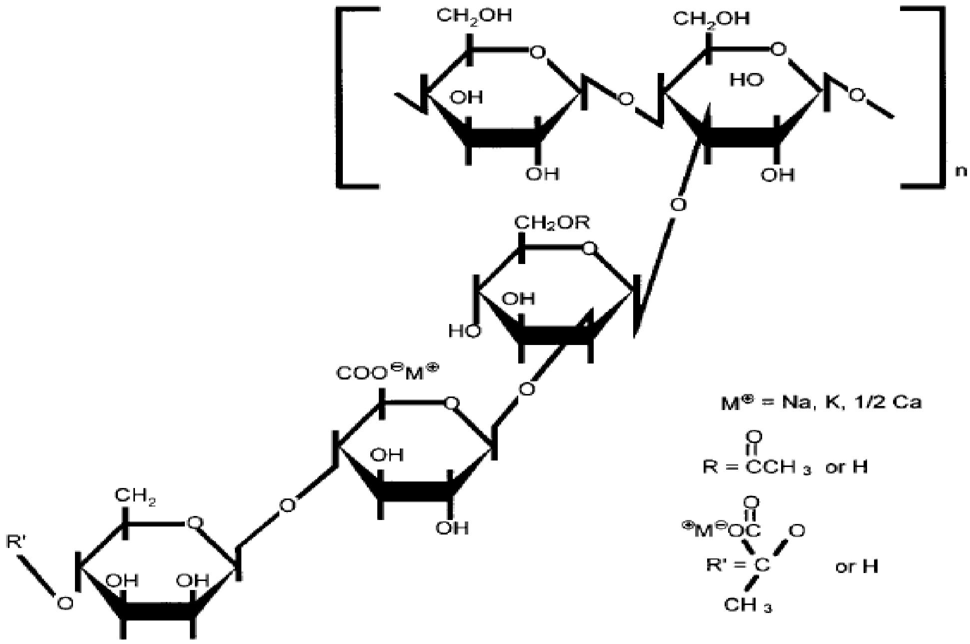

Figure 1.2 Primary Structure of xanthan gum (taken from Philips and Williams, 2000)

1.2.6.1.3 Functionality

Xanthan gum is soluble both in cold and hot water. Its solutions exhibit highly pseudoplastic flow; it exhibits instantaneous shear thinning behavior. It recovers its viscosity when shear is removed. Its viscosity has excellent stability over a wide pH (pH 2-12). Moreover its viscosity is stable over a wide range temperature. It is resistant to enzymatic degradation.

Xanthan gum is synergistic with the guar gum and locust bean gum (LBG). It results in enhanced viscosity them (Philips and Williams, 2000).

When xanthan is used at levels of 0.15 % or higher and in the presence of 0.02-0.07 % sodium chloride, it reaches its peak viscosity (Hoefler, 2004). It shows a gel-like structure at levels of more than 1 %.

It is widely used as a thickener or a viscosifier, and it is also used as a stabilizer for a wide variety of suspensions, emulsions, and foams. Typical food applications of xanthan gum are salad dressings (emulsifiying agent), bakery fillings (emulsifying agent), cheese (syneresis inhibitor), ice-cream (stabilizer and in crystallization), juice drinks (suspension), powdered flavors (encapsulation) , sausage casings (film formation) , beer (foam stabilizer), syrups (pseudoplasticity) jams and sauces (thickening agent) (Becker et al.,1998).

1.2.6.2 Guar Gum

1.2.6.2.1 Source

Guar gum, one of the seed galactomannans, is obtained from the seed of the guar plant, *Cyanaposis tetragonolobus*, an annual summer legume that grows mainly in arid and semi-arid zones (Philips and Williams,2000); it grows in India and Pakistan as a food crop, and in Texas and Arkansas as a commercial crop (Hoefler, 2004) .

1.2.6.2.2 Structure

Guar consists of a chain of (1→4)- linked β- D- mannopyranosyl units with single α-D-galactopyranosyl units connected by (1→6) linkages, on average, to every second main chain unit

1.2.6.2.3 Functionality

Guar gum is a cold water soluble, nonionic, and salt tolerant natural polysaccharide. It has many uses as a food stabilizer and as a source of dietary fiber. Moreover it is an excellent additive in salad dressings, ice cream mixes and bakery products because of its strong hydrophilic character (Koksel, 2009).

Guar gum functions at the levels of 0.1-0.35 % total formula basis. It can cause a rubbery crumb when used more than this level.

1.3 Wheat and Wheat Bran

Wheat is one of the world's most important grains, cultivated worldwide with annual production of 607 million tons according to the 2007 datas

(http://en.wikipedia.org/wiki/Wheat). It is the most valuable of all food grains (Hui, 2006), and is widely used to make flour for breads, cakes, biscuits, pastas, noodles, cookies, breakfast cereal. It is also used for fermentation to make beer, and other alcoholic beverages, or also in producing biofuel (http://en.wikipedia.org/wiki/Wheat).

Wheat flour is obtained by a dry milling process of wheat. In this process, germ and bran are separated from the wheat and the endosperm is broken down into fine particles which constitute the flour. A large amount of wheat bran is produced as a byproduct of the milling process; 11 percent of the total product (Xie et al., 2008).

By-products of wheat "have unique functional and nutritional properties related to colour and cooking performance and to their content of dietary fiber" (Esposito et al., 2005). Wheat bran has been an undervalued by-product of the white flour and nowadays the studies done has begun to underline the high nutritional potential of it (Hemery et al., 2010). It is packed with nutrition with offering many dietary benefits (Christensen, 2010); wheat bran contains a number of high value components, such as proteins, phenolic compounds, soluble and insoluble dietary fiber and starches (Xie et al., 2008). One cup of it (58g) meets 34 percent of the US recommended daily allowance (RDA) for iron and 99 percent of fiber, (Christensen, 2010). It is also high in phosphorus, magnesium, zinc, manganese, niacin, and vitamin B6, and is low in fat, with no cholesterol, and no sugar or sodium (Christensen, 2010). After seeing all, it is obvious that wheat bran can be added into foods to increase the nutritional potential of them. Wheat bran can be taken in bulk, which makes it quite easy to add to baked goods. Therefore to increase nutritional value of a food, the wheat bran can be easily added to cakes, biscuits, waffles and cookies (Christensen, 2010). Because of the high value of wheat bran, it can be even taken in powdered form by some people in order to get their needed dietary fiber each day.

1.4 Bakery Products

The baking industry is one of the most stable sectors in the food manufacturing industry (Hui, 2007). In fact bakery foods are almost common in every culture. They form a specific part of diet since as cereals and grains occupy a special part in the regular diet.

Breads and bread products, cakes, biscuits, crackers, pastries, cookies and baking ingredients are all constitute the bakery products. They are famous worldwide and consumed by many people. Bakery foods come in large variety of flavor and constitute mixture of different ingredients like flour, sugar, salt, milk, water, etc. Every bakery product is unique in its operation but the procedure is not rigid for all the products. The important point is the taste of them should be satisfactory for the consumers.

1.4.1 Bread

Bread is one of the most important bakery products which consist of two distinctly different parts named as crust and crumb. While the crust is the dry and crispy surface layer of the bread (Hui, 2007), the crumb is the soft part under the outer surface. It is important to produce a soft and fine crumb and this is achieved during dough mixing of bread by the proper development of a gluten network during.

There are lots of different varieties of bread that differ in shape, size, texture, color, and flavor. The ingredients can vary or the baking conditions may differ bread to bread (Hui, 2007).

Flour, water, leavening agent (yeast or chemicals) and sodium chloride (Scanlon and Zghal, 2001) are the basic ingredients that form the bread dough. Since flour and water are the substances that affect the texture and crumb the most, they are the most crucial ingredients in a bread recipe (Mondal and Datta, 2008). In a recipe flour is always 100%, and the rest of the ingredients are a percent of that amount by weight (Mondal and Datta, 2008).

Three objectives are sought in the processing operations of bread. The first operation is the mixing and dough development (mixing and fermenting); then foam structure formation in the dough (moulding, proofing and baking) follows; and finally porous structure stabilization by the help of heat (baking) comes (Scanlon and Zghal, 2001).

1.4.2 Cake

Cake is the bakery product which is made by the formation of a batter and which is a complex emulsion and foam system with an appreciable amount of bubbles inside (Hui, 2007). Flour, water, fat, sugar, egg, milk, salt are the basic ingredients of cake batter. Ingredients of cakes batter are similar to bread dough. However the properties of flour are different in cake since weak wheat flour is needed. In cake a gluten network is not required since it will make the cake firmer and chewier (Hui, 2007). Moreover the ratio of water to flour is high in cake batter compared with bread dough.

1.4.3 Biscuit

Biscuits are small baked products made principally from flour, sugar and fat (Manley, 1998). Biscuit is a low-moisture bakery product typically less than 4%. However this moisture content can varies since the thickness and weight of biscuits changes during forming and shaping of it; its moisture content can be up to 10 % (Hui, 2007). They have a long shelf life compared with bread and cake when packaged in moisture proof containers.

Biscuits differ in shapes and sizes, can be flavored with lots of ingredients, can be covered with chocolate, creams, and etc. Appearance, aroma, flavor, and texture are the most important quality parameters for biscuits. Cracking or checking is the defects usually seen in biscuits. Moisture gradient that accumulates in the product after baking causes these defects (Hui, 2007). While the moisture content of freshly baked biscuits is high in the center, it is low at the edge. As the time pass, moisture migrates from the center to the edge causing an expansion at the edge, but a contraction at the centre (Hui, 2007). This causes stress development in the biscuit and finally there occurs crack in the biscuit.

1.4.4 Others

Besides the major bakery products described so far (bread, cake and biscuit), there are also numerous other types of bakery products, including pizzas, pastries, bakery ingredients, breakfast cereals, (Hui, 2007) and so on.

1.5 Functional Foods

The term "functional foods" and "functional food ingredients/nutraceuticals" are applied to foods and food constituents, respectively, that provide specific health or medical benefits, including the preventation and treatment of diseases, as well as nutritional value (Hui, 2007).

Increased life expectations and awareness towards healthy nutrition of the consumer, obesity and increased coronary heart diseases lead to an increase in production and consumption of functional foods by consumers expecting health benefits in addition to its nutritional values (Meral and Doğan, 2009).

Functional foods and nutraceuticals include food additives, vitamin and mineral supplements, herbs, phytochemicals, and probiotics (Hui, 2007).

1.5.1 Hydrocolloids Used in Bakery Products

As mentioned before hydrocolloids, or gums, are water-soluble polysaccharides with high molecular weights, obtained from variety of sources and exhibit a wide range of properties (Sreenath et al., 1996). They are multifunctional ingredients that add flexibility, functioning as fat replacer, water binders, texturizers and adhesives (Shalini and Laxmi, 2007). They confer stability to the products because of the high water retention capacity. They are also used to reduce the oil uptake in cereal products (Shalini and Laxmi, 2007). Some important functions of the hydrocolloids are: (i) improving food texture, (ii) increasing moisture retention, (iii) slowing down the retrogradation of the starch, (iv) extending the overall quality of the product during time, and also (v) modifying the viscoelastic properties of gluten in bread doughs (Rojas et al., 1999).

Their properties make them suitable for use in a wide variety of applications in the food industry. Compared to other food manufacturers, the baking industry uses relatively small amounts of gums, but gums perform an indispensable function in bakery-related applications (Sreenath et al., 1996). Gums were originally added to cake batters to increase moisture retention during baking (Sreenath et al., 1996) so to enhance final product moistness which prevent staling. They also used for volume increases and texture changes.

The function of gums is very application-sensitive. Their functionality is affected by many factors, such as chemical nature of the gum, temperature, pH range, concentration, particle size, presence of other inorganic ions, and chelating agents (Koksel, 2009).

Gums are added at low concentrations (generally lower than 0.5% on total formula basis) so although gums have the ability to absorb several times of their weight in water, the increase in dough water absorption due to the addition of a gum is relatively small. The additional water is small but here the important point is the increased product moistness and as a result viscous, slippery mouth feel that was gained by the addition of the gum.

Gums can make the baked crumb rubbery and elastic. This may be perceived as softer or fresher at sufficiently low levels, and also as tough or chewy at elevated levels (Koksel, 2009).

There are studies in the literature about the effects of different hydrocolloids on the quality of the baked products. Locust bean gum, alginate, sodium alginate, κ-carrageenan, xanthan gum and hydroxypropyl methylcellulose (HPMC), guar gum were investigated in baked products, mainly in bread making. It was founded that they have effects (also their type and concentrations) on crumb moisture contents, texture parameters such as firmness, hardness, and chewiness, on the rate of staling, weight loss, on the final quality of breads such as the specific volume and moisture retention, rate of moisture loss, on the rheology. Turabi et al. (2008) studied the rheological properties of batters and quality of rice cakes formulated with different gums and an emulsifier blend and obtained the best results (in terms of emulsion stability and apparent viscosity of cake batter; texture, volume and porosity of the cakes) for xanthan gum and guar gum. In addition to these, they also observed a synergistic interaction between xanthan and guar gum which results in increased apparent viscosity of cake batters as compared to other gums (Koksel, 2009).

1.5.2 Dietary Fiber

Nowadays beneficial effects of healthy diet on the quality of life are widely recognized by the people and as a result the food industry is trying to develop new food products with special health-enhancing properties. Such products are in response to an aging population, increasing health care costs, consumer interest in nutrition, and food technology advances (Lebesi and Tzia, 2009). The development and use of functional ingredients is widely used by the food industry, principally those with high dietary fiber levels (Rodrı´guez-Ambriz et al., 2008). Several people have searched the importance of dietary fiber since 1970s (Sudha et al., 2007). Because there is a growing belief throughout the world that natural fiber foods are an integral part of a healthy lifestyle, food producers source an increasing proportion of their raw materials from nature itself

(Phillips and Williams, 2000). There is a growing demand from an increasingly health conscious consumer for enhanced fiber foods of all types since fiber has an important role in many physiological digestive functions, such as providing bulk for waste elimination and regulating blood glucose and lipid levels (Nelson, 2001).

Food manufacturers are trying to respond to the consumer demand for foods with higher fiber content by developing products in which high-fiber ingredients are used. However foods containing such ingredients will need to match the quality of the original product and without adverse dietary effects and this is done by using dietary fibers which can interact with water to form new textures and perform specific functions (Phillips and Williams, 2000).

1.5.2.1 Definition

Dietary fiber is defined chemically as the sum of polysaccharides and lignin which are not digested by the endogenous secretions into the human gastrointestinal tract (Rani and Kawatra, 1994). It can affect the utilization of food by the body (Manthey et al. ,1999).

Dietary fiber is the edible part of plants or analogous carbohydrates and it consists of polysaccharides that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine (Lebesi and Tzia, 2009; Esposito et al., 2005).

Dietary Fiber (DF) includes cellulose and lignin, hemicellulose, pectins, gums (Valencia et al., 2007; Sudha et al., 2007), algal polysaccharides, mucilages (Rani and Kawatra, 1994) and other polysaccharides and oligosaccharides associated to plant (Esposito et al., 2005). All these components differ in their chemical and morphological structures (Rani and Kawatra, 1994).

Dietary fiber can be divided into two category as insoluble dietary fiber (cellulose, hemicellulose, lignin, etc.) and soluble dietary fiber (pectins, gums, mucilages, etc.) (Lebesi and Tzia, 2009). Water-soluble dietary fiber can form viscous solutions and insoluble dietary fibers usually have high water-holding capacity (Manthey et al., 1999).

1.5.2.2 Fuctionality

Dietary fiber is an important constituent due to its functional properties. It can be used in the formulation of foods, resulting in texture modification and enhancement of food stability during production and storage (Lebesi and Tzia, 2009).

Interest has arisen in increasing fiber in the diet because of its various health benefits. By many researchers potential health benefits of dietary fiber have been documented. Epidemiological studies have been continuing to suggest that fiber consumption helps to reduce obesity, some kinds of cancer, cardiovascular diseases, and gastrointestinal diseases (Gomez et al., 2010). This is the subject that has been extensively investigated. Both the consumers and food processors have become really interested in the nutritional and physiological importance of fiber.

Dietary fiber functions as a bulking agent and increases the intestinal mobility and moisture content of the feces (Sudha et al., 2007). When it is not taken enough in the diet, various diseases such as colon cancer, diverticular disease, hyperlipidemia and gall stone begins to occur (Rani and Kawatra, 1994).

Chemical composition and physical form, such as solubility, affects the physiological effects of dietary fiber by changing the extent of fermentation in the large intestine. Soluble and insoluble dietary fiber differ in their functionality; for example while soluble dietary fiber plays an important role in lowering serum cholesterol and glucose level, insoluble dietary fiber is essential in maintaining intestinal health (Noor Aziah and Komathi, 2009). The main physiological effect of insoluble fiber is the improvement of gut peristalsis, which is related with the water holding capacity and the effect on viscosity (Esposito et al., 2005).

On the other hand soluble fiber has multiple functions. Consumption highly viscous soluble dietary fibers, is usually associated with moderate postprandial glycemic responses, a property of importance in the dietetic treatment of diabetes (Valencia et al., 2007). They represents a good substrate for some microorganisms that are beneficial for gut health (prebiotic action), and they reduce plasmatic cholesterol (Esposito et al., 2005).

14 g/1,000 kcal of dietary fiber per day (for adults) should be taken for an adequate intake (Lebesi and Tzia, 2009). Numerous health organizations indicate the necessity of increasing fiber consumption up to 20–35 g per day (Gomez et al., 2010).

1.5.2.3 Sources

The interest in dietary fiber that continues to grow in last years has resulted in the development of a large market for fiber-rich products and ingredients (Valencia et al., 2007). Public concern about the health effects of dietary fiber has prompted a fast-growing market of it (Sievert et al., 1990). All the factors have led to research into methods of including fiber into the diet (Sreenath et al., 1996).

There are various sources for fiber; it can be natural and unprocessed (e.g., bran), it can be isolated (e.g., cellulose and various gums) or modified (e.g., carboxymethylcellulose), or non-plant (e.g., xylans and polydextrose; Gordon 1989) (Lebesi and Tzia, 2009).

The content of dietary fiber in food shows variations depending on the type of food and food processing method. Plant foods, especially fruits and vegetables are known to be good sources of dietary fiber. However they all show variations in the level of dietary fiber components. Each component has different effects so all of them should be estimated exactly for accurate prediction and explanation of their effects. Up to now there have been lots of estimations for various fiber components of many plant foods being the major sources of fiber in diet however still the reference data are very scanty and the results differ from lab to lab depending on the type of procedure used (Rani and Kawatra, 1994).

Fruits and vegetables are important sources of dietary fiber, although the content is not as high as in cereals (Noor Aziah, and Komathi, 2009). Cell walls are the dietary fiber sources in the fruits and vegetables. Dietary fiber obtained from fruits and vegetables mostly consist of soluble dietary fiber. This kind of fibers show some functional properties, such as water holding, gel formation, oil holding, or swelling capacity (Valencia et al., 2007).

Over the past decade, high dietary fiber materials from fruits (such as apple and citrus) have been introduced into the markets (Valencia et al., 2007). But since the food selection patterns of people are dominated by sensory preferences for taste and texture, dietary patterns of them are difficult to change (Sreenath et al., 1996). In view of this food, processors have begun to incorporate the fiber in popular, mostly consumed foods to satisfy consumer needs for increased fiber intake without sacrificing sensory attributes. From this perspective, ketchup and cake will be a logical option to add fiber as an ingredient since they are well liked by consumers all over the world. Already there are studies about increasing fiber content of cakes. In order to increase the fiber content in cakes, several raw materials such as bran and outer layers of cereals , legume outer layer , and processing by-products of apple and potato have been used (Gomez et al., 2010).

Most cereal bran products are characterized by high levels of insoluble fiber, ash, vitamins, lipids, and pigments (Lebesi and Tzia, 2009). Up to now, cellulose, wheat bran and oat bran were used in bread making. Dietary fiber is extracted from the bran layer of the cereal grains.

Moreover potato peel, a by-product from potato industry, rich in dietary fiber, was used as a source of dietary fiber in bread making (Sudha et al., 2007). Dietary fibers from different sources have been used to replace wheat flour in the preparation of bakery products (Sudha et al., 2007). Kaack and Pedersan (2005) used dietary fiber for processing of cakes to reduce the content of fat as previously done using apple pomace and yellow pea hulls peach fiber and oat meal (Kaack and Pedersen, 2005).

When the fiber used in food products, the advantage will not be only the increase in the fiber content of foods since fiber can be used to improve the texture, to reduce the energy content, to improve the colour and aroma of the final product. As an example it was stated that lemon and apple fiber having relatively high water holding capacity can be used in breads and cakes and also in other similar cereal products in order to obtain softer products with reduced energy content (Uysal et al., 2007).

Cellulose

Cellulose is the primary structural component of plant cell wall (Mehta and Kaur, 1992; Nelson, 2001). It is a polysaccharide with a linear, unbranched polymer of glucose units. The linear chains of cellulose can hydrogen-bond with each other to form very rigid, inflexible crystalline microfibrils up to 25 nm in diameter, or roughly a structure that is 30-100 chains wide, giving cellulose a strong, dense, partially crystallline, chemically and enzymatically resistant nature. Cellulose is insoluble in water and in dilute solutions of acids or bases. It has a high water-sorption capacity (Nelson, 2001).

Hemicellulose

It has a more complex and varied structure compared to cellulose. Hemicelluloses are polysaccharides with several different types of side chain units, which can singly, or in combination, make up the polymer backbone. Their monosaccharide backbone units consist of glucosidic bond of glucose, xylose, galactose, mannose, or arabinose. Side chain units of polymers consist of uranic acids such as mannuronic, galacturonic, and glucuronic acids. They are insoluble in water and dilute solutions of acids but soluble in dilute solutions of bases (Nelson, 2001). They have often been reported as chemically associated or cross-linked to other polysaccharides, proteins or lignins (Dimitriu, 2005).

Lignin

Lignin is not a polysaccharide, it is a polyphenylpropane polymer, composed of the plant aromatic alcohols cinnamly, syringyl, and guaicyl, which are also referred to as phenylpropane units. It is highly insoluble in water and is responsible for the structural adhesion of the plant cell wall components because it excludes water when it forms networks by cross-linking with other polysaccharide-type molecules in plants. It is very resistant to chemical, enzymatic and bacterial breakdown (Nelson, 2001).

Pectins

Pectins are the largest source of soluble fiber in plant food materials. The principal building block of pectins is galacturonic acid (GalA) (Beri, 2005). Besides, they contain large quantities of other sugars as side chains, consisting of galactose, glucose, rhamnose, and arabinose, located on the polymer backbone. They are generally soluble in water but sometimes can be insoluble depending on the side chain constituents (Nelson, 2001).

1.6 Cake

Bakery products constitute one of the most consumed foods in the world. Among them, cakes are particularly popular and associated in the consumer's mind with a delicious product with particular organoleptic characteristics (Matsakidou et al., 2010). It is mechanically and chemically embossed bakery product (Doğan and Yıldız, 2004). The interest to cake among bakery products is increasing day by day. Bakery products' market size is 145 billion dollars in world and 1.6 billion dolars in Turkey, and cake is one of the most important products of this market (http://www.marketingturkiye.com/yeni/Haberler/NewsDetailed.aspx?id=13529).

The main ingredients of cake are flour, liquid (commonly water), sweeting agent (commonly sugar), binding agent (commonly egg), fats, leavening agent (commonly baking powder) and flavors. Each ingredient plays an important functional role in the structure and eating quality of the cake.

Cake batter is a complex emulsion and foam system that is processed by being heat set (Matsakidou et al., 2010). It is a complex mixture of numerous air bubbles and dispersed fat particle in continuous aqueous phase (Sumnu and Sahin, 2008).

Cake batters can be considered as oil in water emulsion (Demirkol, 2007). Coupled with that is a foam system, initially in the fat phase but being transferred to the aqueous phase when the fat melts during baking, resulting in a complex emulsion and foam system (Sumnu and Sahin, 2008).

The dry ingredients, such as flour, sugar, baking powder and salt are incorporated into the liquid phase and then they become part of it and the fat or oil phase remains dispersed in lakes or clumps throughout the continuous or liquid phase. During the preparation of the batter, air cells are incorporated and they are stabilized in the fat phase when sugar is beaten into the shortening to give an aerated cream (Demirkol, 2007). The air cells gives rise to a foam, and s oto obtain a large number of small cells is important to provide high volume cake. They are the structures which finally create texture of cakes. Firstly the air cells in the batter are held in the fat phase at room temperature but during heating, air bubbles expands rapidly and many of them move from fat into the aqueous phase. They become partly stabilized by egg proteins. The bubbles take a layer of fat with them as they move into the aqueous phase because in the baked cake, the surface of the air bubbles is coated with fat (Demirkol, 2007).

Baking of the cake is the time when the batter changes from an emulsion to a porous structure due to starch gelatinization, protein denaturation, carbon dioxide gas produced, air occlusion during mixing, and the ingredients' interaction. Baking is difficult to clarify because of the complexity of the cake ingredients. During baking, with the increase in temperature, there occurs an increase in the water vapor pressure and in carbon dioxide gas formation. This leads to the air bubble formation and as a result expansion of the cake batter takes place. Baking process results with a product which has light and aerated structure. Moreover during the process, a great amount of volatile compounds that have a significant role in the development of the typical flavours of cake are formed (Matsakidou et al., 2010).

The quality of a cake is dependent on variations of certain factors. However, there is much more to making an acceptable product (Hui, 2007). While the proper formulation (types of ingredients and their percentage) can be taken as the main principle for the quality of cake, the role of optimal mixing and baking final procedure should not be ignored. Alteration of the baking and mixing process as well as the selection and mixing of raw materials can modify cake structure and aroma composition.

Cakes are broadly divided into several categories, according to ingredients, cooking techniques or according to their shapes. Essentially there are two types of cakes; sponge cakes and layer cakes. While sponge cakes are very airy batters that turn into cakes with a rather open structure, layer cakes are the cakes that contain a solid fat which, when creamed with sugar results in an aerated batter with distinct flow properties and cakes that have a fine grain and relatively small air cells (Demirkol, 2007). In both type of cake, foam is formed as aeration of a liquid batter occurs. Then air bubbles expand within the foam during baking and finally foam transforms to a final structure.

1.6.1 Cake Ingredients

Cakes have a higher proportion of fat, sugar, and milk to flour than do breads, and the flour used is usually cake flour. Both flour and eggs contain the proteins that contribute strength and structure to cakes (Hui, 2007). Moreover incorporation of specific additives has been found to be beneficial for improving the quality of baked products (Demirkol, 2007).

1.6.1.1 Flour

Flour is the ingredient which distinguishes bakery products. It plays various roles in products' structure, gives unique textural and appearance characteristics to them. That is, it provides structure, texture, and flavor to cake.

Flour can be bleached or unbleached. Bleached flour is chemically treated flour and it has less protein than the unbleached flour. Unbleached flour is the flour that is bleached naturally as it ages.

In cake making process usually cake flour is used. There are lots of characteristics that is different for cake flour and they make it unsuitable for bread or biscuit making. Cake flours are generally made from wheat but it may also come from corn, rice, legumes, nuts and some fruits and vegetables. Cake flour is made from the endosperm of soft wheat. It is the finest flour since endosperm is the softest part of the wheat kernel. It contains mainly protein, starch, lipids, some minerals and vitamins, ash, etc.

Cake flour is a fine-textured (finely milled), soft-wheat flour with a high starch content and low protein content (typically, cake flour is around seven percent protein). The protein content of cake flour is the lowest among the other wheat flours. Bread flour, for example, has twice that amount of protein. For baking, if highly elastic dough is needed, it is preferred to handle flour with high protein content (Demirkol, 2007).

Moreover cake flour is strongly bleached; chlorinated. Bleaching process is done to make it white and to break down the protein in the flour. This process leaves the flour slightly acidic, sets a cake faster and distributes fat more evenly through the batter to improve texture. Cake flour has the capacity to hold the rise in the cake so the cake is less liable to collapse.

In cake making a light, fluffy cake with a tender crumb is aimed which is achieved with low protein content flour since protein promotes the production of gluten, which can make baked goods tougher. Moreover lighter, less dense texture is needed in cake and this is done by using finely milled flour. The fine grain absorbs fat readily, ensuring that butter and other fats in cakes are well distributed throughout the batter (http://www.wisegeek.com/what-is-cake-flour.htm). Small particle size causes less gluten formation and as a result a cake with fine grain, delicate structure and velvety texture is obtained.

In cake making, flour that is starchy and have ability to hold large amounts of fat and sugar without collapsing is required (http://www.wisegeek.com/what-is-cake-flour.htm). Cake flour is high-starch flour with a high water holding capacity and can carry a high volume of sugar when compared with the flours having higher protein content.

The flour contains a high amount of starch and less gluten which results in lighter, less dense textures or a more "tender, fine crumb".

Moisture content is one of the other important parameters in order to specify the flour. The moisture content of the flour is most commonly about 14% and should not vary more than 1% (Demirkol, 2007).

The ash content of flour, total alpha amylase and falling number, damaged starch, water absorption and rheological properties of flour and the knowledge of any treatment that the flour has experienced are also the important parameters for flour specification (Demirkol, 2007).

All purpose flour (the general purpose flour) can also be used in cake making. It is the blend of hard and soft wheat. It has higher protein content than the cake flour. All-purpose flour has a larger particles size compared to cake flour It is usually translated as "plain flour" and can be bleached or unbleached. However it is used as bleached in cake making. By adding corn starch and /or baking soda, a softer structure can be achieved since otherwise it will result with a firmer or denser cake structure. Hui (2007) claimed that the all-purpose flour can also be used in cake making but it may result in cakes with a slightly coarser texture and lower volume.

1.6.1.2 Liquid

In cake making, water, milk or fruit juice is used as liquid. Their functions are the same. Liquid serves as a solvent in the cake batter to dissolve dry ingredients and also it is essential for gelatinization of starch. It is also necessary for the release of carbon dioxide from either the baking powder or baking soda (Hui, 2007). It also produces steam along with carbon dioxide. The quality of liquid is important for the cake batter rheology or for the final product texture. The amount and types of dissolved minerals and organic substances present in the liquid can affect the flavor, color, and physical attributes of the finished baked goods (Demirkol, 2007) for example; the hardness of water is one of the important characteristic for cake making since soft waters can result in sticky doughs.

1.6.1.3 Sweeting agent

The types of sweeteners most commonly used are sucrose (cane or beet sugar) and various hydrolysates of corn starch (corn syrup, dextrose, etc.) (Matz, 1992). Among these, sugar is the one which is mostly preferred. In addition to sweeting effects, it also affects the cake structure, tenderness, texture, appearance, color, volume, moistness, and calorie content of the product. It also affects the aeration, keeping quality, humectancy, crumb and crust color, shelf-life, flavour and aroma.

Sugar plays a role in controlling batter viscosity, the degree of gelatinization of starch and heat setting temperature of proteins (Demirkol, 2007). It raises the temperature at which gelatinization and coagulation occur, which gives the gluten more time to stretch, thereby further increasing the volume of the baked product and contributing to a finer, more even texture (Hui, 2007). By delay in starch gelatinization during baking, air bubbles expand properly due to vapor pressure build up by carbon dioxide and water vapor before the cake sets resulting in the desired cake structure.

Nearly all commercially available sugar contains in excess of 99.8% sucrose, with less than 0.05% moisture, about 0.05% invert sugar and other carbohydrates besides sucrose, and a trace of ash (Demirkol, 2007). Sugar in the high-ratio cake formulation results in a good air incorporation leading to a more viscous and stable foam (Demirkol, 2007).

1.6.1.4 Egg and Egg Products

Eggs affect the texture of cakes as a result of their emulsifying, leavening, foaming, coagulation, tenderizing, and binding actions (Demirkol, 2007). Egg is the common binding agent used in the cake making. However other than egg, gluten or starch is used (used by lacto-vegetarians and vegans) as a binding agent. The egg has substantial effects on the cake properties; incorporation of it enhances the nutritional value and functional properties of the products. It effects flavor, texture and also the color. They are essential for obtaining the characteristic organoleptic qualities.

Egg yolk and egg white are the constituents of the egg. Egg yolk is a dispersion of particles in a continuous phase which contains egg lipids and triglycerides makes up the 70% of this lipid. Phosvitin and lipovitellin are the particles which constitute nearly 25% of the dry matter of the yolk. The continuous phase contains 75% of the dry matter of the yolk in the form of lipovitellin and globular protein (Demirkol, 2007). Moreover lecithin and cholesterol are also present in egg yolk. A yellow coloring pigment xanthophyll gives the color of the folk. Egg white or albumen is made up of a complex structure of proteins, such as ovalbumin, ovotransferrin, lysozyme and conalbumin. It contains in dry matter about 85% of the total protein content (approximately 40 different proteins) of an egg. Unlike the egg yolk, it contains a negligible amount of fat. The egg white is very viscous and alkaline in a fresh egg and contain natural inhibitors, such as lysozyme, which form a chemical protection against invading microorganisms. (Demirkol, 2007).

Three main attributes of egg and egg products in cake making are; foaming, emulsification and coagulation. These properties are uniquely combined in eggs.

Foaming is the incorporation of air into a product, usually achieved by whipping (Bennion and Bamford, 1997). Egg white proteins have the capacity to form very stable foam. They produce a large foam volume which is relatively available for cooking and coagulate on heating to maintain the foam (Demirkol, 2007).

Emulsification is the stabilization of the suspension of one liquid in another (Bennion and Bamford, 1997). Egg achieves this process by the help of lecithin which is an excellent food emulsifier found in egg yolk.

Finally coagulation can be described as the conversion of the liquid egg to a solid or semi-solid state, usually accomplished by heating (Bennion and Bamford, 1997). Egg proteins coagulate over a wide range of temperatures.

In addition to above tasks, egg products have good binding and thickening properties in batter and dough because their proteins bind water and form more or less permanent foam-like structure since their proteins coagulate during heating (Matz,1992). Moreover the egg protein acts as a surface active agent to form a protective film around air bubbles. This helps to keep the air bubbles in the batter during mixing (Hui, 2007).

1.6.1.5. Shortening

"Shortening" is a word used to describe fats, oils, and various processed versions of fats and oils that are used as ingredients in doughs and batters and it may contain substances other than fats and oils, for example, flavors, colors and emulsifiers (Matz, 1992). It is one of the important ingredients in a cake formulation. Fairly high levels of shortening can be needed for most types of cakes for the development of their characteristic crumb structure. It modifies the physical properties of doughs and batters so that these intermediate products can be processed more efficiently. Addition of shortening affects the visual texture and tactile texture of the crust and affects the tenderness and moisture of the cake in desirable ways. It imparts desirable flavor to the product. It lubricate the internal structure of cake batter and so allow greater expansion during proofing and baking and make the texture of finished product more tender (Matz, 1992).

Fat plays role in entrapping air during the creaming process resulting in aeration. This process leavens the product.

To keep the product fresh for longer, oil or fat solid is needed. With the addition of oil/fat, the batter becomes an oil-in-water emulsion system (Hui, 2007).

In addition, fats 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.

In spite of the number of functions played by fat in improving the overall quality of cake the content is wanted to be reduced or replaced to protect consumers from several health hazards such as cardiovascular disease, atherosclerosis, diabetes and obesity (Demirkol, 2007). The number of low-calorie foods has increased steadily over the last few decades and this concern also reflected to bakery industry. The aim is to reduce the calorie without changing the texture and taste. There are numbers of fat and sugar replacers in the market. One group of fat replacer is the carbohydrate based fat replacers. Carbohydrate-based fat replacers are cellulose, dextrins, fiber, gums, inulin, maltodextrins, oatrim, polydextrose, polyols, modified starch, food starch, Z-Trim (Demirkol, 2007). Protein-based fat replacers are microparticulated protein, modified whey protein concentrate, simplesse. Fat-based fat replacers are caprenin, salatrim, olestra, emulsifiers, sucrose polyesters (Demirkol, 2007).

Emulsifiers are fat-based substances which are used with water in replacing (all or part of it) shortening content in cake, icings, cookies, and vegetable dairy products. They give the same calories as fat but because of their lower level of usage, fat and calorie intake reductions take place. Until the cake structure is set, they provide the necessary aeration and gas bubble stability during the process (Turabi et al., 2008). They facilitate the disruption of emulsion droplets during homogenization. Moreover emulsifiers reduce batter viscosity so helping the air incorporation in the batter during mixing. Moreover, emulsifiers, as surfactants, also help to stabilize gas bubbles during mixing and baking. They also affect pasting properties of starch during cooking and cooling cycles, which alter the rheological properties (Sakıyan et al., 2004) of batter and the final characteristics of the cake (Ronda et al., 2008).

Proteins and lipids are two main classes of food emulsifiers relevant to cake manufacture. Both can be used to aerate and reduce the density of batter (Demirkol, 2007).

1.6.1.6 Leavening Agent

Baking powder, yeast, or baking soda are the leavening agents used in cake manufacture. Baking powder is the leavening agent produced by the mixing of an acid reacting material and sodium bicarbonate, with or without starch or flour (Demirkol, 2007). Bicarbonate and acid are essentially two components in a chemical leavening system. Carbon dioxide gas is produced as a result of the action of the acid on bicarbonate. Bicarbonate supplies carbon dioxide gas and acid triggers the liberation of carbon dioxide from bicarbonate upon contact with moisture (Demirkol, 2007). This leads to aeration of batter during mixing and baking. There yields not less than 12% of available carbon dioxide providing a light, porous cell structure, fine grain, and a texture with desirable appearance along with palatability to baked goods.

1.6.2 Rheology of Cake Batter

Understanding the rheological characteristics of food materials is necessary for plant and products design. They are important in product development. Quality of cake can be correlated with rheological properties of batter since volume and texture is dependent on the cake batter rheology. For cakes an increase in batter viscosity and an improvement in batter stability are important in obtaining a noncollapsing, porous cake structure (Demirkol, 2007).

Cake batters are complex fat-in-water emulsions with four bulk phases; aqueous, fat, gas, and solid starch granules (Shelke, Faubion, 1990). The viscosity of these batters plays a large part in determining the characteristics of the resulting cakes. flour, water, fat, milk, egg, sugar, and salt are the basic ingredients of the cake batter and among them while flour, egg white, milk solids, and salt are used to toughen the cake, sugar, fat, and egg yolk are used to tenderize the cake (Sumnu and Sahin, 2008).

Different food ingredients affect the rheology of food materials. Rheological properties of fluid foods are complex and depend on many factors. Factors such as composition, shear rate, shear stress, thermal processes, and all of these application durations affects the rheology. Up to now effect of different food ingredients on rheology is investigated by many researchers.

The effect of salt and oil or their mixture on the rheological constants of raw and steamed wheat flour batter, the effects of dextrin or dried egg on the rheological properties of batters for fried foods, effect of fat content (found as the most influencing parameter as compared to emulsifier and thickener) on the rheology of salad dressings, effect of the type of starch and starch concentration on starch-milk-sugar pastes were all investigated (Demirkol, 2007).

Viscosity of cake batter is the controlling factor for the final cake volume. The rate of bubble rise due to buoyancy force is inversely proportional to the viscosity (Sumnu and Sahin, 2008). If the viscosity of the batter is low, then the batter can not hold the carbon dioxide and the produced water vapor and let them evolve which results in lower cake volume. Namely to retain more bubbles in the batter, higher viscosities is required in the cake batter. This will retard the rise of bubbles to the surface and will conclude with the desired cake mixing and baking process.

In addition, the velocity gradients in the batter during baking induces convection current at any given time depending on its viscosity, with lower batter viscosity resulting in more convection flow and higher batter viscosity prevents the entrapped air from coalescing due to drainage of surrounding batter during baking and reduces shrinkage (Sumnu and Sahin, 2008).

Shortly batter viscosity is really an important issue that is if the viscosity of the batter is too low, batter cannot hold the air bubbles inside and cakes will be low in volume and firm in texture.

There are many studies in the literature in which rheological properties of cake batter are correlated with the quality of cakes. The increase in batter density (decrease in air content incorporated in batter) decreased the storage (elastic) and loss (viscous) moduli of cake batter and also the specific volume of cake (Sumnu and Sahin, 2008).

1.6.3 Baking of Cakes

Baking is a critical process in cake baking since it effects is really important in final cake quality. It is important to select the suitable baking temperature and time. Baking is a complex process where the emulsion of cake batter aerated in mixing is converted to a semisolid porous, soft structure mainly due to starch gelatinization, protein coagulation, carbon dioxide gas produced from chemicals dissolved in the batter, air occlusion during mixing, and the interaction among the ingredients. During baking there occurs “a series of physical, chemical and biochemical changes in food such as gelatinization of starch, denaturation of protein, liberation of carbon dioxide from leavening agents, volume expansion, evaporation of water, crust formation and browning reactions” (Demirkol, 2007).

Baking is a simultaneous heat and mass transfer within the product and with the environment inside the oven. Temperature of the oven should be selected according to product’s size, shape, ingredients. If it is too high, then the final product will have small volume, high crust color and in irregular shape and also it can have an undesired taste. On the other hand, it the temperature is too cold, then the product will have large volume, weak crumb structure with poor crust color. The time is inversely related to the baking temperature, i.e. is a batter needs lower baking temperatures, and then it will need higher time. For example, batters with high sugar content and batters with larger in size need lower baking temperatures and higher times. The optimum conditions are determined according to the ingredients and their percentages, and according to batter size.

In mixing process before egg is added, sugar is beaten into the fat to give an aerated cream and so the fat sugar cream is prepared. The sugar goes into solution and water in oil emulsion is formed, the air cells being dispersed in the fat phase only (Demirkol, 2007). Then the flour is added and its particles are suspended in the aqueous phase of the complete batter. When the temperature rises to 40 °C, the fat begins to melt and the irregular shaped fat particles roll up into spherical droplets, and any water-in-oil emulsion portions of the batter convert into oil-in-water and then the air bubbles are released from the fat phase to the aqueous phase.

Followingly cake batter undergoes a considerable amount of bulk flow and the water vapor and carbon dioxide move into air cells and total batter expands. In the final part of baking the final cake structure is formed as a result of gelatinization of starch and coagulation of proteins in the final stages of.

1.6.4 Quality of Cakes

Quality is the most important issue in terms of both manufacturers and consumers. Cauvain and Young (2006) list the factors contributing to variation in baked-product quality as in Table 1.3.

Cake quality is determined mainly by three factors: suitability of the individual ingredients for the specific type of cake being made, the proportions or balance in which the ingredients are combined in the cake Formula, and the procedures followed in mixing and baking (Mizukoshi, 1985). High-quality cakes have high volumes, tenderness, uniform crumb structure, longer shelf life; tolerance to staling, desired color and flavor and tasty mouthfeel.

Table 1.3 Factors contributing to variation in baked-product quality

Size	Dough or batter piece weight
	Product volume
Shape	Moulding, shaping, forming or depositing
	Using pans, trays or processing as a free-standing item
External colour	Ingredients and their qualities
	Formulation, ingredient ratios
	Baking and other processing technologies
Crust character	Baking temperatures, times and control of oven atmosphere
	The use of steam or oven damper
Crumb cellular structure	Ingredient qualities
	Formulation, ingredient ratios
	Mixing and other processing Technologies
	Heat transfer during baking
Internal colour	Ingredient qualities
	Formulation, ingredient ratios
	Crumb cellular structure
Crumb softness	Final product moisture content
	Ingredient qualities
	Formulation, ingredient ratios
	Crumb cellular structure
	Baking temperatures, times and control of oven atmosphere
	Post-baking treatment, for example packaging and staling
Mouth-feel	Moisture
	Crumb cellular structure
	Formulation, ingredient ratios
	Post-baking treatment
Taste	Specialist processing, such as prolonged fermentation of bread dough
	Ingredient qualities
	Formulation, ingredient ratios
	Crumb cellular structure
	Baking temperatures, times and control of oven atmosphere
	Post-baking treatment
Aroma	Specialist processing
	Ingredient qualities
	Formulation, ingredient ratios
	Crumb cellular structure
	Baking temperatures and times
	Post-baking treatment

In order to make a satisfactory cake, all the ingredients must be properly balanced. All the ingredients have different effects on cake. While the ingredients such as fat and sugar have softening effects, eggs have firming effects on cakes. In general, cakes with a low specific volume are firm (Gélinas et al., 1999). Since the quality of the final product depend on the balanced formula, aeration of cake batters, stability of fluid batters in the early stage of baking, and thermal-setting stage, the substances other than the basic cake ingredients, can be used to modify the quality of the cake.

Fiber components could be used to partially predict the parameters of cake quality such as viscosity, tenderness, volume, cell size, cell wall thickness, and grain (Jeltema and Zabik, 1732). They can be used to improve food texture, improve moisture retention and enhance the overall quality of the products during storage. They can affect texture and rheology of the cake batter and so affect the final cake quality.

Every parameter that plays an important role on the acceptability of the cakes can be measured by various methods. Subjective scoring sheets for size, shape or/and taste can be used. Height data can be taken to compare, volume, moisture content, density and color can be measured, cellular structure of the crumb can be assessed by eye or by using objective image analysis. Moreover texture parameters can be measured by both sensory evaluations and uniaxial compression methods. Firmness of cakes can be quantified by compressing the sample and measuring the force necessary to attain a predetermined penetration. Instrumental Texture Profile Analysis (TPA) has been widely adapted to the study of textural properties of bakery goods (Koksel, 2009). Parameters such as hardness, springiness, chewiness, cohesiveness, gumminess and fracturability are measured using TPA by compressing a sample of specific dimensions uniaxially.

1.7 Objectives of the Study

The primary aim of this study was to evaluate the potential of tomato fiber coming from tomato waste, and wheat fiber coming from the wheat bran as a rheology modifier, texture modifier and water holding agent. In order to do this, rheological properties and water holding capacity of the ketchups with obtained tomato fiber were examined and compared with other ketchups produced with tomato powder and with the ketchups sold in the market. Water holding capacity was examined by using lumisizer. In the same way, in terms of rheology, cakes with wheat bran fiber and wheat bran were compared. Moreover for both tomato fiber and wheat bran fiber the microstructures were examined by Scanning Electron Microscope (SEM) and compared with the powders' microstructures.

As a texture modifier wheat bran was investigated by considering volume, outer surface, hardness, cohesiveness and gumminess.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

For tomato ketchup preparation, tomato paste, vinegar, sugar, and salt were bought from local markets. Tomato wastes used in the study was obtained from Tukas Industry Co. Inc. (Izmir; Turkey). Tomato powder was prepared from dried tomato skin by using hammer mill.

For the cake preparation, flour (Piyale, Istanbul, Turkey), sugar, salt, baking powder (Dr. Oetker, Izmir, Turkey), shortening (Becel, Unilever, Turkey), non-fat milk powder, were bought from local markets. Egg white powder containing 8% moisture, 82% protein and 4% carbohydrates was obtained from Igreca (Seiches Sur le Loir, France).

2.2 Methods

Tomato fiber and wheat bran fiber obtained from tomato wastes and wheat bran respectively. Micro structures of the produced fibers were characterized by using particle size analyses and microscopic techniques; scanning electron microscope (SEM). Rheological properties (flow properties, yield stress, viscoelastic properties) and water holding capacity of produced fiber were examined. Produced tomato fiber and wheat bran fibers were also tested in different concentrations during ketchup and cake production respectively as a rheology modifier and water holding agent. Rheological properties and water holding capacity of the ketchup with produced tomato fibers were examined and compared with ketchups sold in the market. The comparison also done between the samples prepared with tomato powder. Rheological properties of cakes prepared with wheat bran fiber and wheat bran were also examined and compared. Furthermore texture analyses were done for the cakes baked.

2.2.1 Production of Fibers

2.2.1.1 Obtaining Tomato Fiber

Tomato waste (skin) appearing from tomato paste production was used to obtain tomato fiber. In the first part of the study, the softening and delignification processes were done by keeping the raw material in a slightly alkali solution of for overnight (pH was set to 8) . Softened fibers underwent the size reduction step using a microfluidizer at two stages. At the first stage 500 bar pressure was used and second stage 1250 bar pressure was used. Finally the obtained micro and nano tomato fiber was centrifuged (6000 rpm) in order to adjust the moisture content of the fiber.

2.2.1.2 Obtaining Wheat Bran Fiber

Wheat Bran Fiber was obtained from wheat bran. First of all, the softening and delignification processes were again done by keeping the raw material in a slightly alkali solution for overnight. Similar to the tomato fiber production softened wheat brans underwent two stages size reduction step using a microfluidizer. Finally to adjust the moisture content of the fiber, the obtained micro and nano wheat bran fiber was centrifuged (6000 rpm).

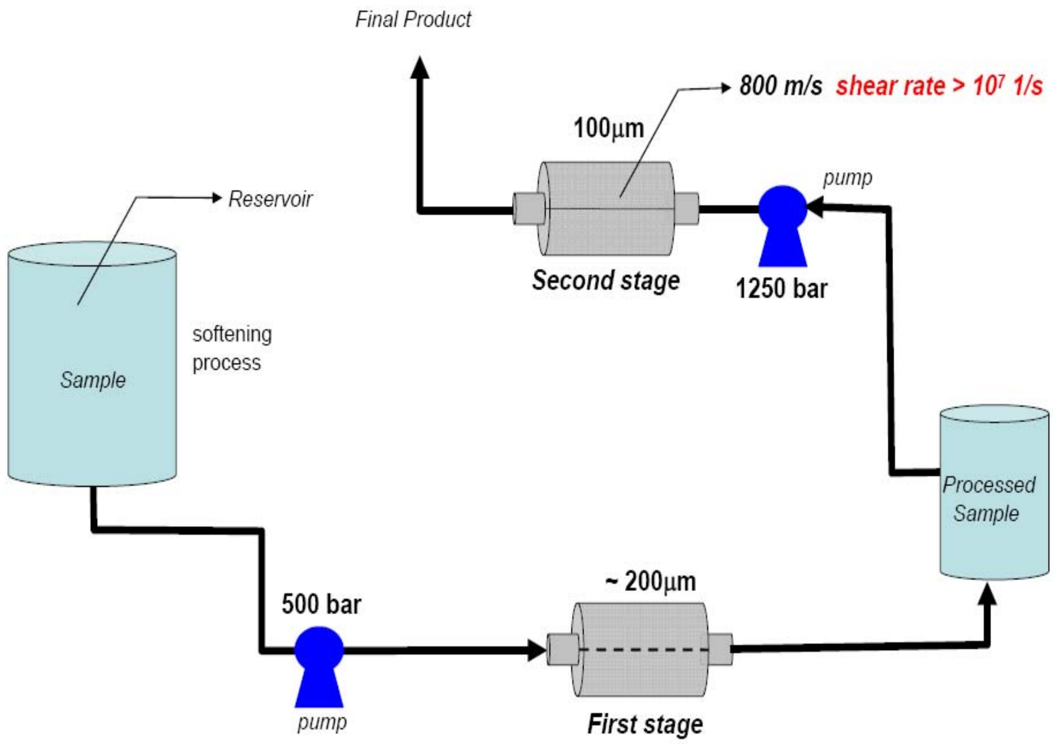

Figure 2.1 Schematic of the size reduction process

2.2.1.3 Size Reduction Steps

After the softening step, the wheat bran or tomato skin samples underwent a series of size reduction steps using a microfluidizer equipment (Figure 2.1). This process separates macro fibers into nano and micro fibers by applying high shear rate. In other words the fibers are forced to pass through a micro channels at velocities up to 800 m/s (speed of sound in air ~300 m/s) causing break up of the bundles.

2.2.2 Micro structures of fibers

Micro structures of the produced fibers were characterized by using particle size analyses and microscopic techniques (scanning electron microscope).

2.2.2.1 Particle Size Analysing

Particle size analyzing was performed by a particle size analyzer (Malvern Mastersizer 2000) from central laboratory of METU (Ankara, Turkey).

2.2.2.2 Microscopic Techniques

Microscopic analysis was performed by a scanning electron microscope (SEM) (QUANTA 400F Field Emission SEM) from central laboratory of METU (Ankara, Turkey). SEM for used for both produced fibers and ketchups prepared.

2.2.3 Rheological properties

Rheological properties of produced fibers, tomato ketchups and cake batters were examined using a rheometer (AR 2000ex Rheometer). Parallel plates with 40 mm diameter were used during experiments. The gap was adjusted either 1.5 mm or 2.0 mm according to the sample. The tests were performed in triplicate. Flow properties; yield stress, viscoelastic properties were measured as the representative rheological properties.

2.2.4 Water holding capacity

Water holding capacity of produced fiber and fiber containing ketchup samples were also examined. It was measured by Dispersion Analyzer Lumisizer

(Germany). The samples were placed in special tubes and exposed to centrifugal force under 3000 rpm. During centrifugation the phase separation between the water and solids were monitored with near infrared light and speed and extent of phase separation were determined.

2.2.5 Measurement of moisture content

Moisture of the samples was determined by using moisture analyzer (IR-35, Denver Instrument). The temperature was set to 106 ˚ C.

2.2.6 Preparation of tomato ketchup

Produced fibers were also tested in different concentrations during ketchup production as a rheology modifier and water holding agent. Ketchups were prepared according to the constituents below:

Tomato ketchup was prepared according to two different formulations. They were;

First formulation:
1- tomato paste (44% wt)
2- sugar (8.3 % wt)
3- vinegar (8.3 %wt)
4- salt (7% wt)
5- water (38% wt).

Second formulation:

1- tomato paste (30% wt)

2- sugar (13 % wt)

3- vinegar (8 %wt)

4- salt (2% wt)

5- water (47% wt).

For both formulations, ingredients were mixed and after mixing process, heated to 90 ˚C. After heating the ketchup samples were prepared by passing the sample through colloid mill at 10000 rpm. For the testing of the effect tomato fiber on ketchup rheology the fibers were added to the ketchup samples at varying amounts as shown in result section.

2.2.7 Preparation of cake batter

Cakes were prepared from blends containing 0%, 3%, 6%, 9% and 15% of wheat fiber (w/w, based on the wheat flour used). The formula included 100 g flour, 100 g water, 80 g sugar, 50 g shortening, 12 g milk powder, 8 g egg white powder, 6 g baking powder and 1.5 g salt. Other than this formula, samples with 80 and 60 g flour were also prepared without changing other ingredients as weight.

Cake batter was prepared using a mixer (Krups). To obtain uniform mixing, ingredients were not poured at the same time; baking powder , shortening, and egg white powder were creamed together to get a fluffy cream; and then milk powder, sugar, and salt is mixed. They were whipped together, and finally flour and water added. Wheat Bran and Wheat fiber was added before flour and water was added at flour based levels of 0%, 3%, 6%, 9%, and 15% and (25 % fiber was also used for 60 g flour containing samples). Cake batter (20 g and 60 g samples) was poured into silicon moulds and baked at 170-175 ˚C for average of

10 minutes for 20 g samples, and 15 minutes for 60 g samples. Cakes were cooled to room temperature. The cakes were evaluated after their relative humidity equilibrated at 80 %.

2.2.8 Baking

Cake samples of 60 g and 20 g were baked in conventional oven (Susler, Istanbul) for 10 minutes (20 g samples) and 15 minutes (60 g samples) at 170-175 ˚C.

2.2.9 Texture analysis

Texture profile of the cake samples was determined using a Texture Analyzer (The TA.XT*Plus*, England). Two types of experiments were basically used. At the first part cake samples were cut using a sharp knife attached to the texture analyzer (Figure 2.2) and the force required to cut the samples was recorded. Extent of the cutting was set to 50% of the initial sample thickness and the speed of cutting was 2 mm /s. Texture profile analysis was also used to characterize cake samples. For this procedure initially the samples were cut into slices with 1 cm thickness. Then by using a 3 cm diameter cylindrical probe the cake slices were compressed twice using 60% strain rate. Finally the results were analyzed in terms of hardness, cohesiveness and gumminess.

Figure 2.2 Experimental setup for cake cutting experiment

CHAPTER 3

RESULTS AND DISCUSSION

In the first part of the study, analyses about tomato ketchup were done. Some rheological properties of tomato ketchup were investigated. Effect of tomato fiber addition was compared with tomato powder in terms of rheology in tomato ketchup. Different concentrations of tomato fiber and tomato powder were tried. Furthermore, different brands of tomato ketchups were also considered. In addition, tomato powder and tomato fiber used in tomato ketchup was investigated under Scanning Electron Microscope (SEM). In ketchup analysis, stability measurements were also done.

In the second part of the study, analyses on cake were done. Rheology of cakes was investigated by considering the amount of flour (100 gram, 80 gram and 60 gram flour) on the cake formulation. Effect of bran fiber addition was compared with wheat bran in cake in terms of rheology. Wheat bran and wheat bran fiber were investigated using SEM. Moreover, texture of cakes prepared was all investigated in terms of volume, outer surface, hardness, cohesiveness and gumminess. For comparison, the cakes having the same formulation, with only changing the amount of flour, and baked in conventional oven were used.

3.A Tomato Ketchup Analysis

3.A.1 Rheology of Tomato Ketchup

The science of rheology has many applications in the fields of food acceptability, food processing, and food handling. Rheological measurements are quite relevant in the food industry as a tool for physical characterization of raw material prior to processing, for intermediate products during manufacturing, and for finished foods (Tabilo-Munizaga and Barbosa-Canovas, 2005).

Rheology defines a relationship between the stress acting on a given material and the resulting deformation and/or flow that takes place. Therefore stress (force per area) and strain (deformation per length) are key to all rheological evaluations. Stress (σ) is a measurement of force per unit of surface area and is expressed in units of Pascals (Pa) and strain is a dimensionless quantity of relative deformation of a material.

The viscous properties of tomato ketchup have been traditionally described by a power-law model (Ostwald de Waele) or by models (Casson and Herschel-Bulkley) involving a yield stress value as a fitting parameter (Valencia et al., 2004).

The oscillatory test, also called the dynamic rheological experiment, can be used to determine viscoelastic properties of food. The knowledge of the linear viscoelastic properties of tomato ketchup is of great importance to obtain information in conditions close to the unperturbed state, to characterize its microstructure and, also, to predict its viscous flow behavior through the development of suitable non-linear viscoelastic models (Valencia et al., 2004).

A useful procedure in the study of food rheology is to subject the same sample to a periodic deformation (Shabora et al., 2005). If the rheological behavior is studied through a dynamic test, the stress is made to vary sinusoidally with time at a determined frequency (w) (Shabora et al., 2005). Oscillation is an ideal method to investigate the structure of foods.

The elastic modulus, G', and the viscose modulus G'' is the key factors used in oscillation tests. G' value is a measure of the deformation energy stored in the sample during the shear process, representing the elastic behavior of a sample whereas G'' value is a measure of the deformation energy used up in the sample during the shear and lost to the sample afterwards, representing the viscous behavior of a sample. If G' is much greater than G'', the material will behave more like a solid; that is, the deformations will be essentially elastic. However, if G'' is much greater than G', the energy used to deform the material is dissipated viscously and the material behaves like a liquid (Tabilo-Munizaga and Barbosa-Canovas, 2005). For a perfectly elastic solid, all the energy is stored, i.e. G'' is zero and the stress and the strain will be in phase. In contrast, for a liquid with no elastic properties, all the energy is dissipated as heat; G' is zero (Sharoba et al., 2005).

3.A.1.1 Analysis of Different Brand Tomato Ketchups

3.A.1.1.1 Steady Rheological Properties

Shabora et al., (2005) studied the rheological behavior of some commercial German and Egyptian tomato ketchups and found that these tomato ketchups behave as non-Newtonian fluids and have a definite yield stress. The rheological behavior was pseudoplastic. The steady flow curves that they obtained were described by the Herschel–Bulkley model.

Yield stress is an important rheological parameter for predicting the product's processing and/or end-use performance. It is important all in the handling, elastic, processing and transport of the product.

The stress level required to initiate flow is usually referred to as yield stress and is related to the level of internal structure in the material, which must be destroyed before flow can occur (Tabilo-Munizaga and Barbosa-Canovas, 2005).

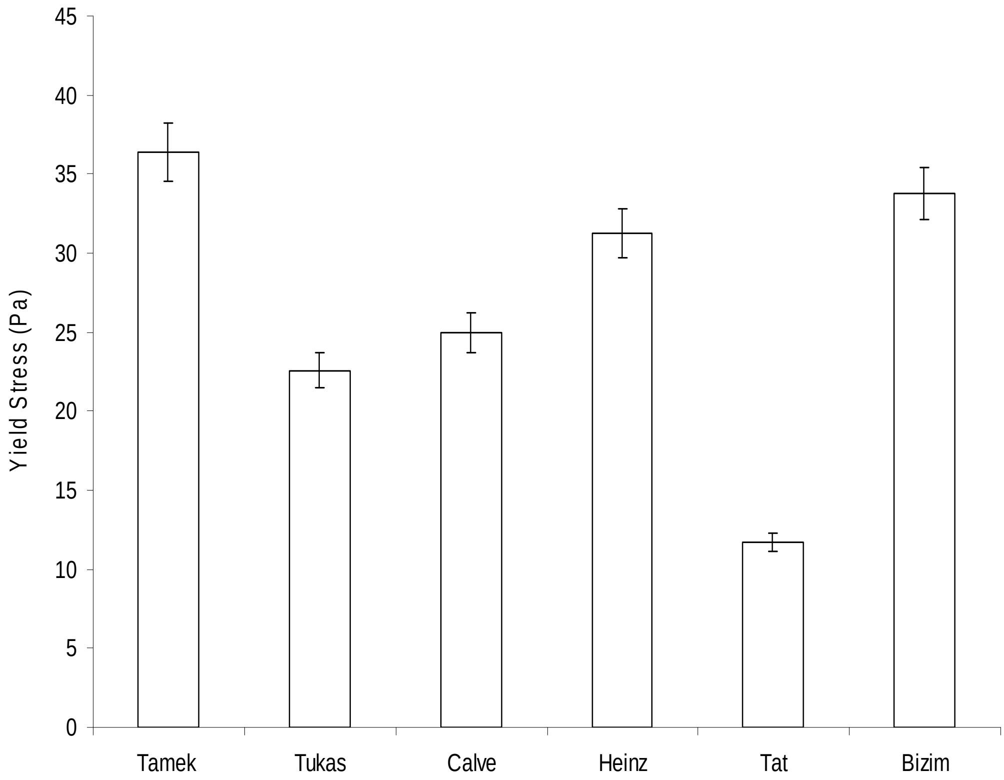

Figure 3.1 Yield stress values of different brand tomato ketchups

The different brands of tomato ketchups showed different yield point values (Figure 3.1). Tomato ketchups tested were Tamek, Tukas, Calve, Heinz, Tat, and Bizim. These kinds represent the most widely available tomato ketchups that are used in Turkey. The yield point was higher for Tat, and Tukas and lower for Heinz, Bizim, Calve and Tamek brands. The yield stress values at 20 °C were 36.4, 22.6, 25, 31.2, 11.7 and 33.8 Pa for Tamek, Tukas, Calve, Heinz, Tat and Bizim brands respectively.

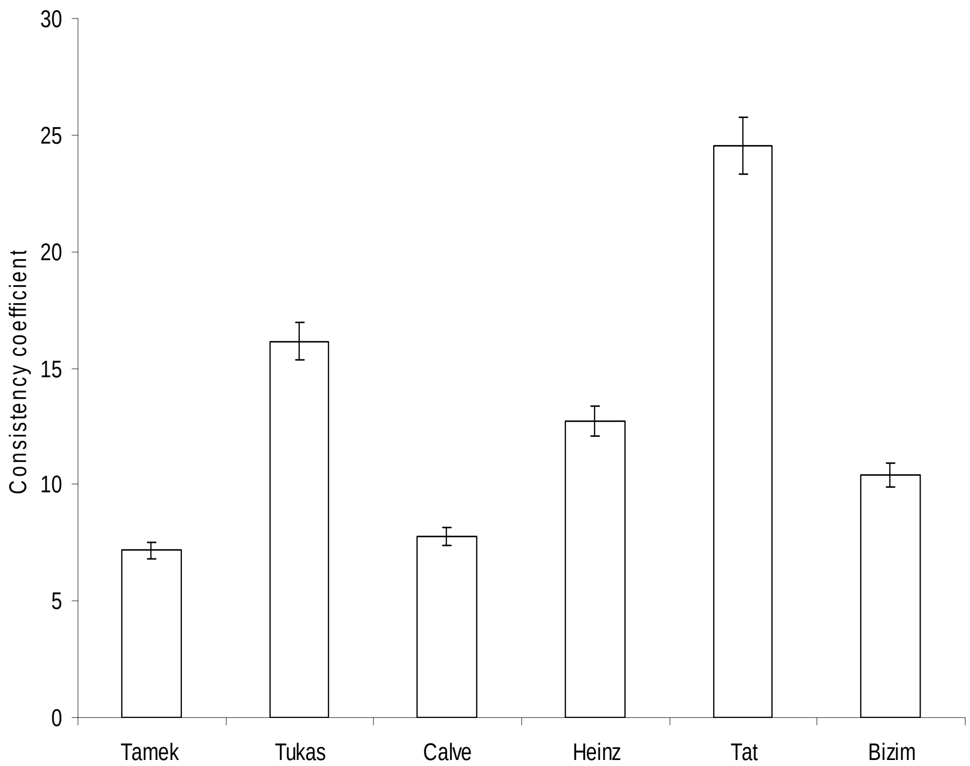

Figure 3.2 Consistency values of different brand tomato ketchups

The consistency is an important parameter for the texture of ketchup. It determines to a great extent the overall feel in the mouth and influences the intensity of the flour. Too thick or too thin texture is undesirable, so to obtain the optimum viscosity ranges is important to increase quality.

When the consistency index values of different brands of tomato ketchups were investigated, it was seen that all brands showed different consistency index values (Figure 3.2). The values of Heinz, Bizim, Calve, Tukas were lower compared with Tat and Tukas. Table 3.1 shows the exact values for the brands.

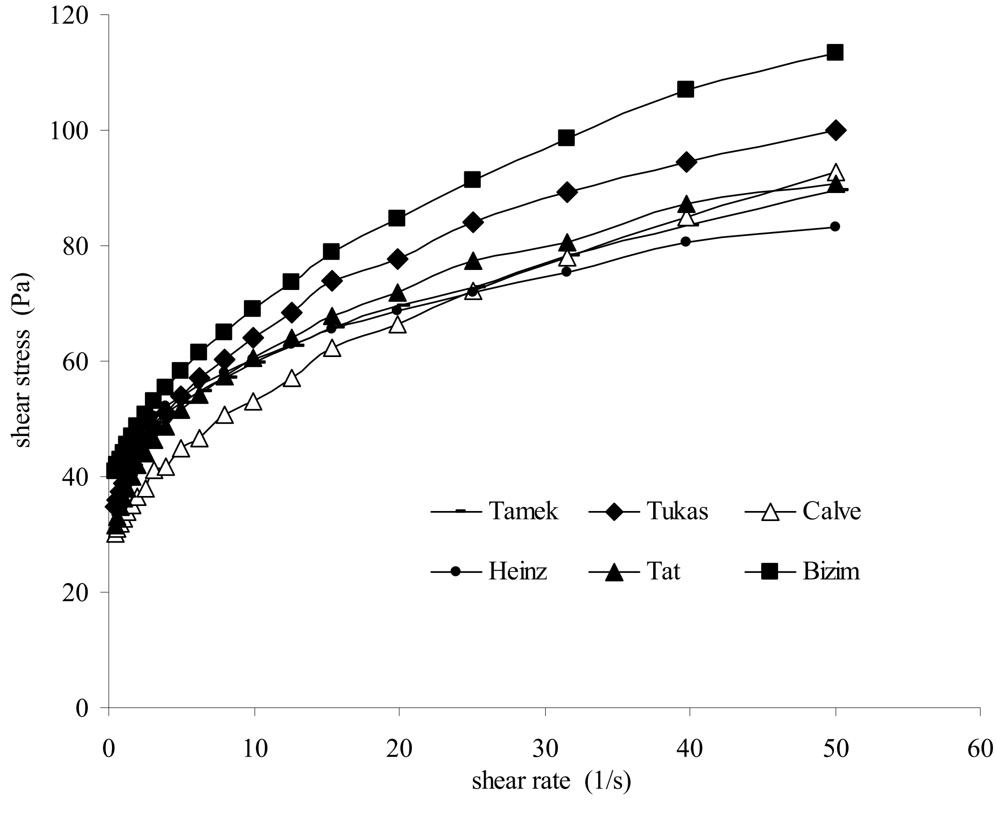

Figure 3.3 Shear stress versus shear rate values of different brand tomato ketchups

It is seen that the yield stress and consistency data are different for each brand, the reason for such differences between different tomato ketchup brands might be referred to the variations in their content of total solids, pectic substances and the particle size and shape (Sharoba et al., 2005). In addition, the type of gum or the amount of tomato that was used to balance the consistency of the product might be the reason for these differences.

Despite the differences in terms of values, all the ketchups under examination were non-Newtonian fluids, since the values for flow behavior index (n) is smaller than 1 (Table 3.1), which was also indicative of the pseudoplastic (shear thinning) behavior (the behavior in the Figure 3.3 was also a demonstrator of the pseudoplastic behavior). The flow index values n for the tomato ketchups are given in Table 3.1. The n values ranged between 0.30 and 0.56.

Table 3.1 Some values related with flow behavior for different brand tomato ketchups

brands	**yield stress**	**consistency index**	**n**
Tamek	36.40	7.18	0.51
Tukas	22.59	16.15	0.41
Calve	25.00	7.75	0.56
Heinz	31.23	12.72	0.36
Tat	11.74	24.56	0.30
Bizim	33.77	10.41	0.53

3.A.1.1.2 Dynamic Rheological Properties

Valencia et al. (2004) studied the effects of tomato paste properties on the linear viscoelastic properties of tomato ketchup prepared using different tomato paste samples. They concluded that the tomato ketchup linear viscoelasticity strongly depends on the tomato paste processing and tomato variety.

Shabora et al., (2005) studied the rheological behavior of some commercial German and Egyptian tomato ketchups and oscillatory test data that they did revealed weak gel-like (dispersion structure) behavior of the ketchup: the magnitudes of G' were higher than those of G''(that is the tomato ketchup were more elastic than viscous), and both increased with oscillatory frequency. They found that the ketchups showed semi-solid behavior at all temperatures assayed and the reason of this semi-solid behavior was the result of a complex interaction among the pulp, soluble pectin, organic acids, soluble solids and the high volume concentration of particles.

The linear viscoelastic behavior shown by the tomato ketchup samples studied was similar to that found with other tomato products studied before (Valencia et al., 2004). Figure 3.4 and Figure 3.5 show that the ketchups under consideration revealed weak gel-like behavior since the magnitudes of G' were higher than those of G''. The frequency dependence of the linear viscoelasticity functions showed a predominantly elastic response, with higher values of the elastic modulus in the whole experimental frequency range studied (Figures 3.4 and 3.5). In all brands both G' and G'' increased with angular frequency.

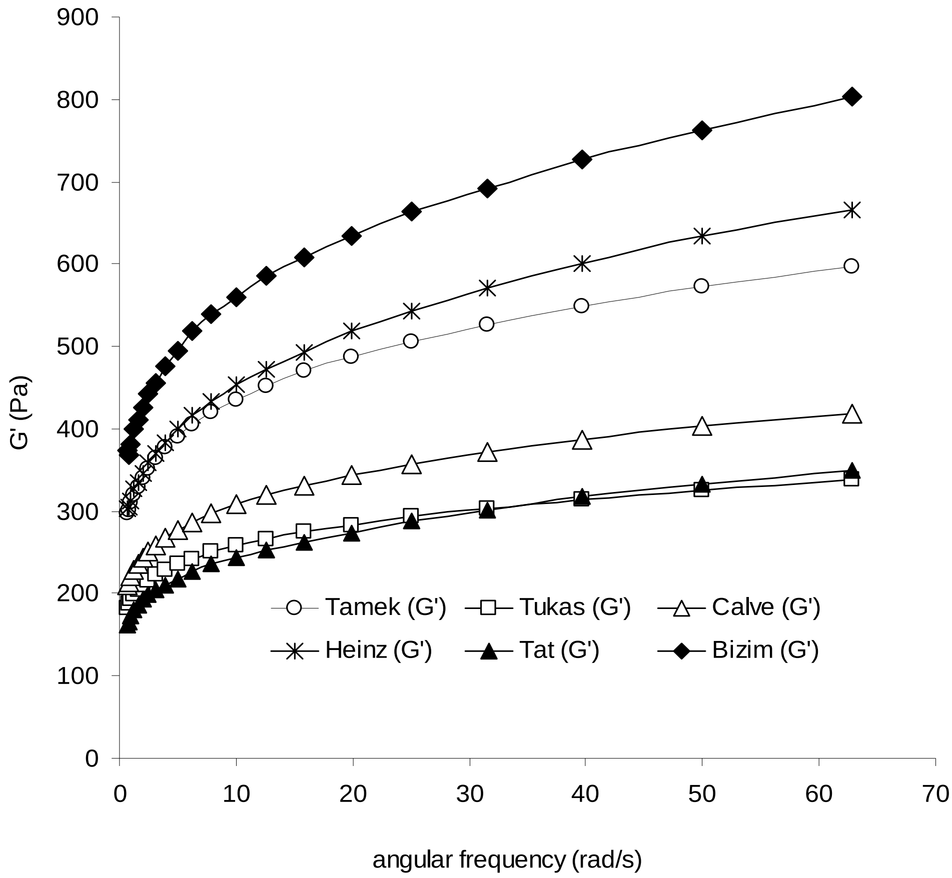

Figure 3.4 Elastic modulus versus angular frequency data of commerical brand tomato ketchups

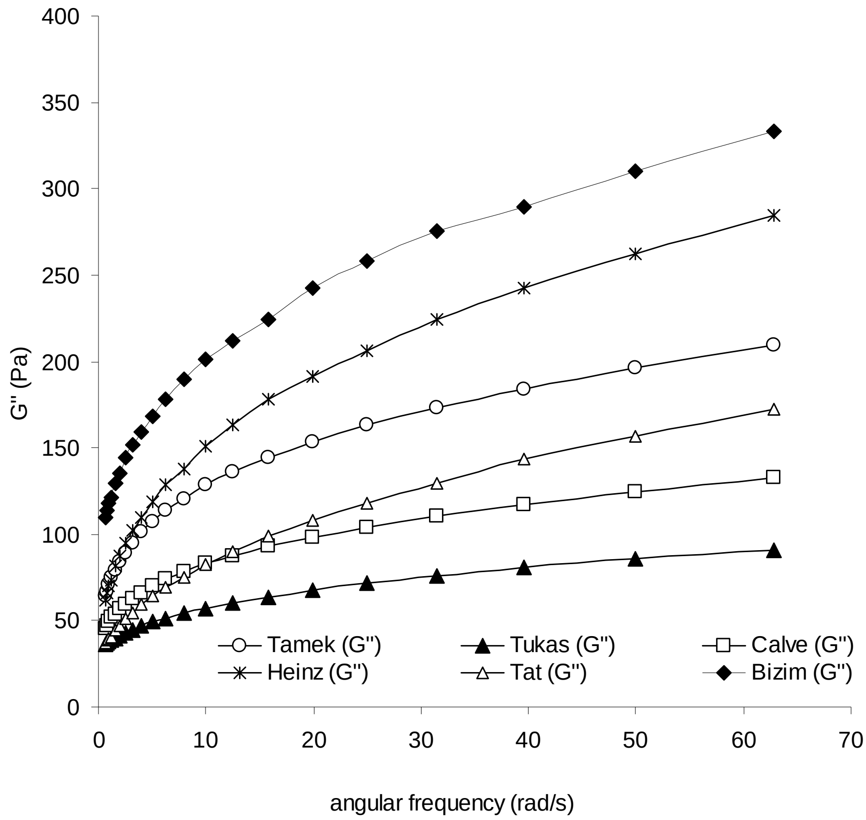

Figure 3.5 Viscose modulus versus angular frequency data of commerical brand tomato ketchup

3.A.1.2 Effect of Tomato fiber Addition on Rheology of Tomato Ketchup

There are lots of factors that can influence the rheology of foods; compositions, variety, ripeness, processing methods, temperature, time, analytical assumptions, instrumental techniques, and analytical methods are some of these factors.

Yield stress and viscosity data, shear stress-shear rate curves, elastic and viscose moduli data are important to understand the rheological behavior.

3.A.1.2.1 Steady Rheological Properties

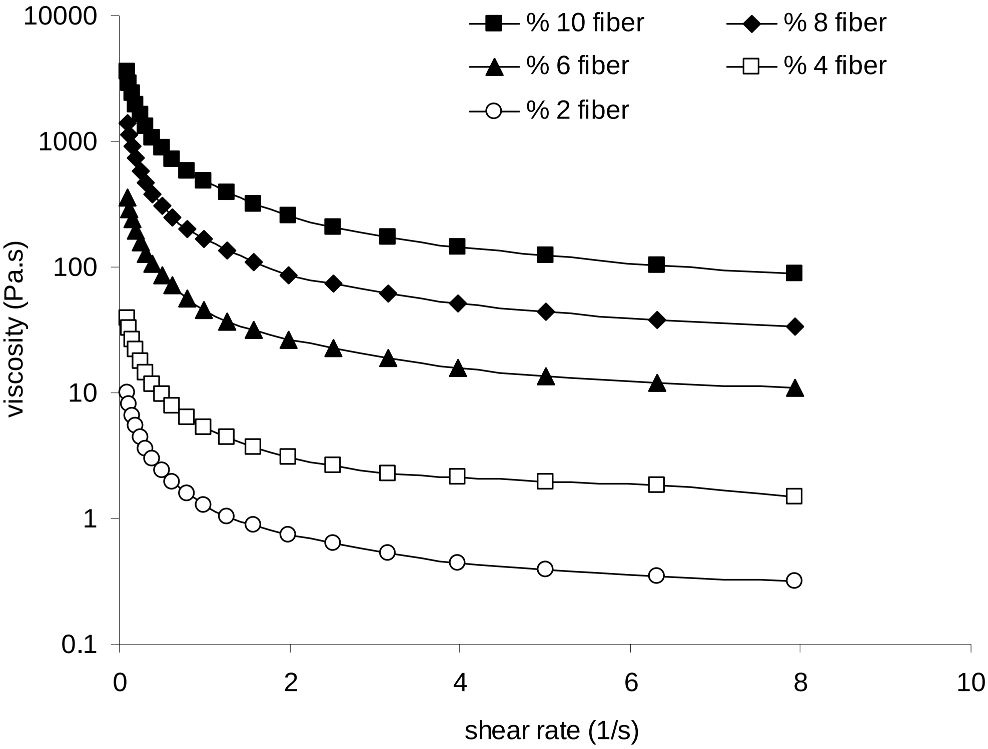

Figure 3.6 Viscosity versus shear rate values of tomato fibers

Both tomato fiber and tomato powder showed non-Newtonian pseudoplastic (shear thinning) behavior (Figures 3.6 and 3.7) that is the viscosity decreased with increasing shear rate but the behavior is very weak in powder formulations. In powder formulations shear rate had limited effect on the viscosity so the curves for powder resembled also to the Newtonian models.

Figures 3.6 and 3.7 also showed that the viscosity values increased as the percentage of tomato fiber and tomato powder increased. From the figures, it can be seen that the viscosity values were much higher in tomato fibers than in tomato powder. If the viscosity values for 10 percent powder and 10 percent fiber are compared, it can be seen that fiber has nearly 100 000 times higher viscosity than the powder which is a really striking result.

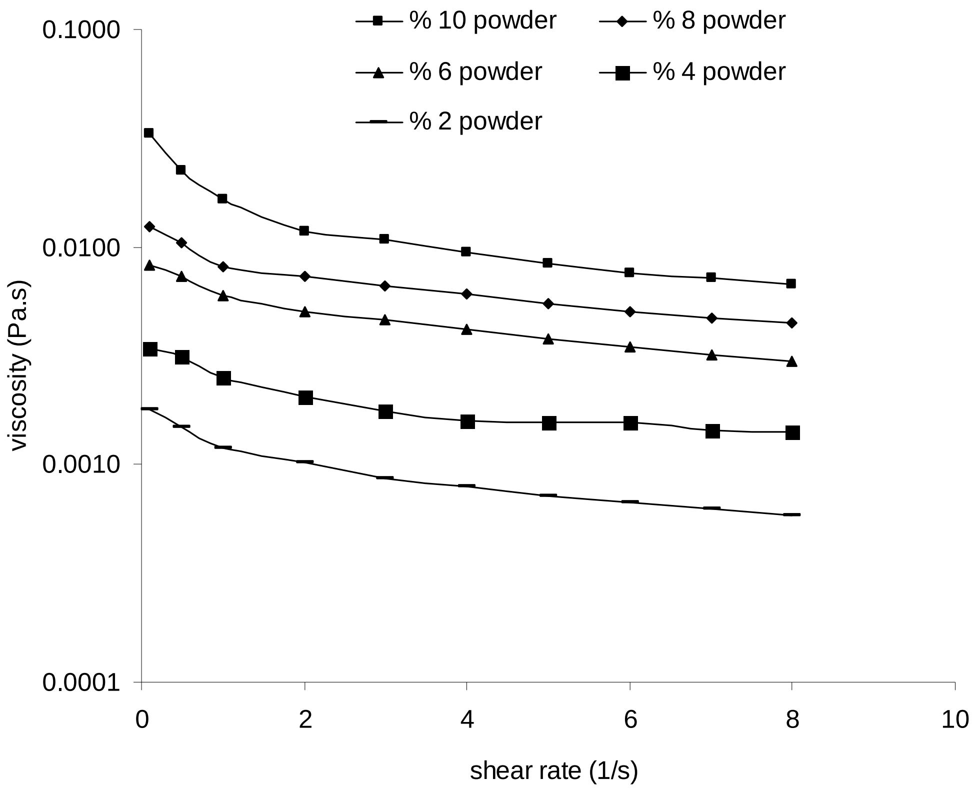

Figure 3.7 Viscosity versus shear rate values of tomato powder

Taking into account the Figures (Figures 3.6 and 3.7) without seeing the results of ketchups formulated with tomato fiber and tomato powder, we may conclude that the influence of the pulp fiber on the rheology of tomato ketchup will be significantly larger. On the other hand tomato powder will not have any significant effect on it.

Table 3.2 Some values related with flow behavior for tomato fiber

	Yield stress	consistency index	n
10% fiber	325	142	0.45
8% fiber	142	28	0.65
6% fiber	37	9	0.77
4% fiber	4,1	3,9	0.85
2% fiber	1,1	0,9	0.91

The consistency index values of tomato fibers are shown in Table 3.2. It is obvious from the figure that the consistency values increase as the percentage of the fiber increase. It is well known that the higher the total solids the better will be the quality of the end product. So as the percentage of the tomato fiber increase, both the yield stress and consistency index values increase.

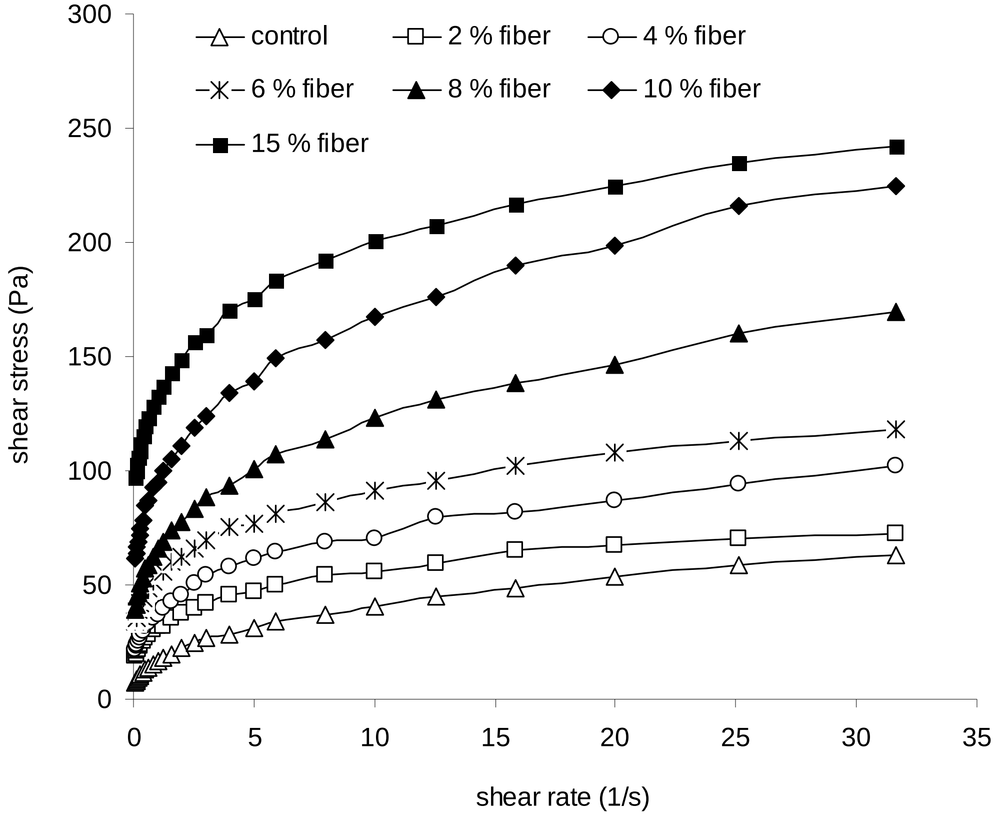

Figure 3.8 Shear stress versus shear rate values of tomato ketchup formulated with different percentage of tomato fiber (based on total dry matter content of tomato paste)

Figures 3.8 and 3.9 show the shear stress versus shear rate graphs of ketchups made with fiber and powder. In these graphs the percentages were based on total dry matter content of tomato paste used on the Formula. Both tomato fiber and tomato powder formulations showed non-Newtonian pseudoplastic (shear thinning) behavior (Figures 3.8 and 3.9) that is the viscosity decreased with increasing shear rate. The flow profiles were best characterized by a Herschel-

Bulkley expression. When the figures (Figures 3.8 and 3.9) compared with the ones belonging to the ketchups sold in the market (Figures 3.3), it can be concluded that the same flow behavior can be obtained when 6 % tomato fiber used in the formulation. In terms of powder, about % 20-25 powder should be used to catch the same trend. This result is coherent with the Figures 3.6 and Figures 3.7, that the effect of the pulp fiber would be much more than the tomato powder.

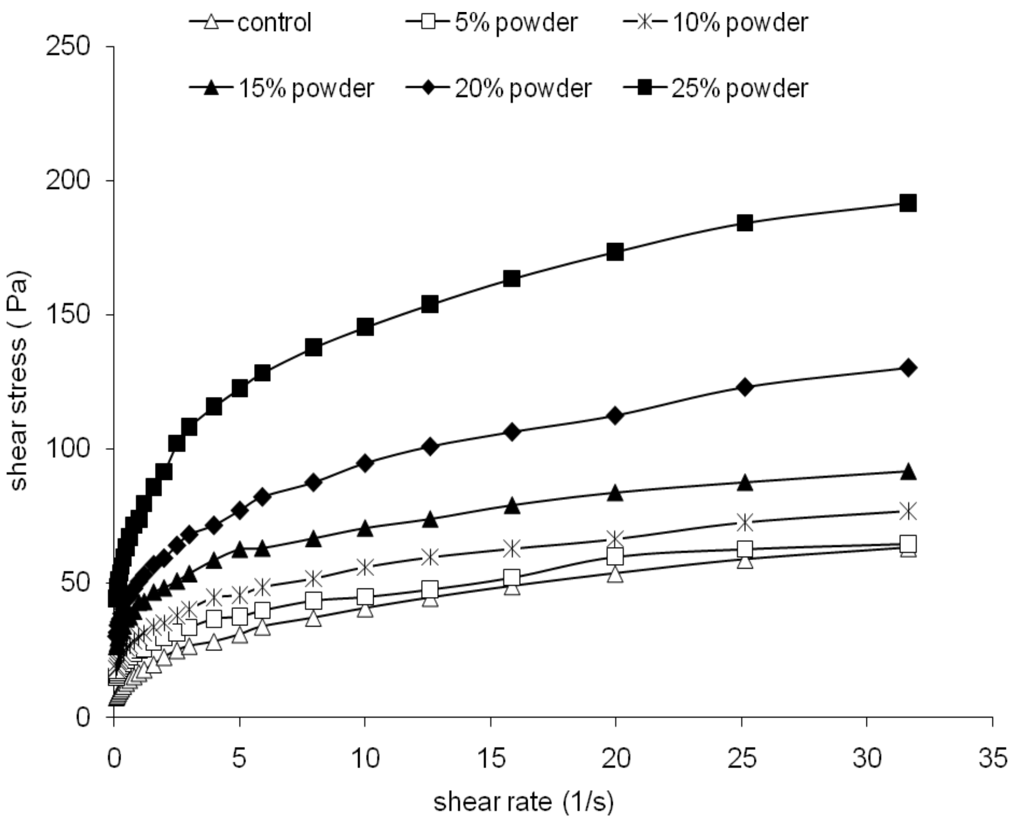

Figure 3.9 Shear stress versus shear rate values of tomato ketchup formulated with different percentage of tomato powder (percentages based on total dry matter content of tomato paste)

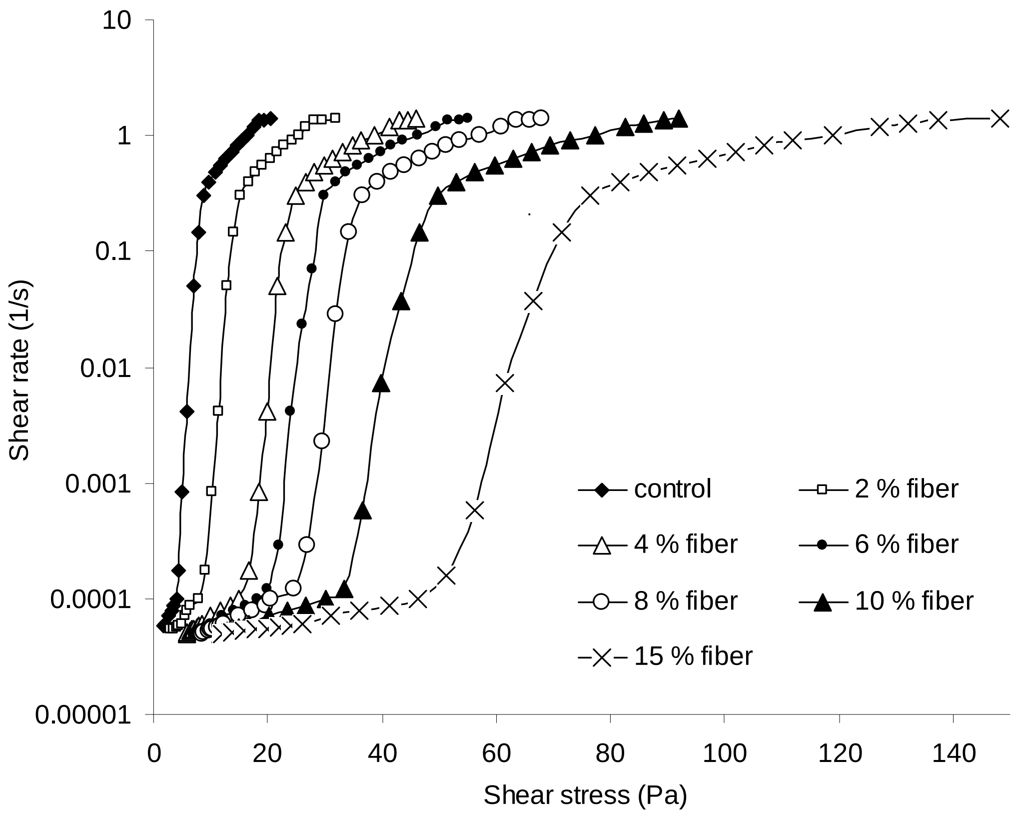

Figure 3.10 Shear rate (1/s) versus shear stress (Pa) values of tomato ketchups formulated with different percentage of tomato fiber (percentages based on total dry matter content of tomato paste)

The ketchup does not flow until reaching a certain levels of stress (called yield stress). As mentioned before, this stress is important from consumers and engineerings' viewpoints. Shear rate versus shear stress graphs can be used to detect this value. The value of shear stress where there is a big change in shear rate gives this value (yield stress). Figures 3.10 and 3.11 show this data.

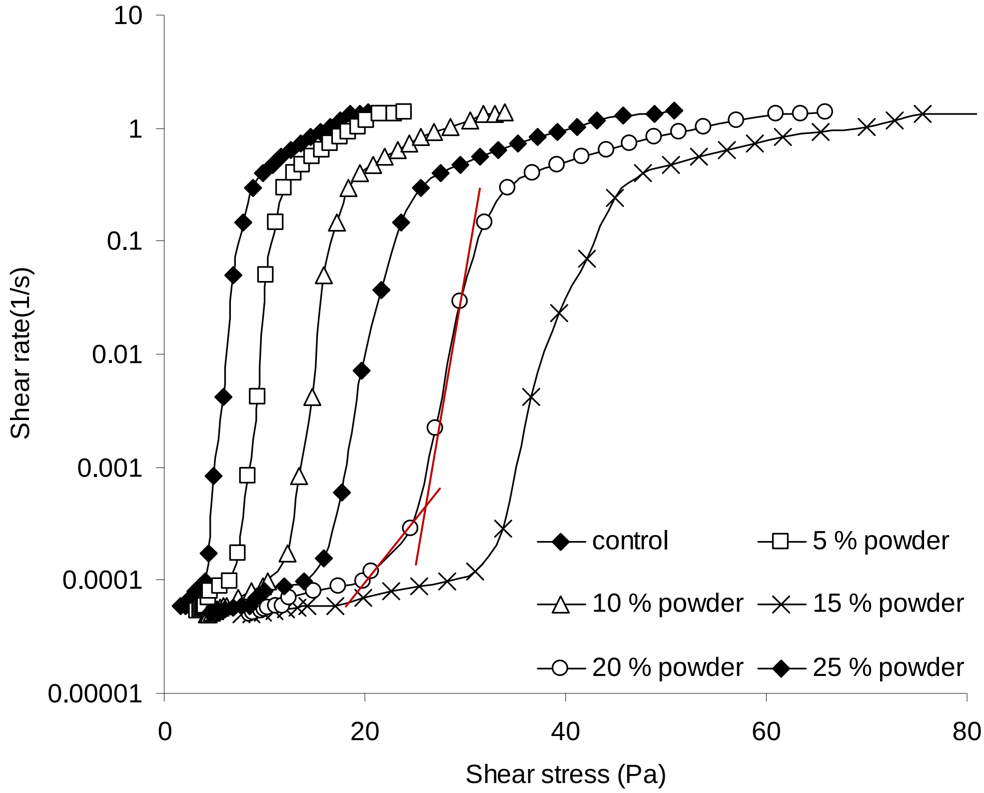

Figure 3.11 Shear rate (1/s) versus shear stress (Pa) values of tomato ketchups formulated with different percentage of tomato powder (percentages based on total dry matter content of tomato paste)

In figure 3.12 yield stress of the samples were found according to the Figures 3.10 and 3.11 (In figure 3.11 the method was shown for 20% powder; the stress corresponding to the intersection gives the yield stress). The resulting graph (Figure 3.12) showed that the increase in both tomato fiber and tomato powder increased the yield stress of the ketchup. However the increase was sharper in the fiber formulations.

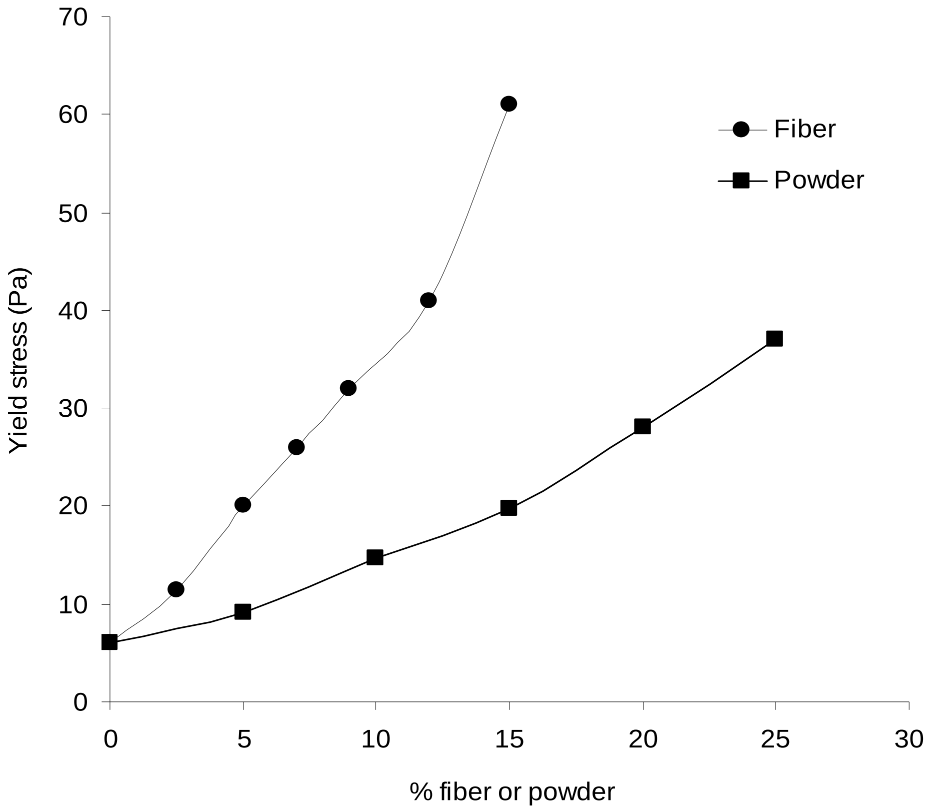

Figure 3.12 Yield stresses of the tomato ketchups done with tomato fiber and tomato powder (percentages based on total dry matter content of tomato paste)

The yield stress of tomato ketchup is of great importance as an important consumer and processing parameter. The yield stress of tomato ketchups was affected by the level of the tomato fiber in the formulation. It was increased as the concentration of the added fiber increased. Farahnaky et al. (2007) used tomato pulp powder as a thickening agent in the formulation of tomato ketchups at different levels (1, 2, 5, 7 and 10 % w/w). They also observed an increase in the yield stress as they increased the level of pulp powder, and they suggested that the ability of the pulp powder to absorb water and the increase in the total solids of the samples as a result of the addition of the pulp powder could be considered as the reason of the increase in yield stress. From the figure (Figure 3.12), it is obvious that the effects of fiber were really larger for fiber than the powder, then it can be concluded that the ability of the pulp fiber to absorb water is much higher than the tomato powder's.

3.A.1.2.2 Dynamic Rheological Properties

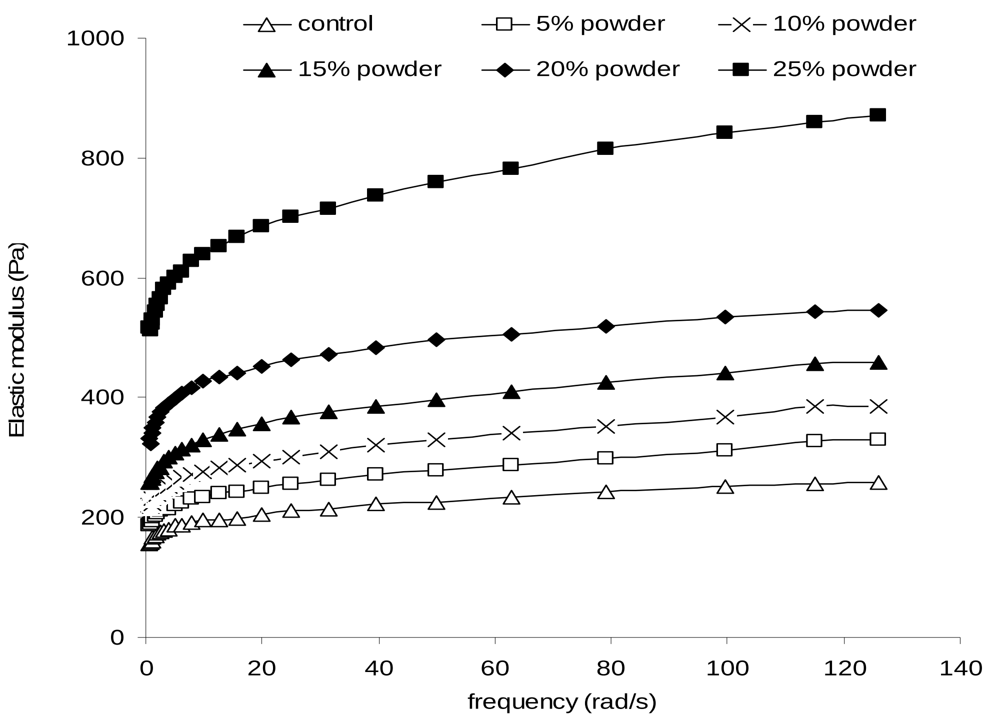

Figure 3.13 Elastic modulus versus angular frequency data of tomato ketchup formulated with different percentages of tomato powder (percentages based on total dry matter content of tomato paste)

Figure 3.13 shows the elastic modulus of tomato ketchup with tomato powder in different percentages as a function of angular frequency. Figure demonstrates that the elastic modulus (G') increases with increasing frequencies.

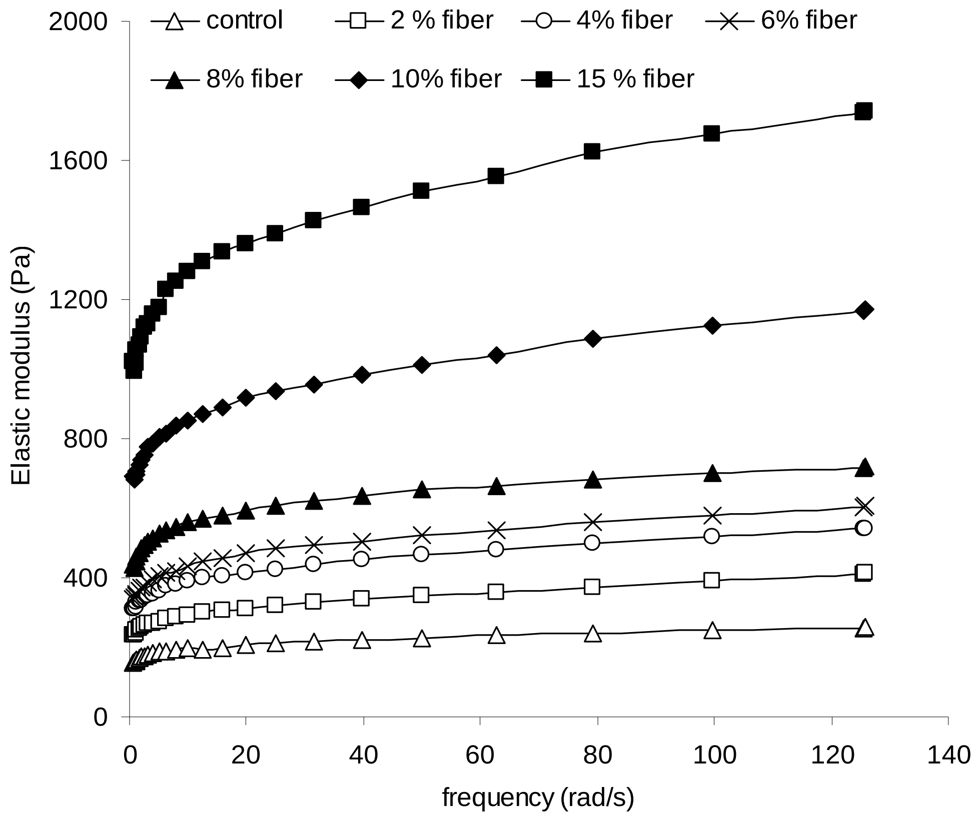

Figure 3.14 Elastic modulus versus angular frequency data of tomato ketchup formulated with different percentages of tomato fiber (percentages based on total dry matter content of tomato paste)

Figure 3.14 shows the elastic modulus of tomato ketchup with tomato fiber in different percentages as a function of angular frequency. The linear viscoelasticity function increases as the percentage of the fiber or powder increase. This increase in the linear viscoelasticity functions can be related to the increase in dry matter content in the Formula.

Figure also demonstrates that the elastic modulus (G') increases with increasing frequencies. The difference between Figure 3.13 and 3.14 is the magnitudes of elastic modulus values. The ketchup samples with tomato fiber gave larger results from the samples with tomato powder in terms of elastic modulus.

When the trends in the figures (Figures 3.13 and 3.14) compared with the trend of Heinz Ketchup (Figure 3.4); a classic American icon, and also one of the most selling brand in Turkey, it can be concluded that the 4-6% tomato fiber will be enough to obtain the same flow behavior, whereas in powder this percentage increases to 15-20.

Figure 3.15 shows the viscose moduli of tomato ketchup formulated with different percentages of tomato powder whereas Figure 3.16 shows viscose moduli (G'') of tomato ketchup formulated with tomato fiber. Both figures indicates that as a function of the angular frequency (w), G'' increases. Moreover the values of viscose modulus are higher in the samples with tomato fiber.

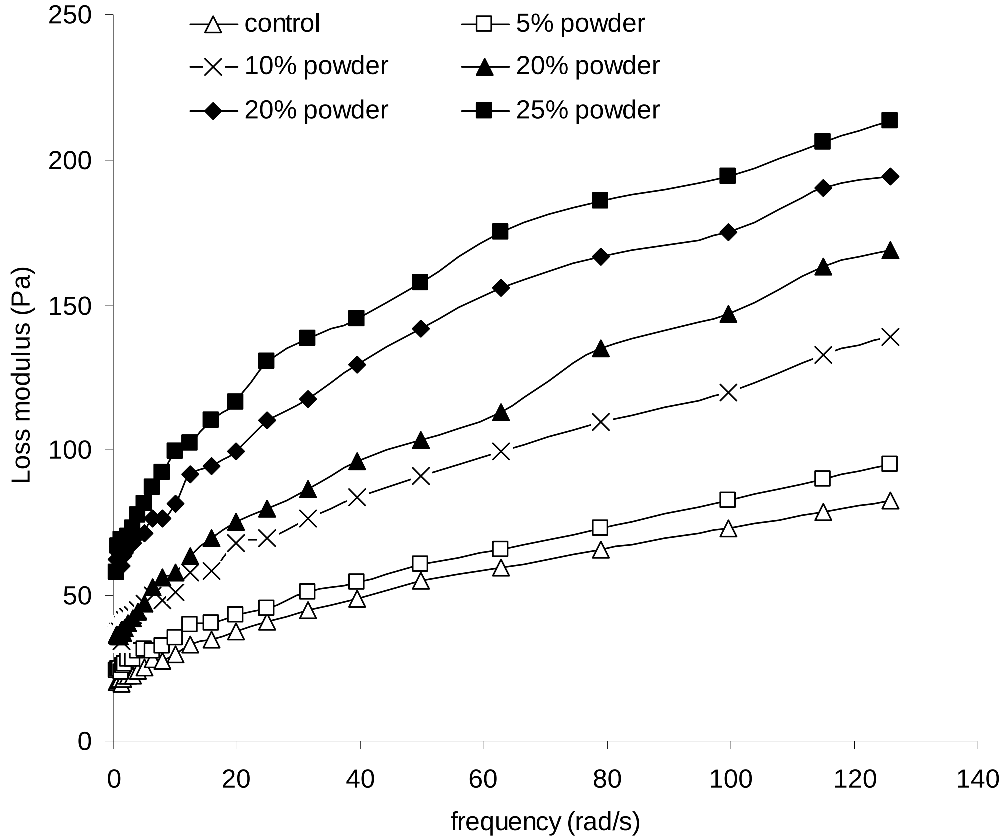

Figure 3.15 Viscose modulus versus angular frequency data of tomato ketchup formulated with different percentages of tomato powder (percentages based on total dry matter content of tomato paste)

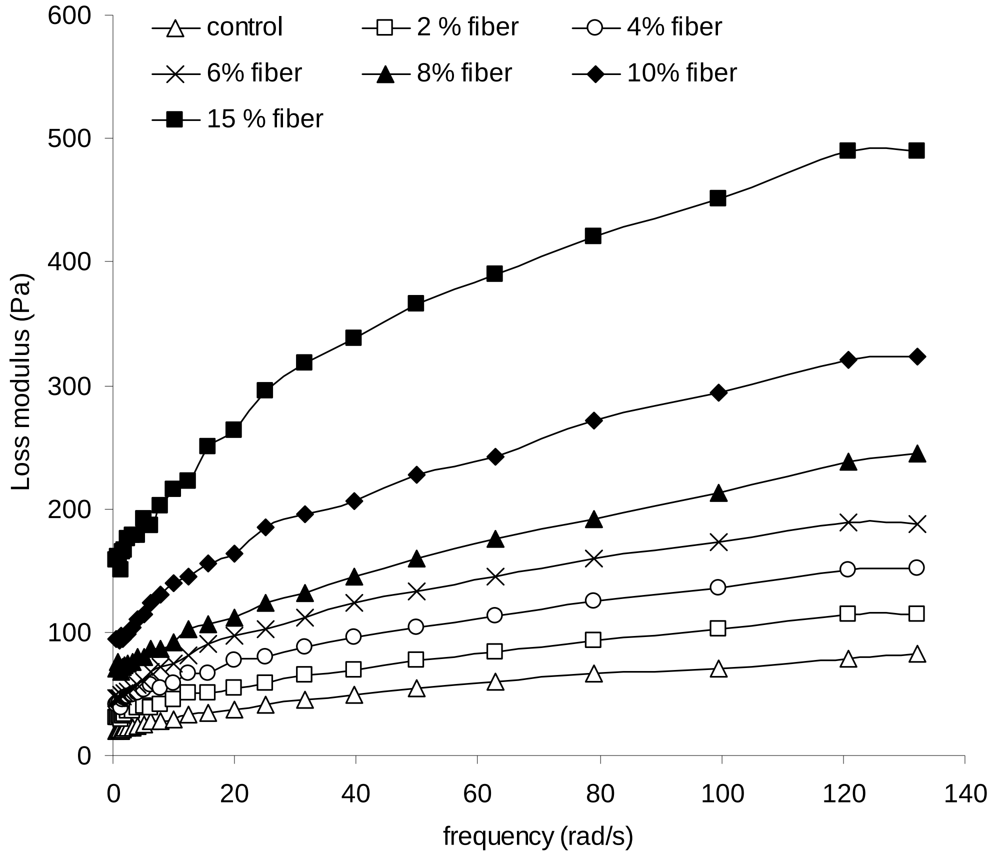

Figure 3.16 Viscose modulus versus angular frequency data of tomato ketchup formulated with different percentages of tomato fiber (percentages based on total dry matter content of tomato paste)

Again when the trends in the figures (Figures 3.15 and 3.16) compared with the trend of Heinz Ketchup (Figure 3.5), it is seen that the 4-6% tomato fiber will be enough to obtain the same flow behavior, whereas in powder this percentage increases to 20-25.

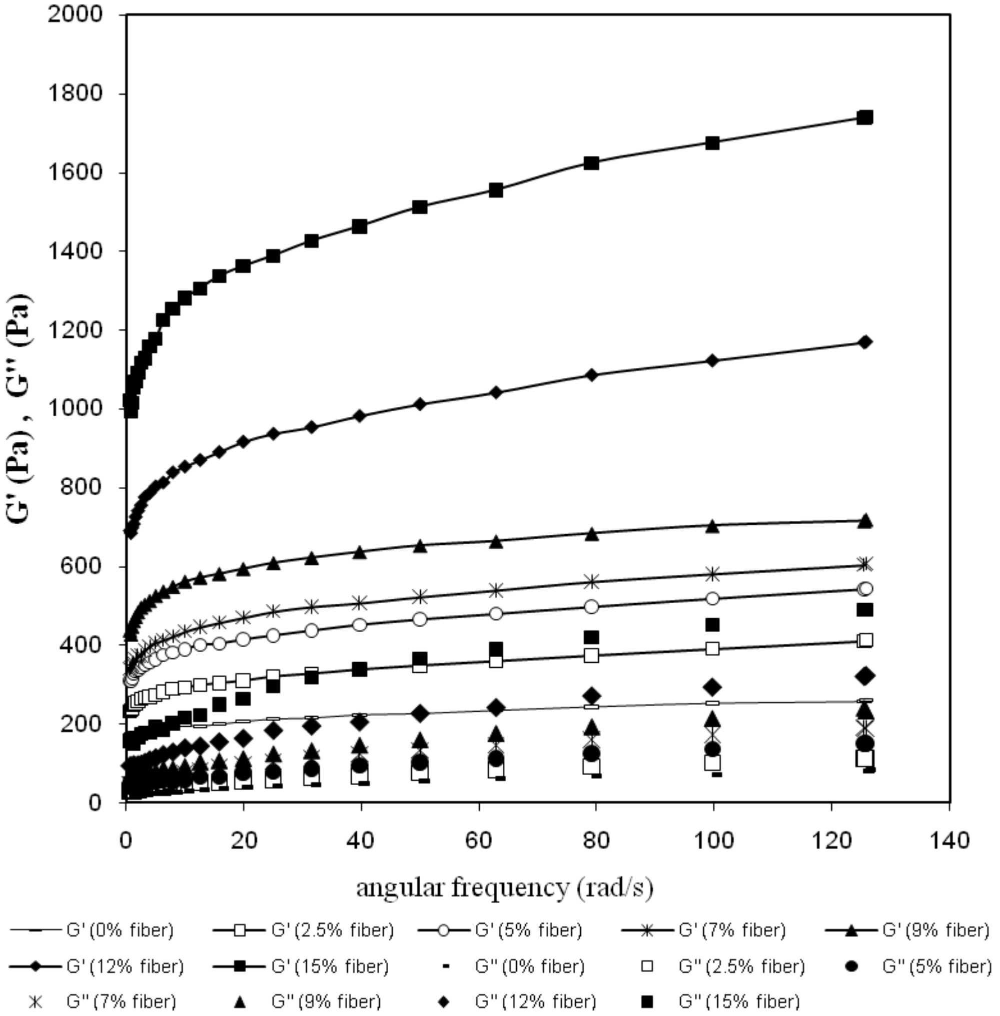

Figure 3.17 Elastic and Viscose modulus versus angular frequency data of tomato ketchup formulated with different percentages of tomato fiber (percentages based on total dry matter content of tomato paste)

Figure 3.17 shows the figures above (Figures 3.14 and 3.16) in a whole. The frequency dependence of the linear viscoelasticity functions showed an elastic response, with higher values of the elastic modulus, G', in the whole experimental frequency range studied. From the values in the graphs (Figure 3.17) it was shown that for all fiber formulations, the G' values are larger than the G'' values. This trend is same also in the powder formulations; that is G' values are larger than the G'' values. The difference is that; the values are larger (for both G'' and G'') in ketchups formulated with tomato fiber than the ones formulated with tomato powder.

Taking into account the above considerations and the results, we may conclude that the using tomato fiber in % 6 will be enough to obtain a product with a good quality.

3.A.2 Scanning Electron Microscopy Analysis

The characterizations of the tomato powder and tomato fiber are done by Scanning Electron Microscope (SEM). In Figure 3.18 picture A shows the SEM picture of tomato powder (A) whereas picture B shows the SEM picture of tomato fiber (B). The difference is obvious from the pictures. Picture A show a lumy structure, there is not a branching. Surface area in the Picture B is much higher. Both Picture (Picture A and Picture B) contains only the tomato pulp as a raw material. However despite being enlarged at the same rate, the appearances are really different.

To increase the surface area of the fibers, high pressure was used. The high pressure resulted in fibers to be bleached and to have a further reduction in size.

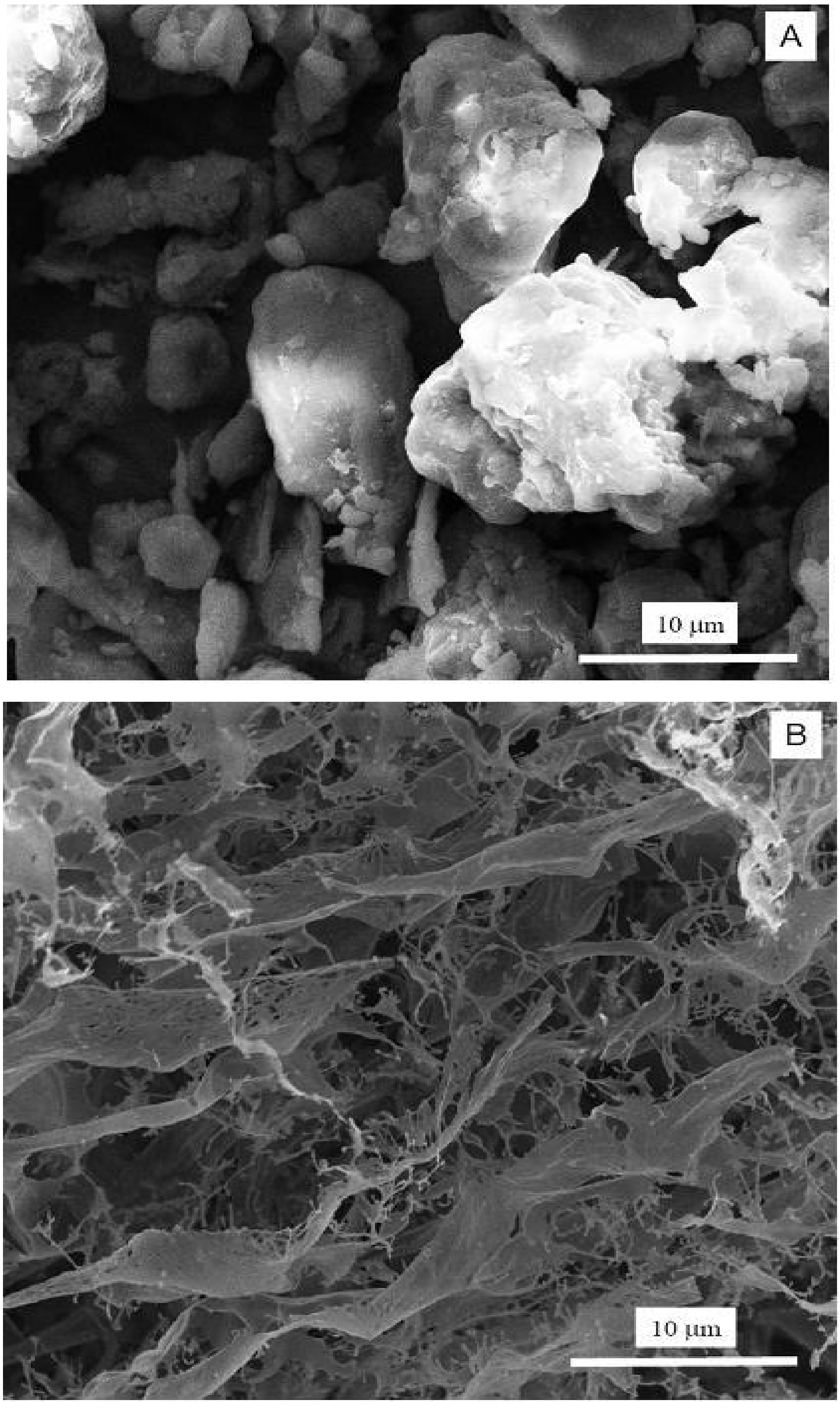

Figure 3.18 Scanning electron microscope picture of tomato powder (A) and tomato fiber (B)

The SEM analysis shows changes in the surface morphology and reduction in size of the fibers.

The shape of the fiber structure is important. It can affect the water holding capacity and some other characteristics. This is partly because short and thick fibers do not produce good surface contact and fiber-to-fiber bonding (Ververis et al., 2004). Picture B in Figure 3.18 show how the obtained fiber structure is suitable to produce good surface contact and to hold water in its inside. Figure 3.19 proves this statement; it is the figure that shows the results of the structure seen under SEM. Picture A in the figure shows the 6 % tomato pulp fiber (tomato fiber), picture B; 6% tomato powder and picture C; 6% commercial tomato powder. In tomato fiber, there is not any phase separation, it is homogeneous. However the phase separation is obvious in tomato powder samples. In the fiber, water are hold in the branched structure, it is imprisoned in the building of the fiber, so the water absorption and water holding capacity are increased many many times. However in the powder the situation is different, since the structure is different. The powder does not have such a structure to hold the water inside of it. As a result, as seen in the Figure 3.19 (B and C) it cannot hold water, and there exists phase separation. Powder and water are separated as a 2 distinct product.

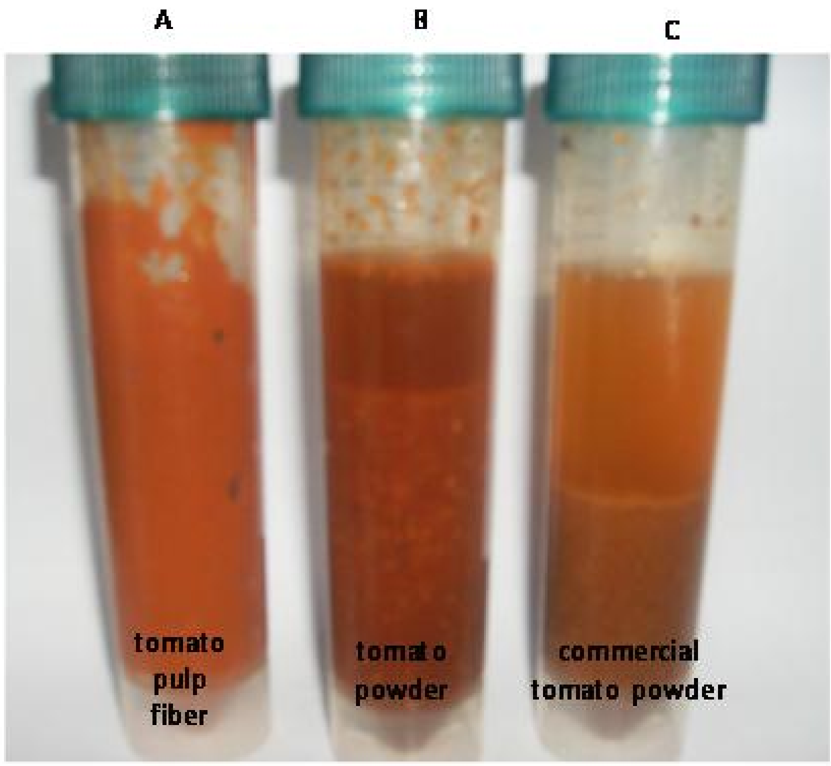

Figure 3.19 Pictures of 6% tomato fiber and tomato powders

3.A.3 Stability measurements of ketchup samples.

Separation phenomena like sedimentation and water separation (synerisis) were studied using the instrument called LUMISIZER (L.U.M. Germany). This instrument (shown in Figure 3.20) basically measures space and time based extinction profiles over time.

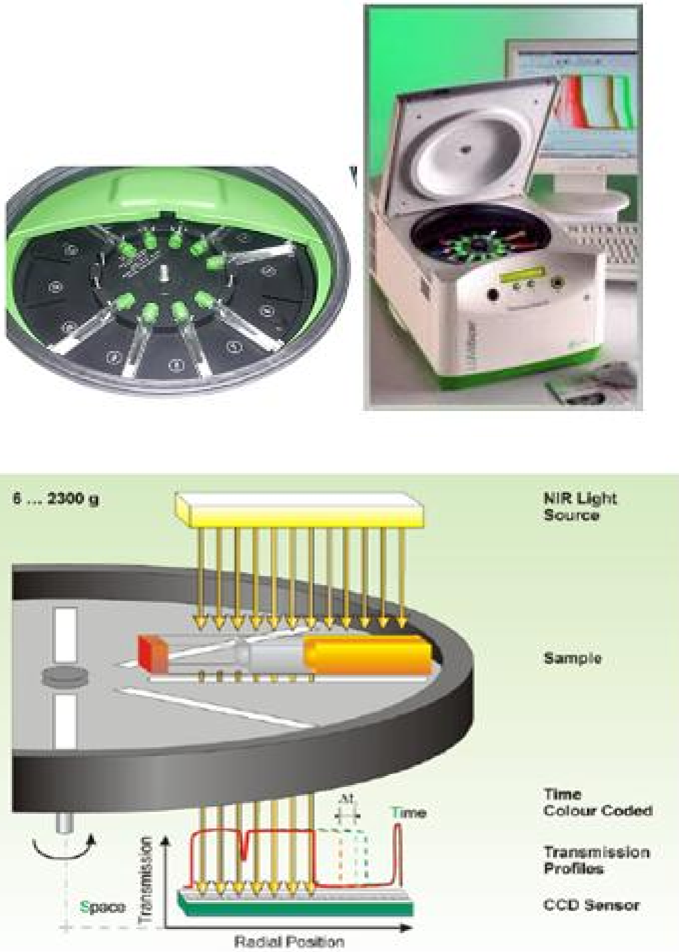

Figure 3.20 Lumisizer instrument used for ketchup stability experiments and its working principle

During measurements near infrared light illuminates the sample and the transmitted light is detected. Since the measurements are conducted under centrifugal force, water separation was detected via monitoring increased transmission zones.

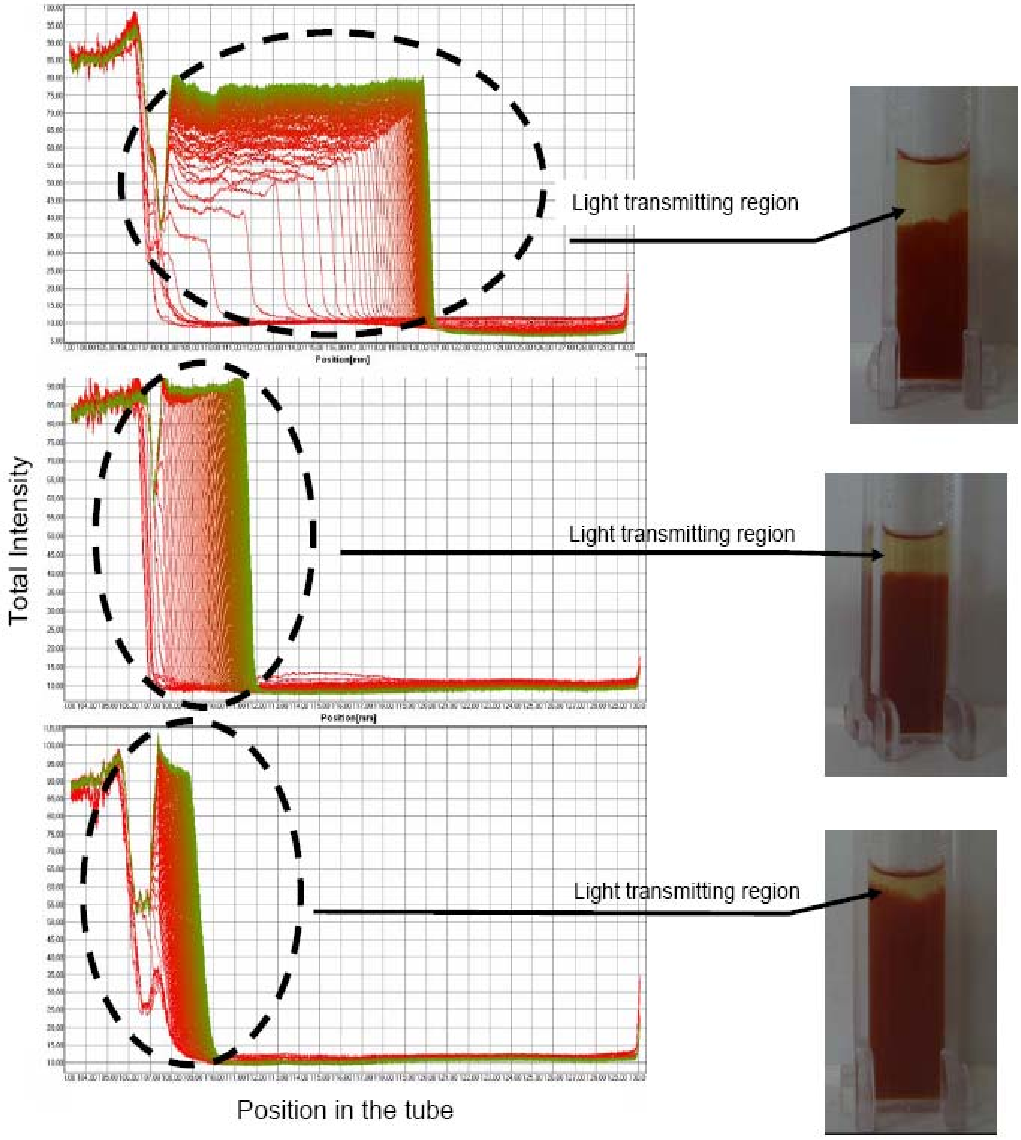

Figure 3.21 Typical Lumisizer results obtained during centrifugation of tomato fiber added samples

Transmission profile of the ketchup samples were recorded for every 10 seconds for the total duration of 1800 seconds at 10°C. The progression of the transmission profiles can be used to obtain information about the kinetics of the separation process. In Figure 3.21 typical results for the fiber added samples are given. As shown in the figure increasing fiber amount reduced the light transmitting region in the tubes. Furthermore slower separation was also observed in the samples with higher fiber containing samples.

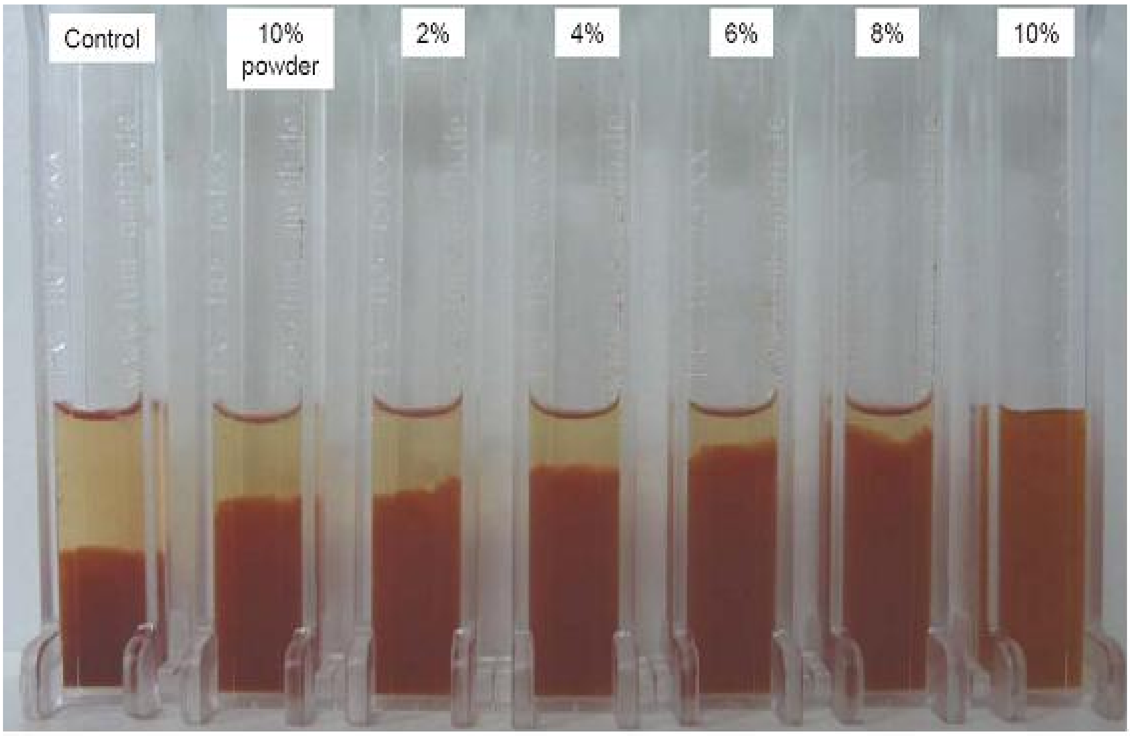

Figure 3.22 Fiber and powder containing ketchup samples after centrifugation

In Figure 3.22 phase separation is given for fiber and powder added samples. As shown in the figure fiber addition significantly improved the stability of the ketchup samples.

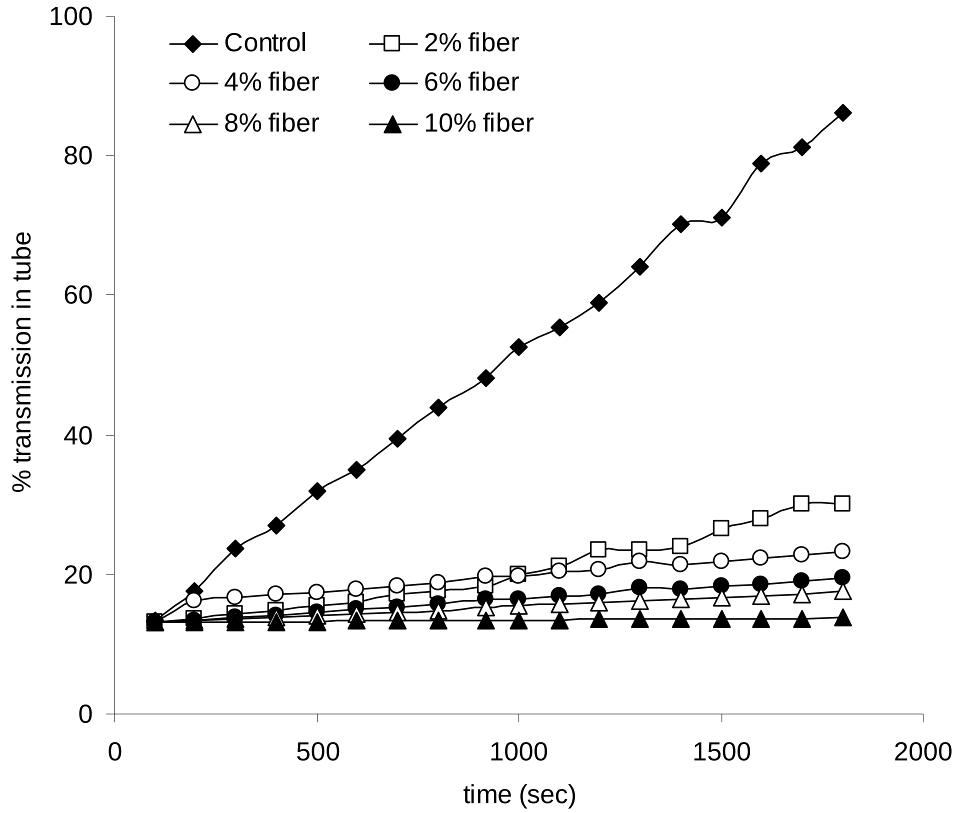

Figure 3.23 Phase separation rates in fiber added samples

The transmission profiles given in Figure 3.21 were obtained during 1800 seconds of centrifugation. Under centrifugal force the region transparent to the NIR light increases and consequently the %transmission also increases. These results are given for fiber added sample in Figure 3.23 and for the powder added samples in Figure 3.24. As shown in these figures the fiber added samples had smaller slope compared to the powder added samples. This indicates that fiber added samples had much slower phase separation compared to the powder added samples.

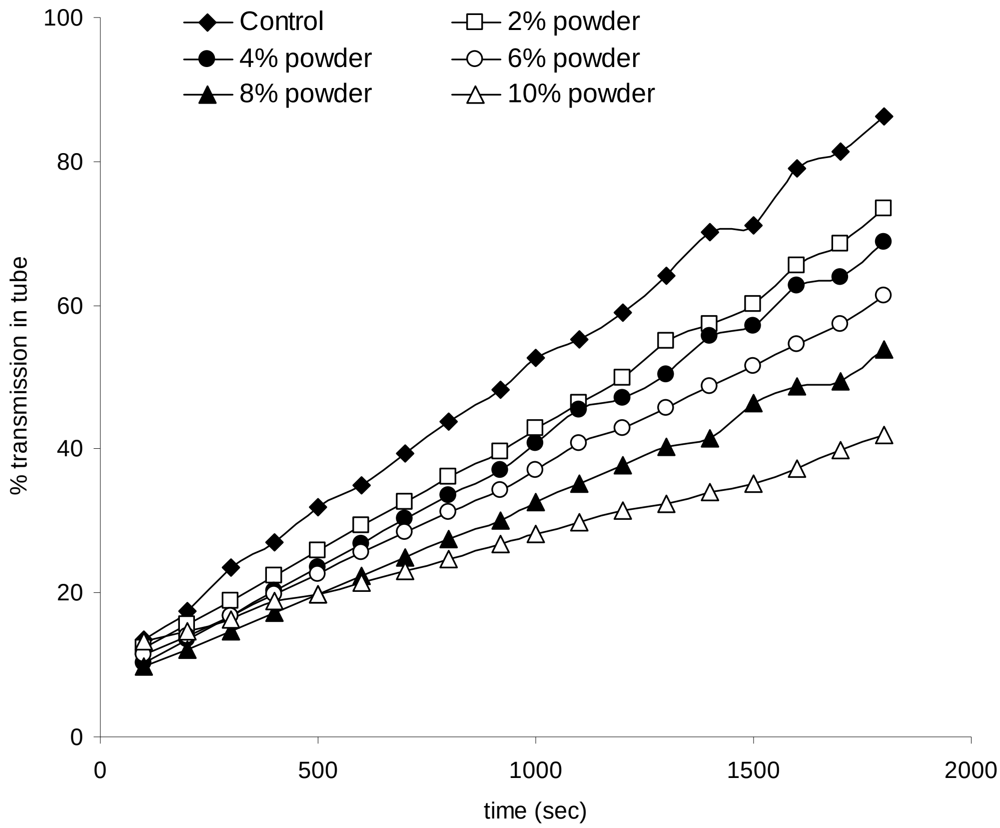

Figure 3.24 Phase separation rates in fiber added samples

In Figure 3.25 the rate of phase separation (slope of the lines given in Figure 3.23 and 3.24) are given. As shown in the figure control sample without any fiber or powder addition had the highest rate of separation. Addition of powder improved the stability in certain extent. On the other hand, addition of fiber (even at small amounts) significantly improved the stability of the ketchup samples.

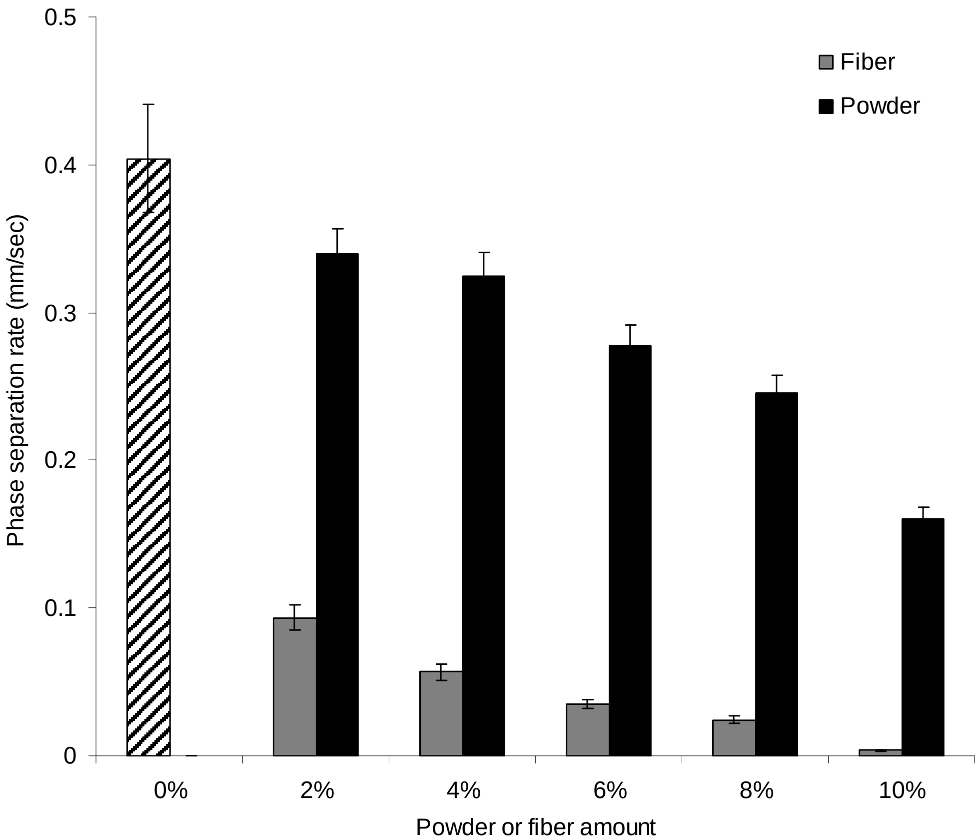

Figure 3.25 Phase separation rates for the fiber and powder added samples

3.B Cake Analysis

3.B.1 Rheology of Cake Batter

As it is stated before, rheological information is valuable in product development. The determination of rheological properties of cake batter is essential because they give useful information related to the quality of baked cakes (Demirkol, 2007).

Turabi et al. (2008) studied the rheological properties of rice cake batter and quality characteristics of rice cakes prepared using different gums (xanthan gum, guar gum, locust bean gum, k-carrageenan, hydroxy propyl methyl cellulose (HPMC), xanthan–guar gum blend and xanthan–k-carrageenan gum blend) with or without an emulsifier blend. In the study performed by Turabi et al. (2008) it was stated that rice cake batters formulated with gums with and without emulsifier blend showed shear-thinning behavior and both Power law and Casson model were suitable to explain the rheological behavior of rice cakes. They observed that the all gums except HPMC increased the emulsion stability of cake batter. Moreover adding xanthan gum to the formulation increased the apparent viscosity of cake batter and prevented collapse of the cakes in the oven while emulsifier blend addition resulted in softer cakes (Turabi et al., 2008).

Different plant fibers are added to various baked food products in order to increase their fiber content and in order to improve cake texture. Apple pomace is the one which is mostly studied. Sudha et al. (2007) incorporated apple pomace produced from fruit juice industry, in wheat flour at 5%, 10% and 15% levels and studied for rheological characteristics. They observed that the water absorption increased significantly (10% increase) with increase in pomace. Moreover dough stability decreased, mixing tolerance index increased (indicating weakening of the dough), volume of cakes decreased with increase in pomace content (Sudha et al., 2007). In general apple pomace affected the elastic properties of the wheat flour dough as well as the pasting properties (Sudha et al., 2007).

Masoodi et al., (2002) used apple pomace in dried and powdered form and in sizes of 30, 50 and 60 mesh sieves and found that the batter viscosity increased with increasing pomace level and decreasing particle size. Specific gravity and pH of the batter decreased with increasing pomace levels. Cake weight, shrinkage and uniformity index increased with increasing pomace levels, whereas, cake volume and symmetry index showed a reverse trend (Masoodi et al.,,2002).

In the study conducted by Masoodi and his friends (2001), different levels of apple pomace with different particle size at each level were blended with wheat flour as a source of dietary fiber and the blends were evaluated for their rheological characteristics. They observed that the water absorption and dough stability increased (but decreased at higher levels of pomace). They stated that the gelatinization temperature did not show any remarkable change with pomace incorporation upto 11 percent. Moreover peak viscosity decreased when pomace level was increased from 0 (control) to 5 percent but thereafter it increased. Temperature at peak viscosity did not show much variation between the blends (Masoodi et al., 2001).

Seker and his friends (2006) used apricot fiber in cake production. They stated that the apricot fiber can be a good source for dietary fiber without changing the cake properties in undesired way.

3.B.1.1 Rheology of 100 g flour based cake formulation

As shown from the Figure 3.26 all the formulations prepared with 100 g flour with bran fiber or wheat bran or none showed shear thinning (pseudoplastic) behavior. The shear stress versus shear rate data obtained from viscometer were fitted well to Herschel-Bulkley model.

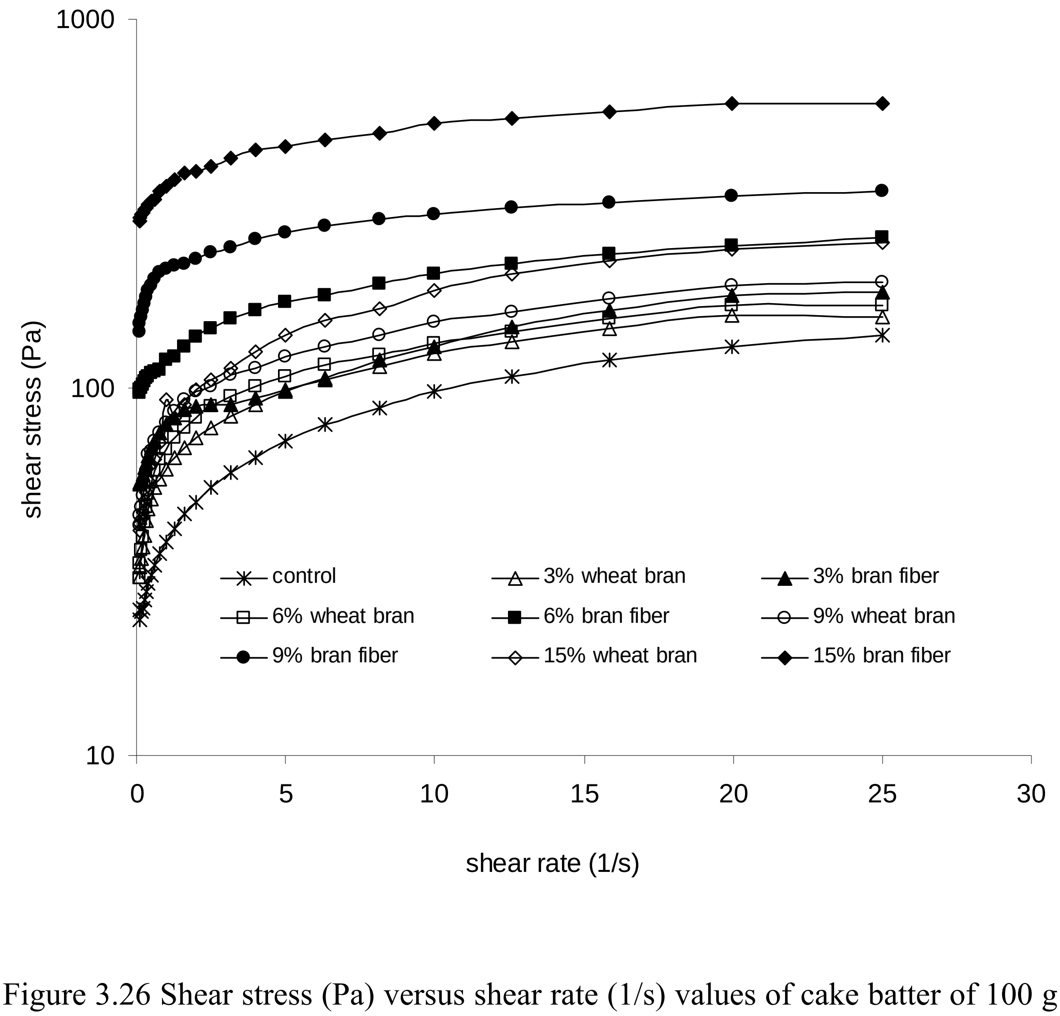

Figure 3.26 Shear stress (Pa) versus shear rate (1/s) values of cake batter of 100 g flour based formulation

Experimental data provided a good fit for the Herschel-Bulkley model;

$\tau = \tau_0 + k\,(\delta)^n$ (Eq. 1.)

where τ_0, k and n are the yield stress, consistency index and the flow behavior index, respectively.

Table 3.3 Rheological parameters of Herschel-Bulkley model describing flow curves of cake batter of 100 g flour having different levels of wheat bran and bran fiber.

	control	3% wheat bran	3% bran fiber	6% wheat bran	6% bran fiber	9% wheat bran	9% bran fiber	15% wheat bran	15% bran fiber
yield stress (Pa)	14	9	54	14	88	17	146	29	324
K ($Pa.s^n$)	15	18	50	76	34	23	76	51	89
n	0.65	0.55	0.62	0.51	0.49	0.55	0.42	0.51	0.49

The parameters k and n for different cake formulations are shown in Table 3.3. Flow behavior index provides us the information whether the flow is shear thinning or shear thickening. If it is 1, then the model reflects Newtonian behavior Flow behavior index (n) of cake batters ranged from 0.42 to 0.65. Since for all cake formulations n values were less than 1, it can be concluded that the cake batter was shear thinning (Table 3.3). This result was also seen with the shear stress versus shear rate graph (Figure 3.26). There was no significant effect of formulation on flow behavior index (Table 3.3). This result is consistent with literature. The flow behavior index was reported to be generally independent of the formulation (Demirkol, 2007).

Control cakes had the lowest consistency index. It increased as the percentage of wheat bran and wheat bran fiber increased. Only the 3 % formulations disordered this situation.

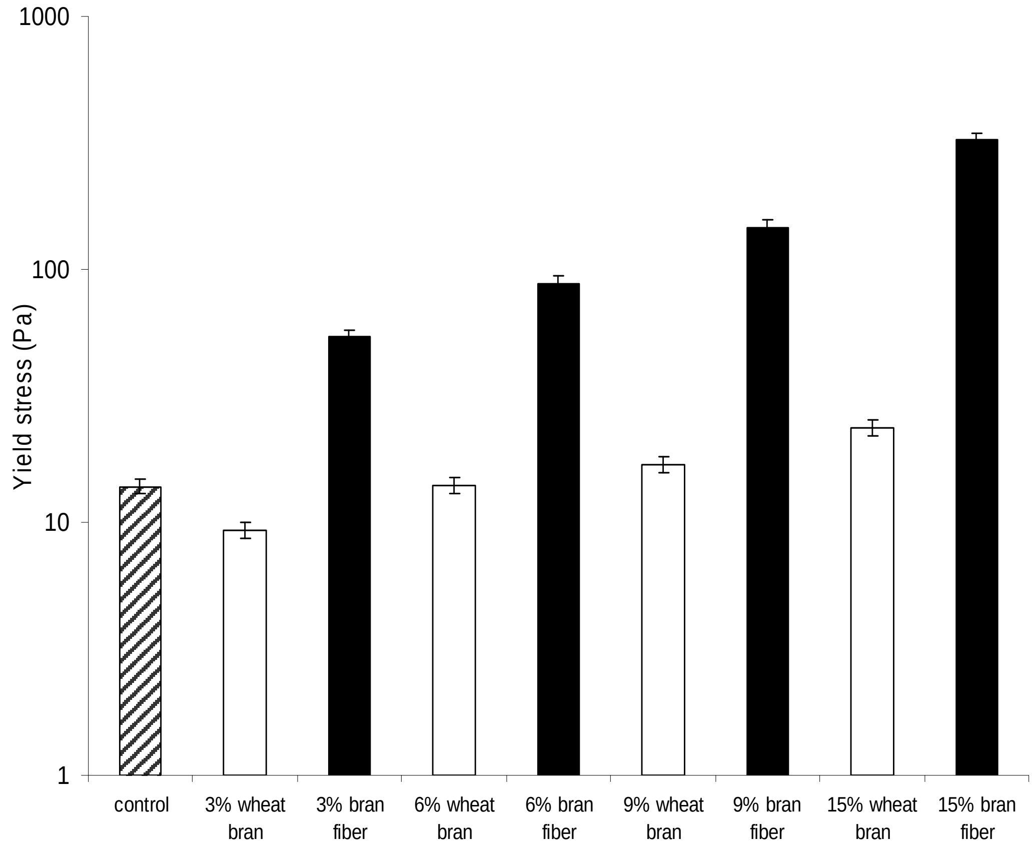

Figure 3.27 Yield stress (Pa) values of cake batter of 100 g flour based formulation

Figure 3.27 shows that the yield stress value increased significantly with the bran fiber addition to cake batter whereas wheat bran did not show such an effect. In level of 3% wheat bran addition, the yield stress decreased and when the concentration of wheat bran increased, there existed an insignificant increase. While the yield stress of 100 g flour cake batter control was 13.88 Pa, it was 54, 88, 146, 324 for the formulas containing 3%, 6%, 9% and 15% wheat bran fiber respectively (Table 3.3). There was really a sharp increase with the addition of fiber. On the other hand when the formulas containing wheat bran samples was compared with control, it was seen the yield stress of the one containing 6% bran fiber was nearly equal to the control(the one containing no wheat bran). Addition of bran fiber (up to 6%) firstly decreased the yield stress, but when the level was increased there happened a little increase.

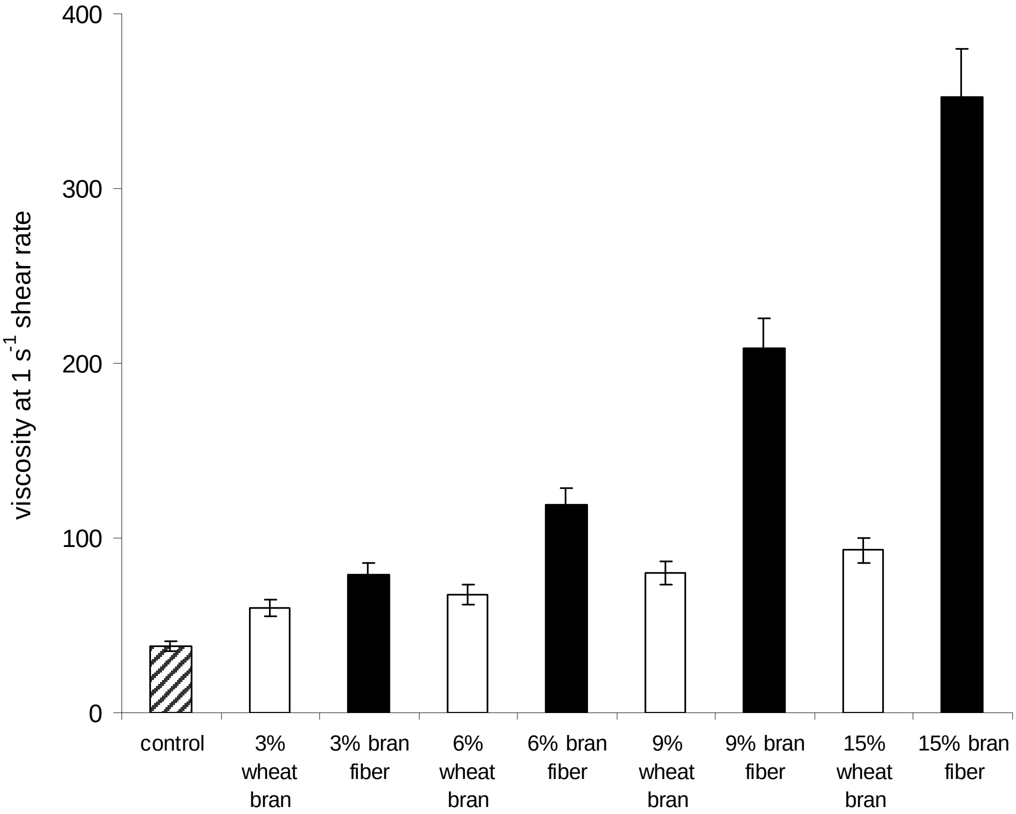

Figure 3.28 Viscosity values (at 1 1/s shear rate) of cake batter of 100 g flour based formulation

The consistency/viscosity of batters is a very important physical property affecting the product quality since it represents retain of the small bubbles, which are initially incorporated into the batter during the mixing time (Turabi et al., 2008). If the viscosity is too low, the bubbles in the batter can easily rise to the surface and are lost to the atmosphere during baking (Turabi et al., 2008).

A relationship exists between batter viscosity and cake structure. It was found that thin batters were not viscous enough to hold air incorporated during mixing or the gas liberated by the baking powder (Masoodi, 2002).

Figure 3.28 shows that the viscosity of cake batter yield increased with both the bran fiber and wheat bran addition. However when wheat bran fiber was used in the formulation, higher viscosity values were obtained as compared to the wheat bran containing batters. The increase in bran fiber formulations is really remarkable. It can be because of the high water holding capacity of the bran fiber. The finer particle size of pomace increased water absorption resulting in more viscosity (Masoodi, 2002).

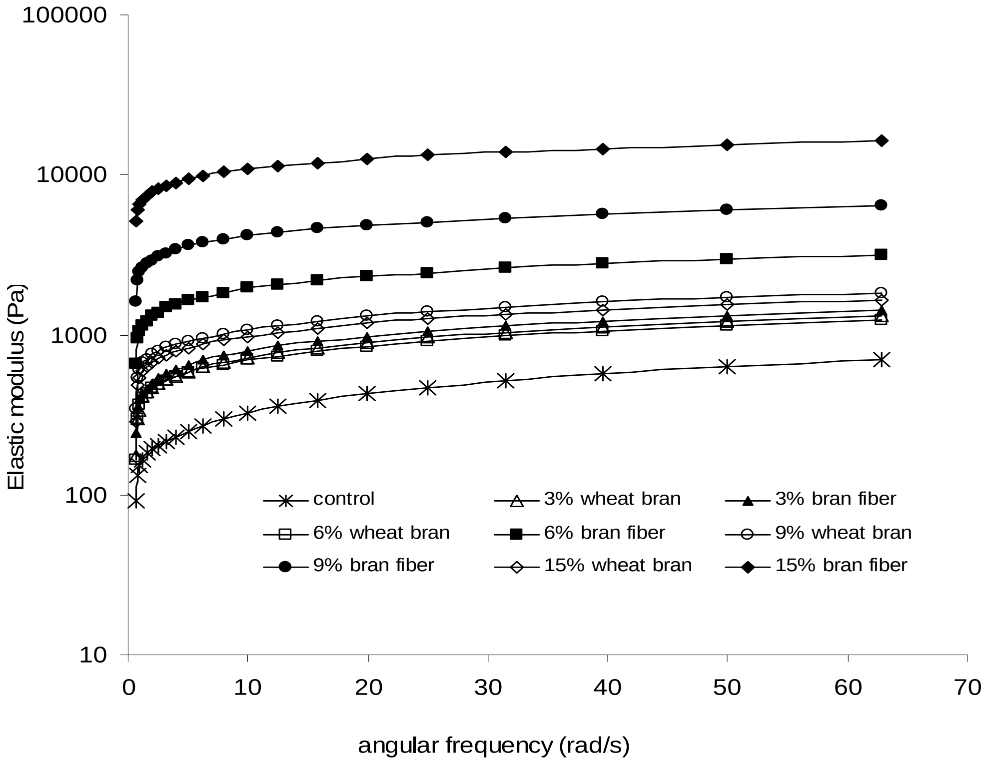

Figure 3.29 Elastic modulus versus angular frequency data of cake batter of 100 g flour based formulation

Both elastic (G’) and viscose moduli (G’’) increased with increasing frequency (Figure 3.29 and 3.30). The G’ values are larger than the G’’ values for both fiber and powder formulations (Figure 3.29 and 3.30) which indicates that cake batter showed an elastic response. Elastic and viscose modulus curve also increased with the increase in wheat bran and bran fiber.

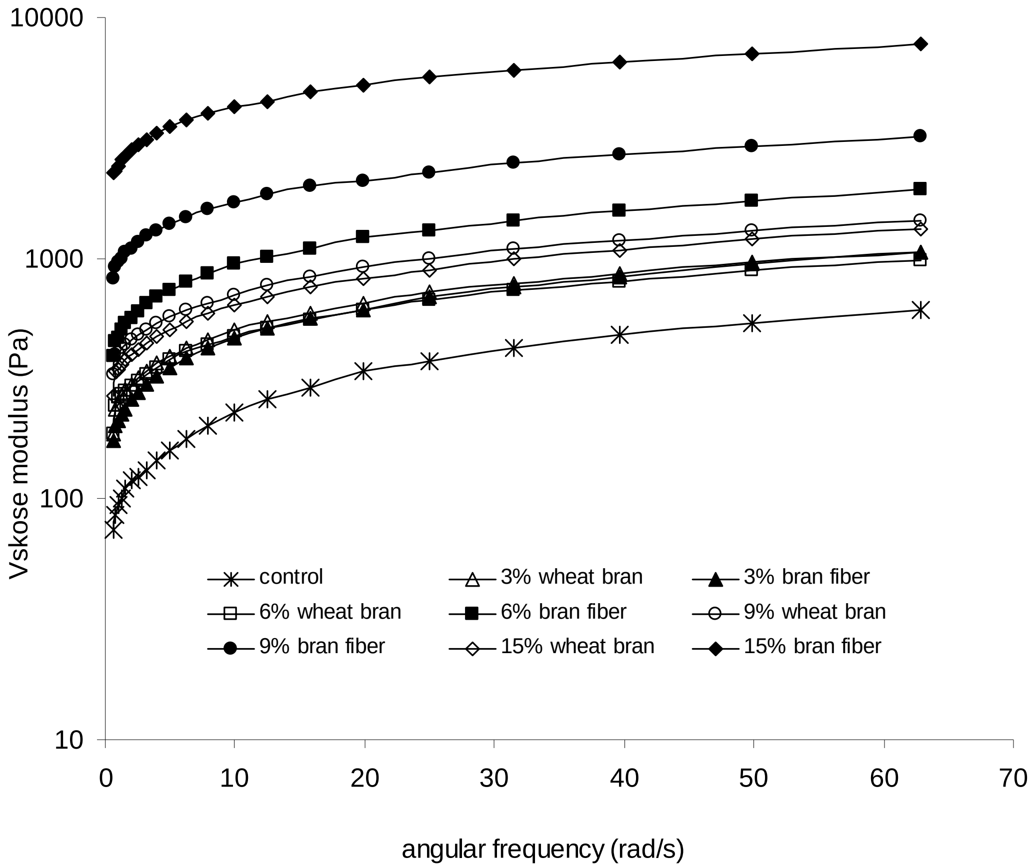

Figure 3.30 Viscose modulus versus angular frequency data of cake batter of 100 g flour based formulation

3.B.1.2 Rheology of 80 g flour based cake formulation

Figure 3.31 shows the shear stress versus shear rate data belonging to 80 g flour formulation. It demonstrates that the flow behavior is again shear thinning (pseudoplastic) behavior in case of both fiber and powder addition.

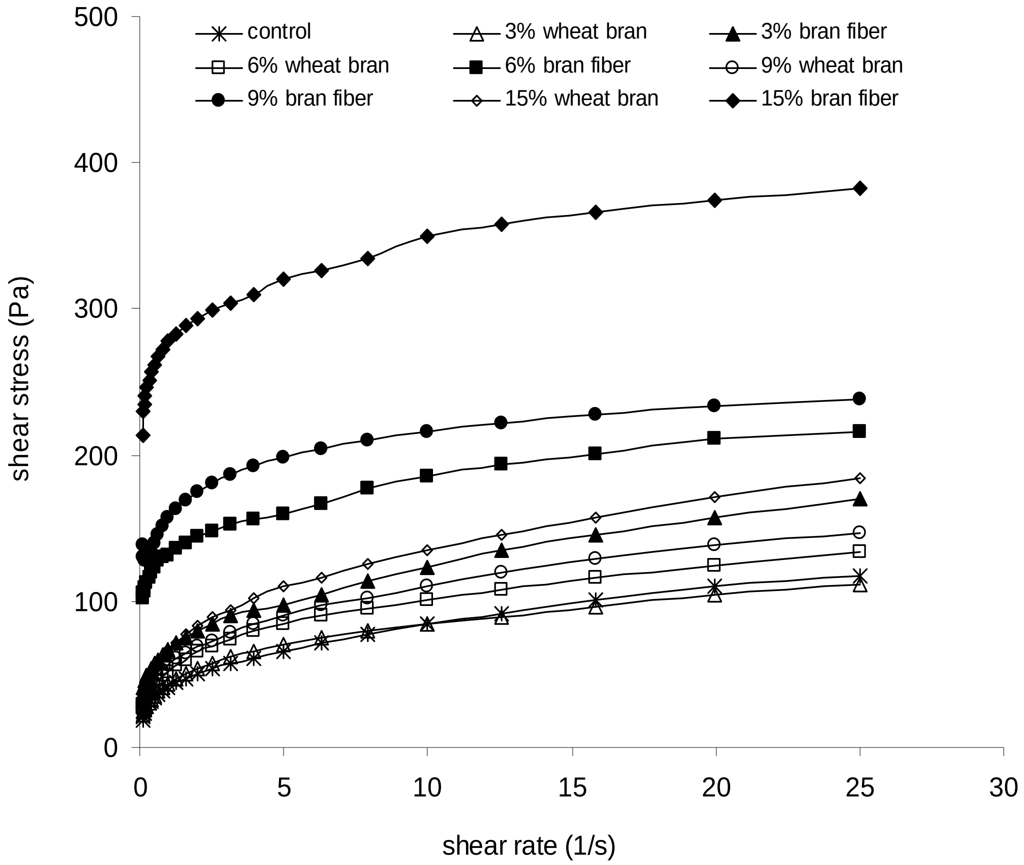

Figure 3.31 Shear rate (1/s) versus shear stress (Pa) values of cake batter of 80 g flour based formulation

In 100 g flour formulation, it was seen that the yield stress was affected by the level of the wheat bran fiber in the formulation. It was increased as the concentration of the added fiber increased. Trend was same in case of 80 g flour formulations i.e., the yield stress increased by the addition of bran fiber.

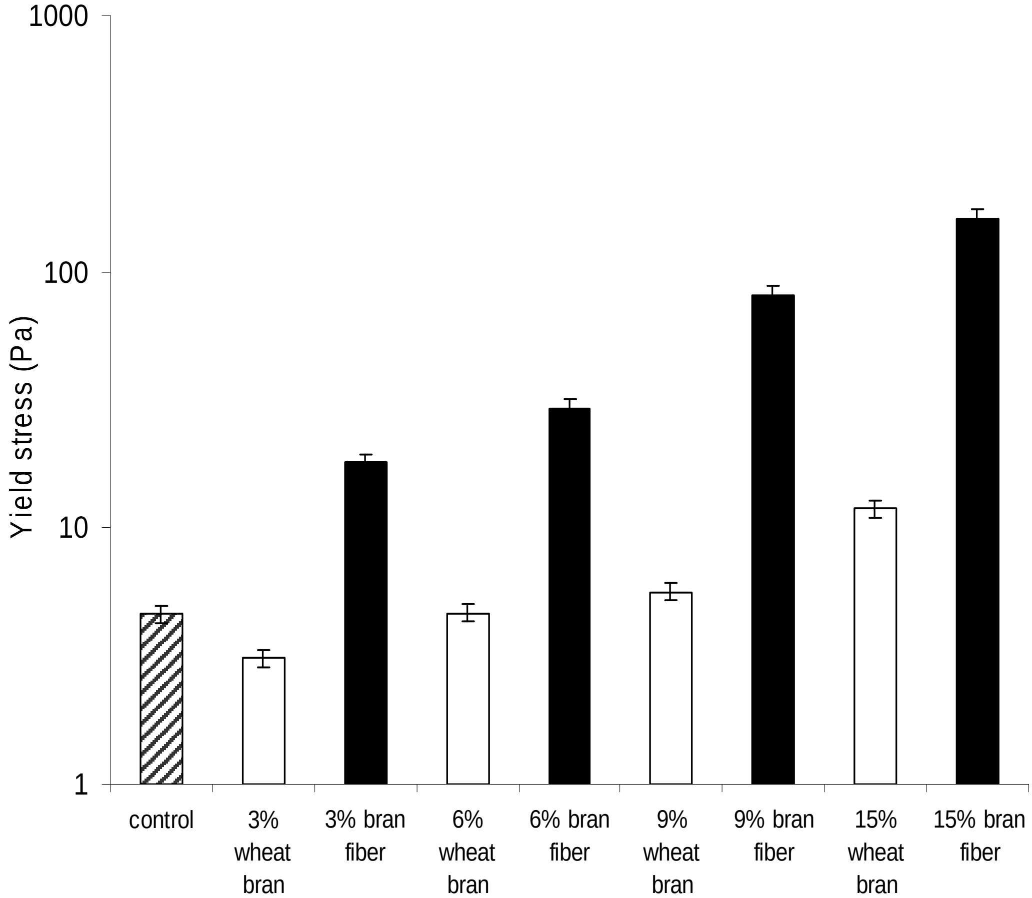

Figure 3.32 Yield stress (Pa) values of cake batter of 80 g flour based formulation

Experimental data provided again a good fit for the Herschel-Bulkley model as in Eq.1. Table 3.4 shows the rheological parameters of Herschel-Bulkley model describing flow curves of cake batter of 80 g flour having different levels of wheat bran and bran fiber. By Figure 3.33 it is again demonstrated that the viscosity values increased with the increasing level of wheat bran and bran fiber. This result is consistent with the literature's. Masoodi et al., (2002) used dried and powdered apple pomace in cake making and then stated that the batter viscosity increased with increasing pomace level and decreasing particle size. The finer particle size of pomace increased water absorption resulting in more viscosity. In the same way using wheat bran and bran fiber made that effect. There is a difference in the effects of two. It can be because of the larger surface area and smaller particle size of the wheat bran fiber. Figure 3.45 shows how the surface area is larger in the wheat bran fiber. Wheat bran fiber had branched structure with resulting in extended surface area. Its particle size is also smaller than the wheat bran's particle size.

Table 3.4 Rheological parameters of Herschel-Bulkley model describing flow curves of cake batter of 80 g flour having different levels of wheat bran and bran fiber

	control	3% wheat bran	3% bran fiber	6% wheat bran	6% bran fiber	9% wheat bran	9% bran fiber	15% wheat bran	15% bran fiber
yield stress	11	7	43	11	70	14	117	23	259
K ($Pa.s^n$)	12	14	40	61	27	18	61	41	63
n	0.78	0.66	0.74	0.61	0.59	0.66	0.50	0.61	0.59

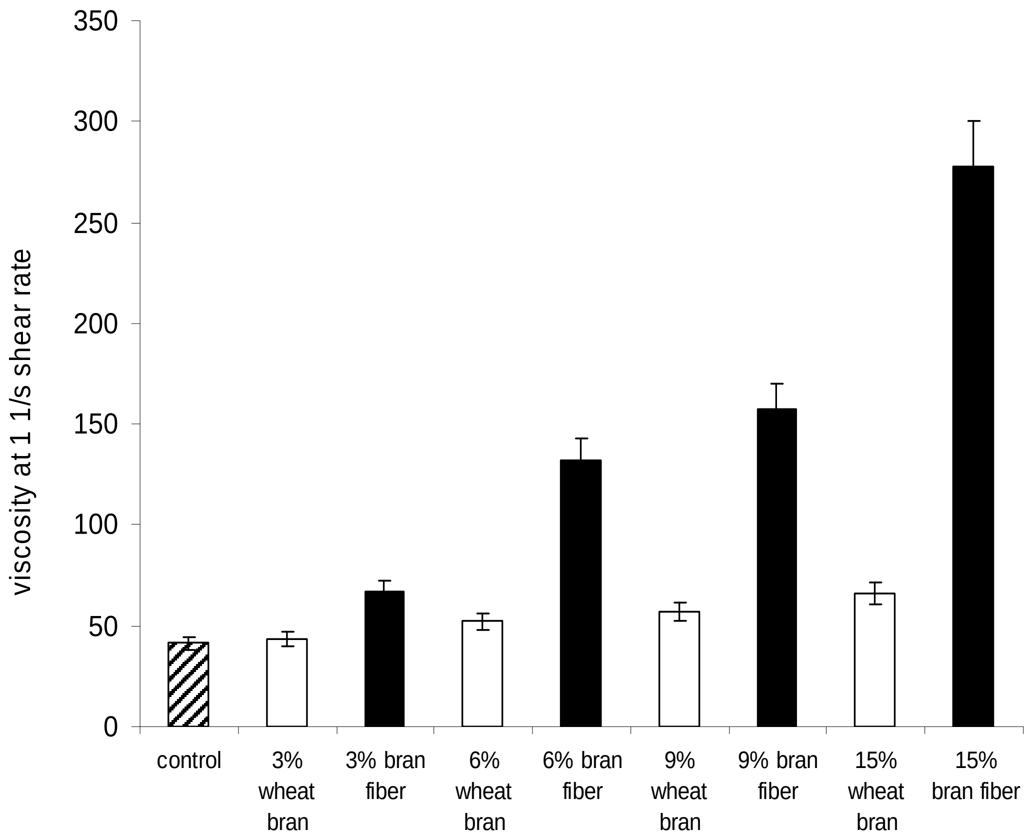

Figure 3.33 Viscosity values (at 1 1/s shear rate) of cake batter of 80 g flour based formulation

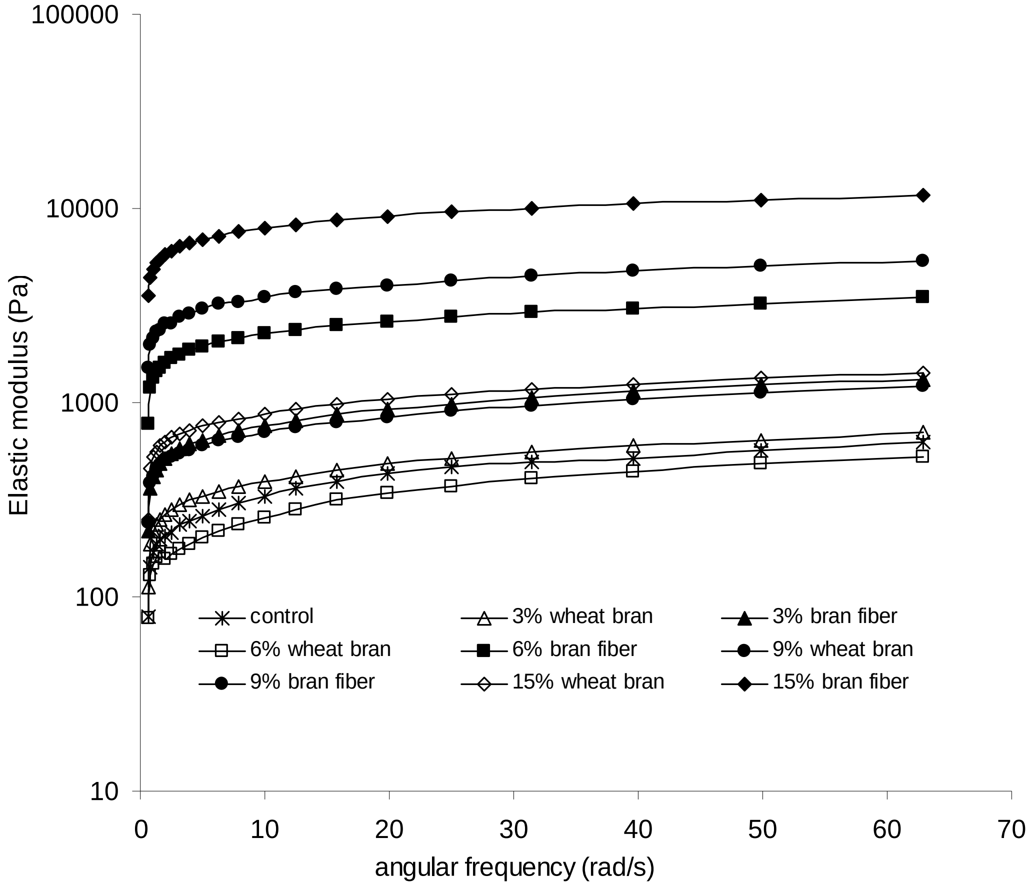

Figure 3.34 Elastic modulus versus angular frequency data of cake batter of 80 g flour based formulation

Figure 3.34 and 3.35 show oscillary test result of 80 gram flour formulation cake batter with wheat bran/ bran fiber. Figure 3.34 shows the elastic modulus and Figure 3.35; the viscose modulus. From this two figure, it can be stated that the magnitudes of G' were higher than those of G''; that is the tomato ketchup were more elastic than viscous. Moreover both G' and G'' increased with oscillatory frequency.

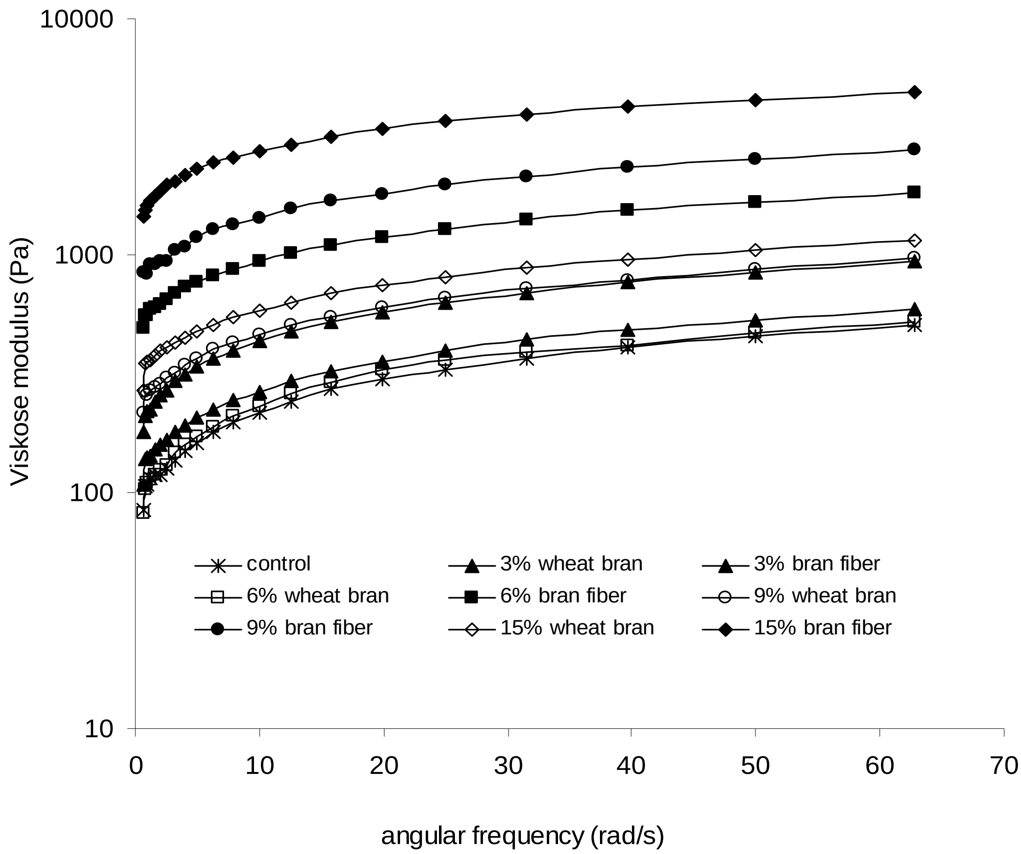

Figure 3.35 Viscose modulus versus angular frequency data of cake batter of 80 g flour based formulation

3.B.1.3 Rheology of 60 g flour based cake formulation

Formulations with 60 g flour showed shear thinning (pseudoplastic) behavior in case of both fiber or powder addition as it was in 100 and 80 g flour formulations (Figure 3.36). That is with the decrease in flour in cake formulation, the behavior of batter did not change.

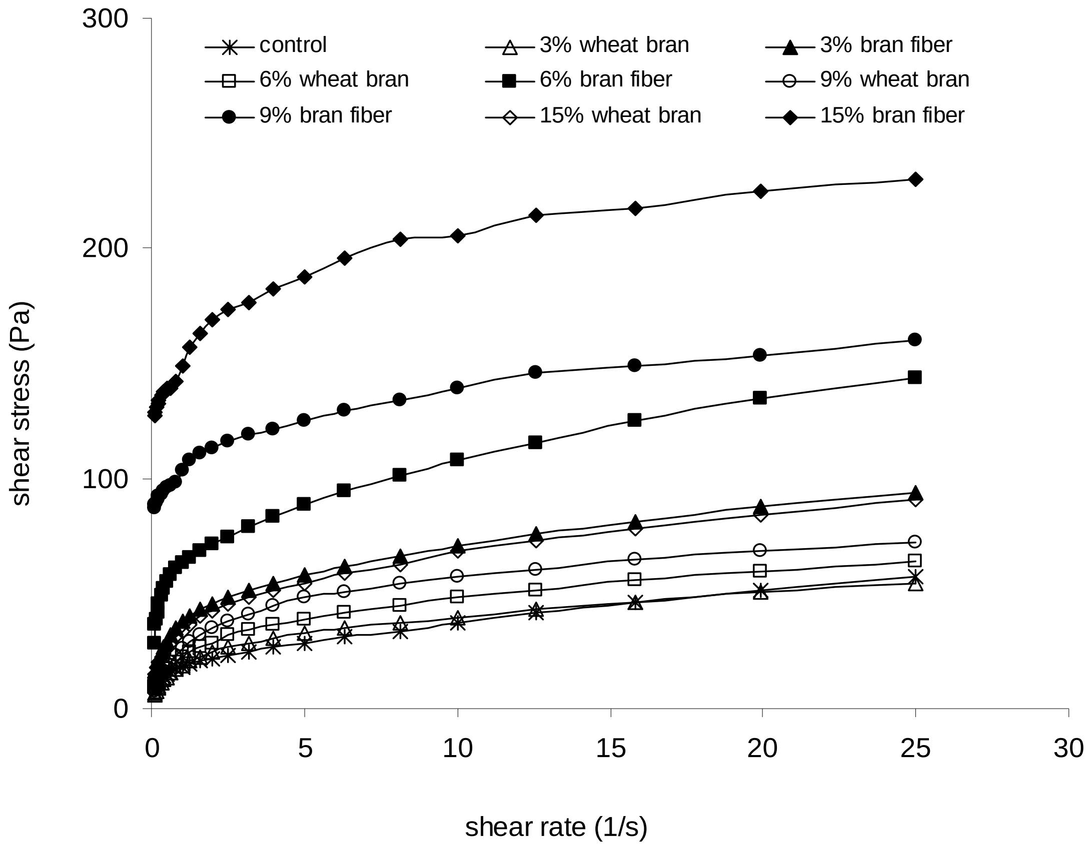

Figure 3.36 Shear rate (1/s) versus shear stress (Pa) values of cake batter of 60 g flour based formulation

Figure 3.37 shows the yield stress values of cake batter of 60 g flour based formulation. The wheat bran did not have any remarkable effect on the yield stress. Firstly when 3% wheat bran was added to the formulation, yield stress decreased, but when the percentage continued to increase, the yield stress also began to increase, but in negligible amount. However the bran fiber immediately showed its effect and increased the yield stress equal to the 100 gram flour control sample in only 3 % addition.

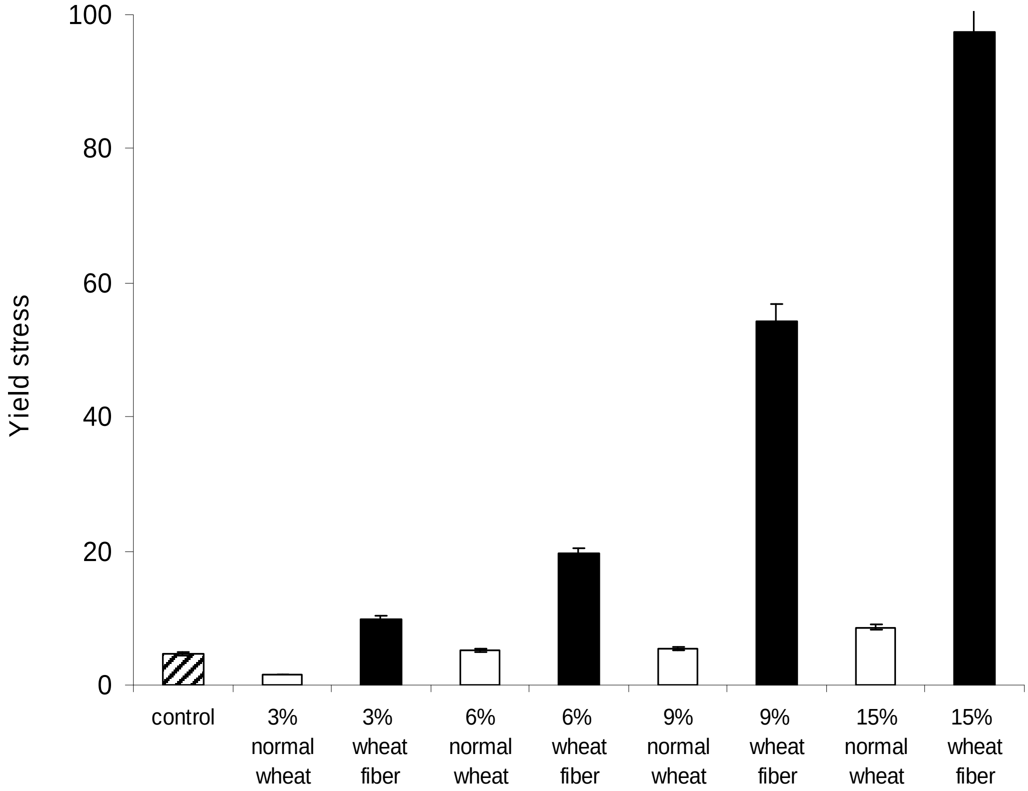

Figure 3.37 Yield stress (Pa) values of cake batter of 60 g flour based formulation

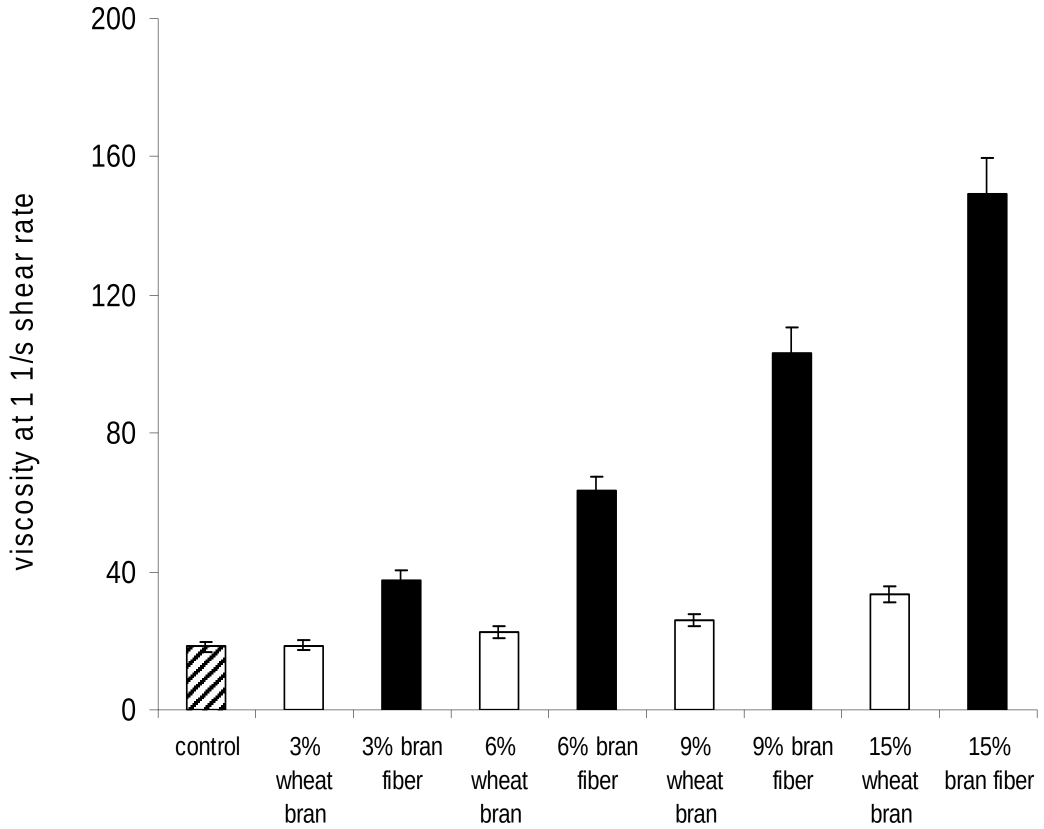

Figure 3.38 Viscosity values (at 1 1/s shear rate) of cake batter of 60 g flour based formulation

The viscosity of 60 g wheat bran formulation cakes are low compared to others because of this the air bubbles entrapped into the batter during mixing could not remain in the cake during baking period and wheat bran containing cakes collapsed (Figure 3.51).

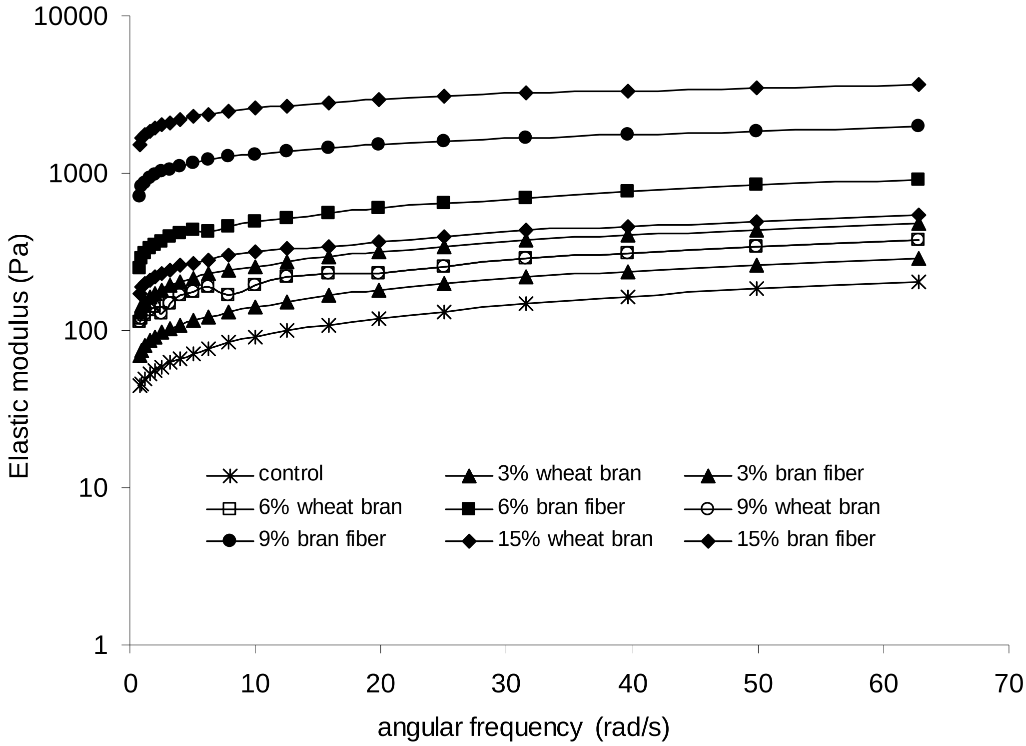

Figure 3.39 Elastic modulus versus angular frequency data of cake batter of 60 g flour based formulation

Oscillary test result of 60 gram flour formulation show that the cake batter did not change its behavior also when the flour decreased to 60 gram , it is still elastic than viscous (Figure 3.39 and 3.40).

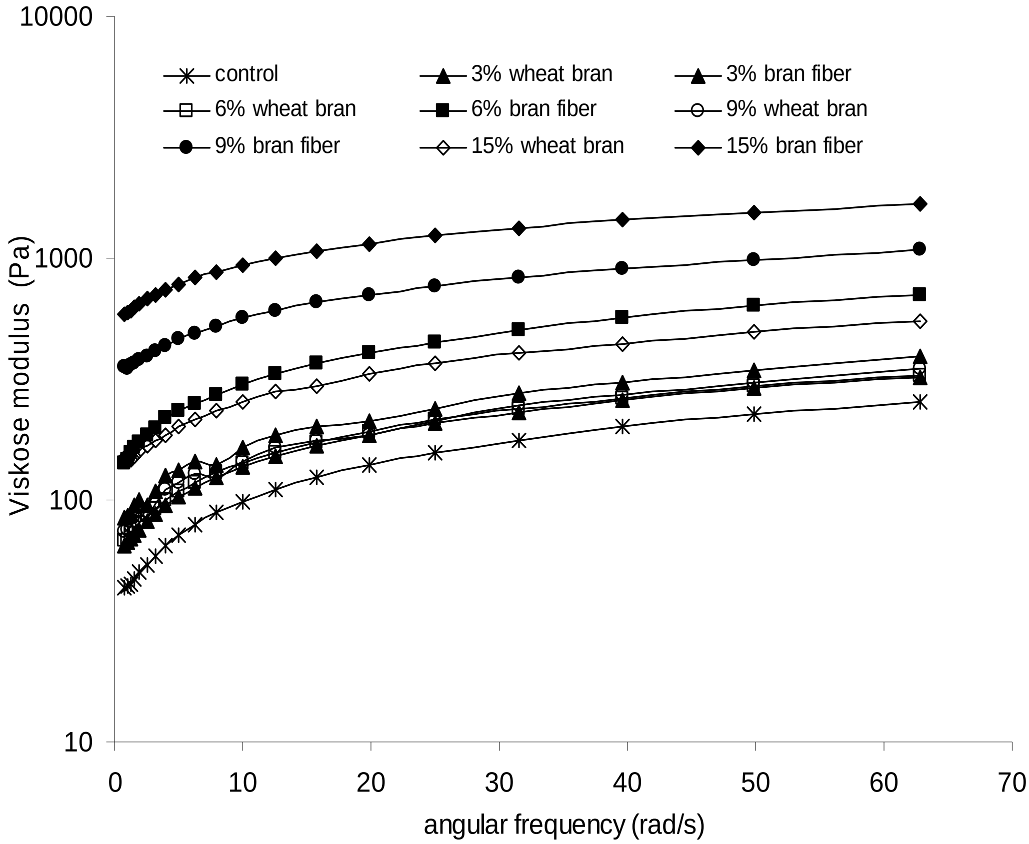

Figure 3.40 Viscose modulus versus angular frequency data of cake batter of 60 g flour based formulation

General View

Figure 3.41 shows the yield stresses of cake batters having different percentage of bran fiber in the formulation. Control batter for 100 g flour had a yield stress of 13.88 whereas control batter for 80 g and 60 g flour had 4.63. All the batter formulations had lower yield stresses than their control batters, which showed that addition of fiber increased the yield stresses of batter. Bran fiber addition into the batters increased the yield stress values significantly. Moreover this increase continued as the amount of flour increased.

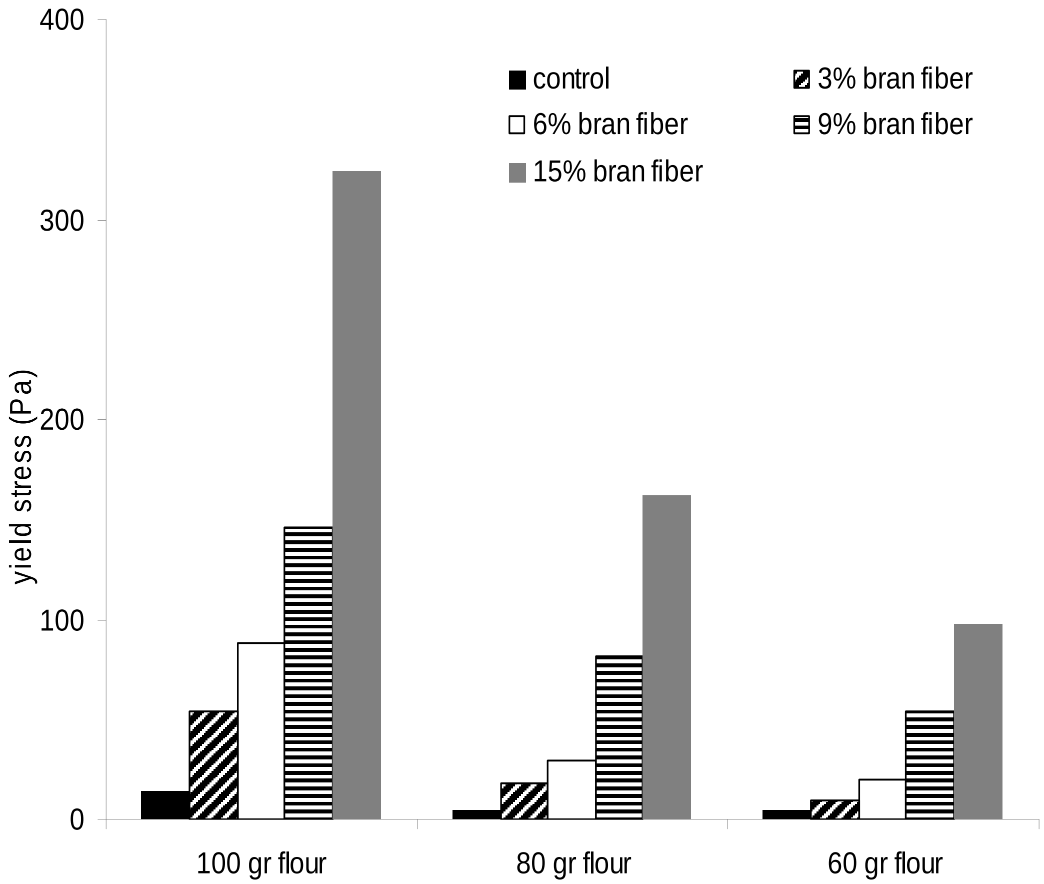

Figure 3.41 Yield stress values of cake batters with 100, 80 and 60 g flour and with different concentrates of bran fiber

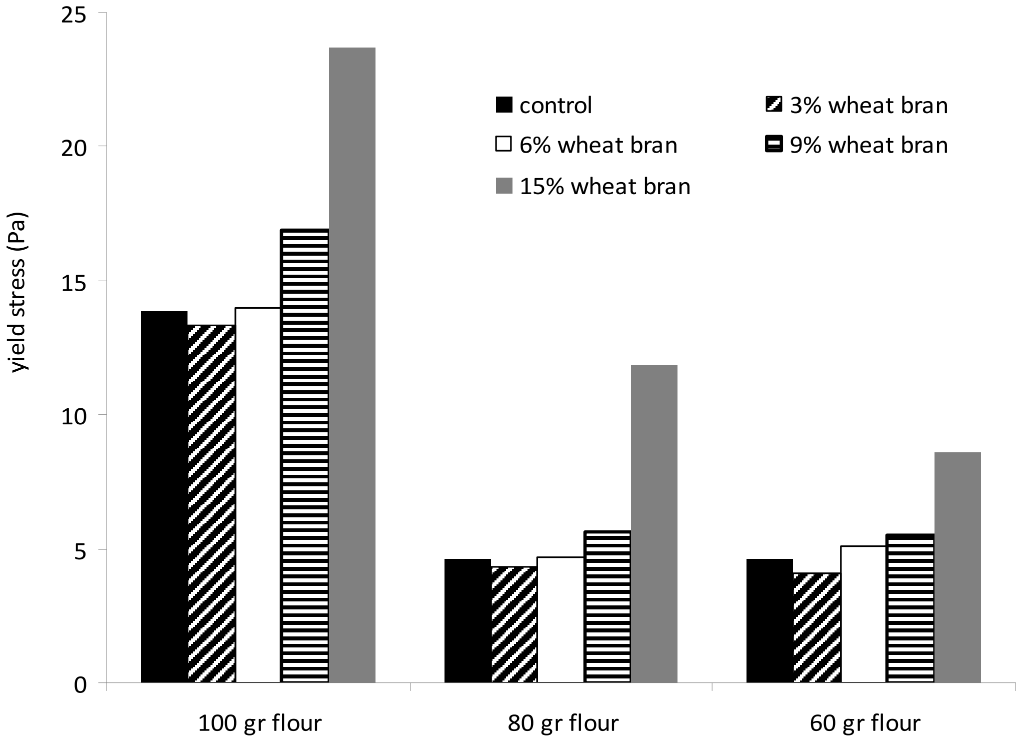

Figure 3.42 Yield stress values of cake batters with 100, 80 and 60 g flour and with different concentrates of wheat bran

Figure 3.42 shows the yield stresses of cake batters having different percentage of wheat bran in the formulation. Control batters are same with the one formulated for bran fiber that is control batter for 100 g flour had a yield stress of 13.88 whereas control batter for 80 g and 60 g flour had 4.63. There is not a precise result that shows that wheat bran addition increases or decreases the yield stress. Yield stress could increase or decrease with the wheat bran addition, wheat bran does not have specific impact on the yield stress of batters.

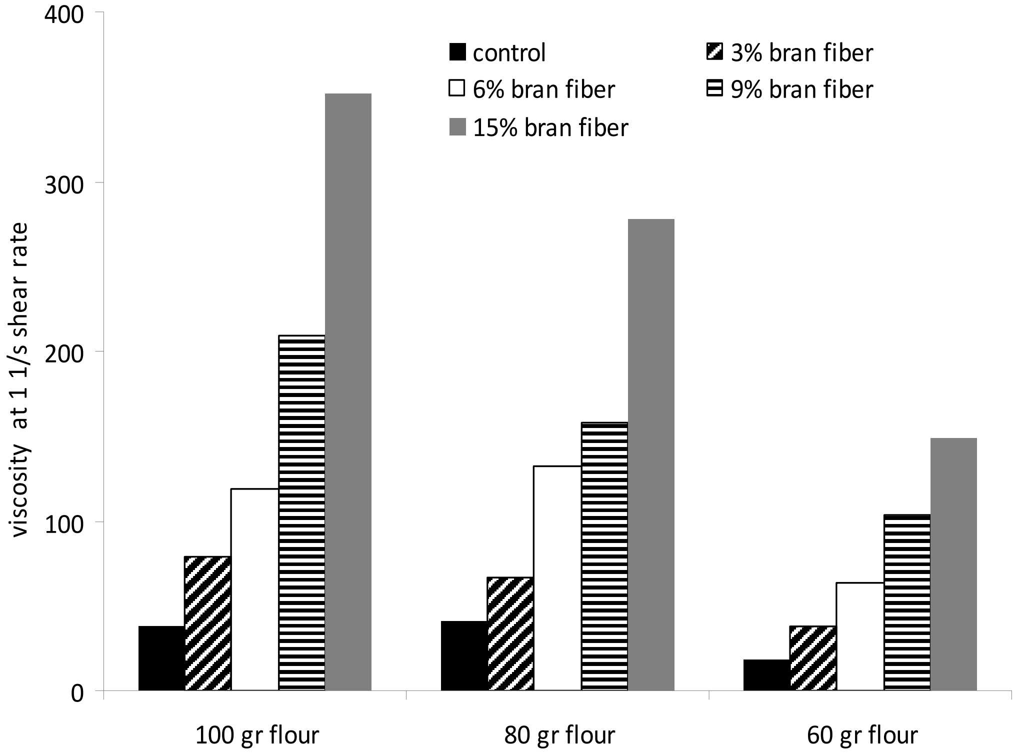

Figure 3.43 Viscosity values (at 1 1/s shear rate) of cake batters with 100, 80 and 60 g flour and with different concentrates of bran fiber

Figure 3.43 and Figure 3.44 show that the viscosity values increased with the increase in percentage of both wheat bran and bran fiber. However for all cake formulations, it was found that the addition of wheat bran fiber resulted in higher viscosity values as compared to the wheat bran addition. Moreover viscosity values decreased as the amount of flour decreased. The reason for the higher viscosity values in wheat bran fiber formulations may be because of the lower amount of air entrapped during mixing.

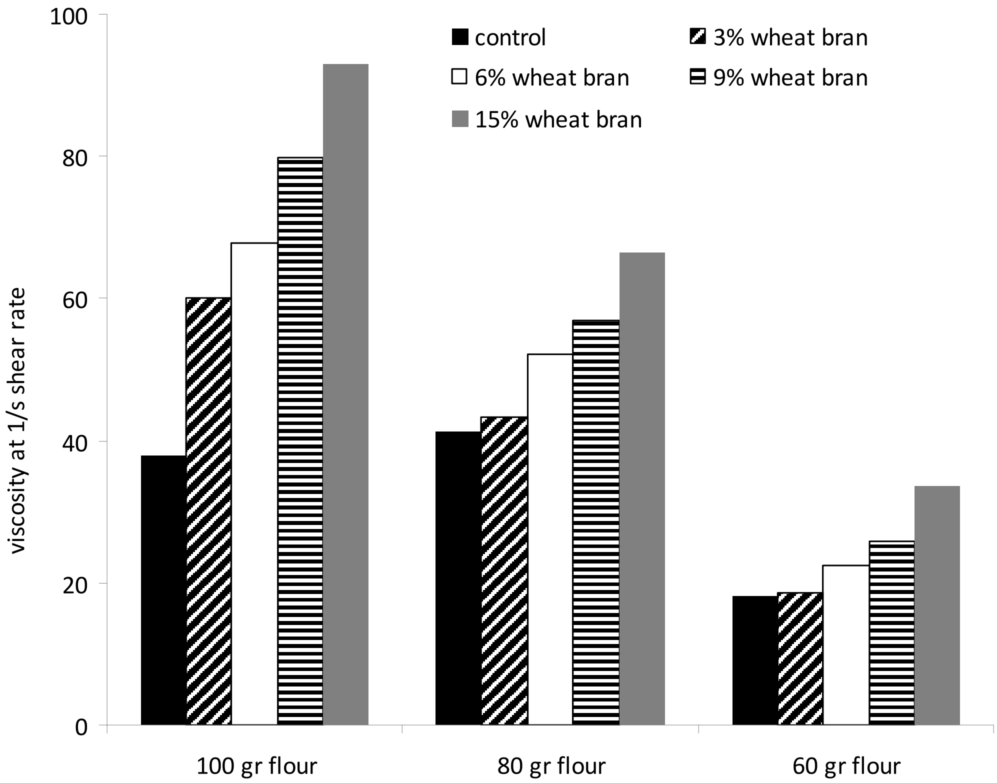

Figure 3.44 Viscosity values (at 1 1/s shear rate) of cake batters with 100, 80 and 60 g flour and with different concentrates of wheat bran

From the figures showing Volume and Outer Surface of Cakes (Figures 3.46, 3.47, 3.48, 3.49, 3.50 and 3.51), it can be concluded that the cakes with wheat bran had larger pores. Due to this higher air entrapped structure in wheat bran formulations, viscosity was lower and also volume was higher and so the pores. On the other hand, in bran fiber formulations, viscosity values were higher but the air entrapped was lower. The other difference was seen during baking when the amount of flour was decreased by %40 (60 g flour) (Figures 3.50 and 3.51), the formulations with wheat bran could not save its structure and they collapsed. However the bran fiber formulations saved its shape during and after the baking process.

3.B.2 Scanning Electron Microscopy Analysis

The characterizations of the wheat bran and wheat bran fiber are done by SEM. In Figure 3.45 picture A shows the SEM picture of wheat bran (A) and picture B shows the SEM picture of what bran fiber (B). As in tomato case, fiber has larger surface area with too much branches. Again after microfluidization process, the particle size became really smaller resulting in micro and nano particles. Figure resembling to Figure 3.19 was obtained again (here it is not included) that is the structure having increased water holding capacity was obtained in fiber form by the help of microfluidization process.

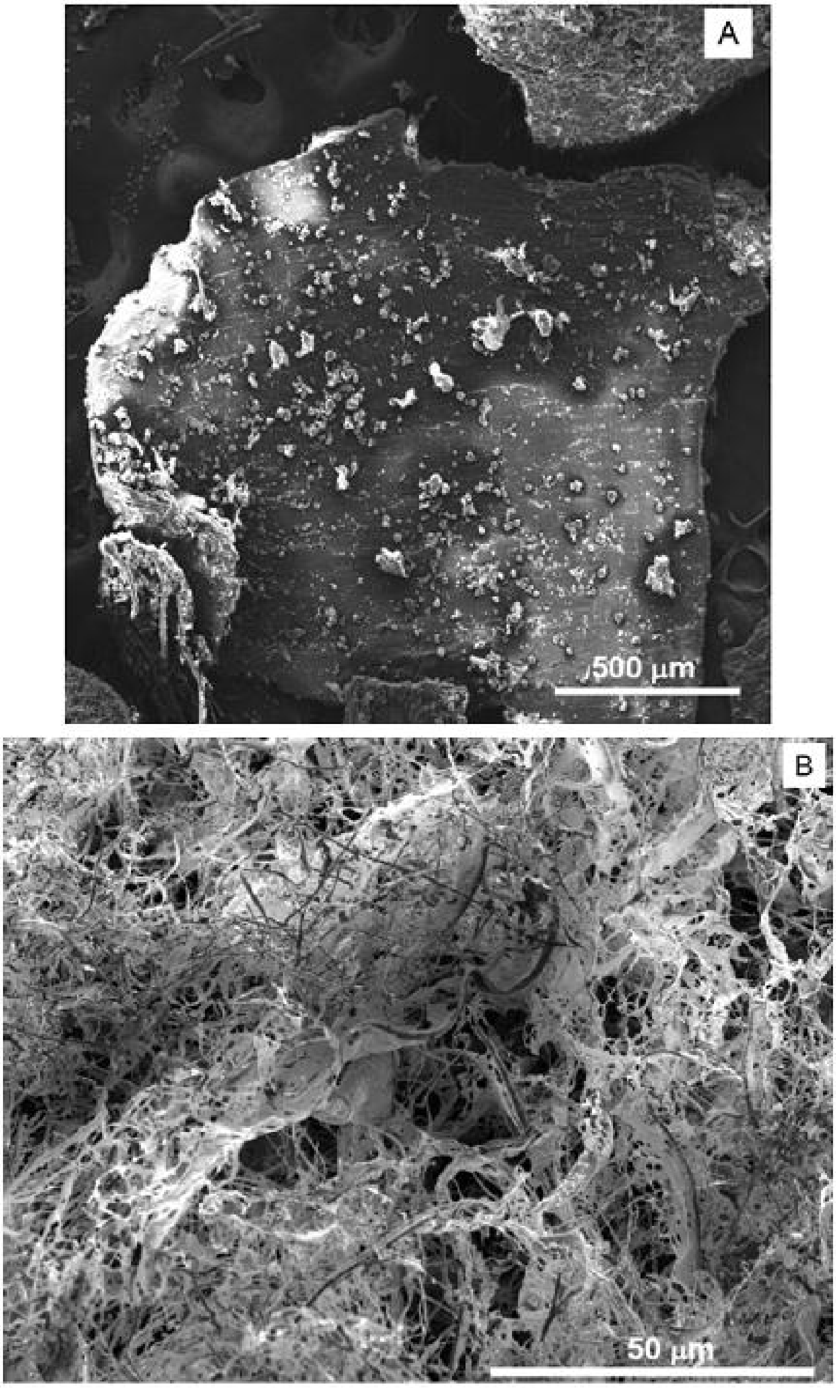

Figure 3.45 Scanning electron microscope picture wheat bran (A) and wheat bran fiber (B)

3.B.3 Texture of Cake

3.B.3.1 Volume and Outer Surface of Cakes

Figure 3.46 and Figure 3.47 show the difference between bran fiber and wheat bran addition to the cake batter for 100 g flour formulation. As the bran fiber was added to the cakes, the firmness was increased. Its pores became moredense and its volume became slightly smaller. Crust and crumb color became more brownish. On the other hand, addition of wheat bran to the formulation affected the color and volume in a smaller portion compared with bran fiber formulation. The cakes with wheat bran resembled to the bread structure in terms of appearance and texture. Wheat bran did not affect the pore size or the firmness of the cakes.

For 80 g flour formulation, the bran fiber again increased firmness and brownish color in final cakes while wheat bran did effect trivially (Figure 3.48 and Figure 3.49). Pictures (Figure 3.49) showed that addition of wheat bran in 80 g flour formulations resulted in increased pores. There was not any significant change in volume in wheat bran formulations.

In the cakes containing 60 g flour, pictures (Figure 3.50) showed that increasing the level of fiber resulted in increased volume of final product. As the percentage of flour in cake formulation decreased, a collapse began to occur in final cakes, but addition of fiber prevented this and also helped to cake to rise. The addition of bran fiber to formulations produced firmer structure which prevents shrinkage and any collapse during baking and effect of wheat bran is negligible compared with bran fiber (Figure 3.50 and Figure 3.51). In short, addition of bran fiber was a supporting ingredient to protect the structure of a cake, to protect it from collapsing and to prevent it from undesired shapes. By using bran fiber, cakes with greater color, texture and appearance could be obtained when the amount of flour was reduced.

As the concentration of bran fiber increased from 0% to 15%, the volume of the cake decreased. This situation is the expected result. Sudha et al. (2007) used apple pomace in cake formulation and stated that the density of the cakes increased due to the strong water binding properties of apple fiber. In the same way using bran fiber increased the density of the cakes and so decreased the volume. This result is the conclusion of the high water binding capacity of the fiber. Figure 3.46 also shows the addition of bran fiber resulted in smaller pores in cake. As the concentration of fiber increased, the size of pore decreased.

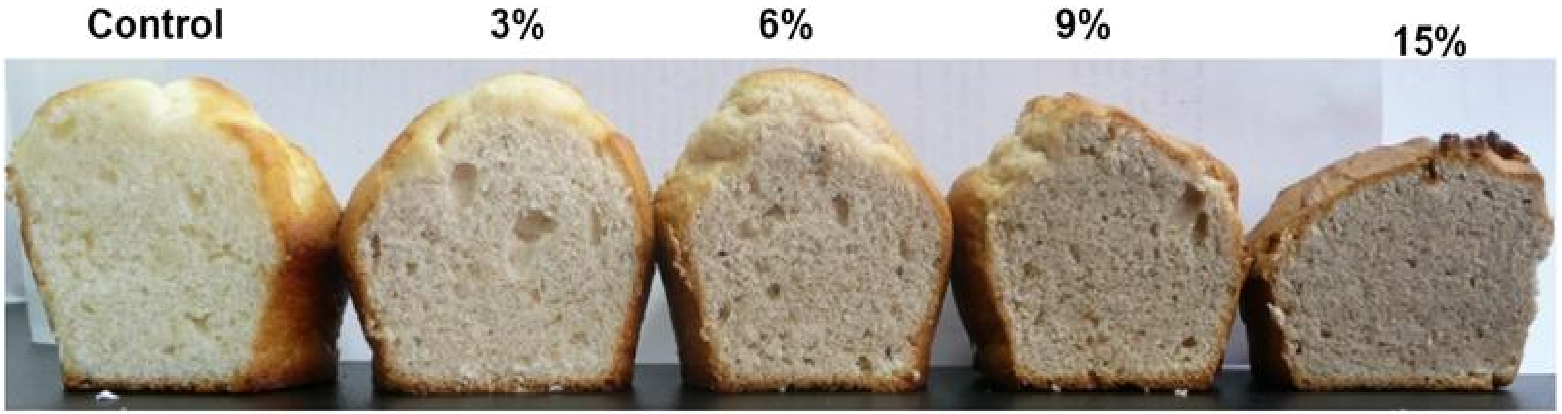

Figure 3.46 Pictures of cakes containing bran fiber based on 100 gr flour formulation: left to right, cakes containing 0%, 3%, 6%, 9% and 15% bran fiber.

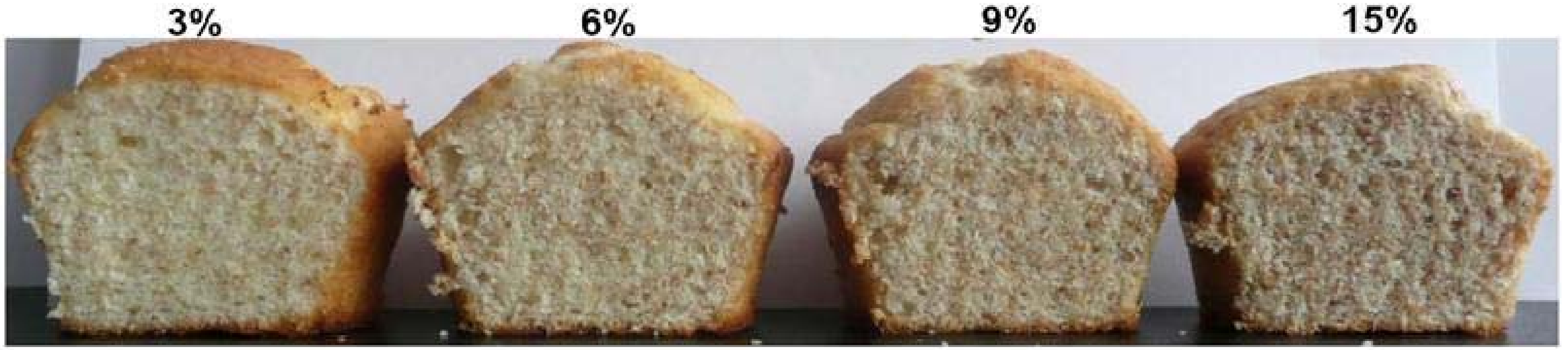

Figure 3.47 Pictures of cakes containing wheat bran based on 100 gr flour formulation : left to right, cake containing 3%, 6%, 9% and 15% wheat bran.

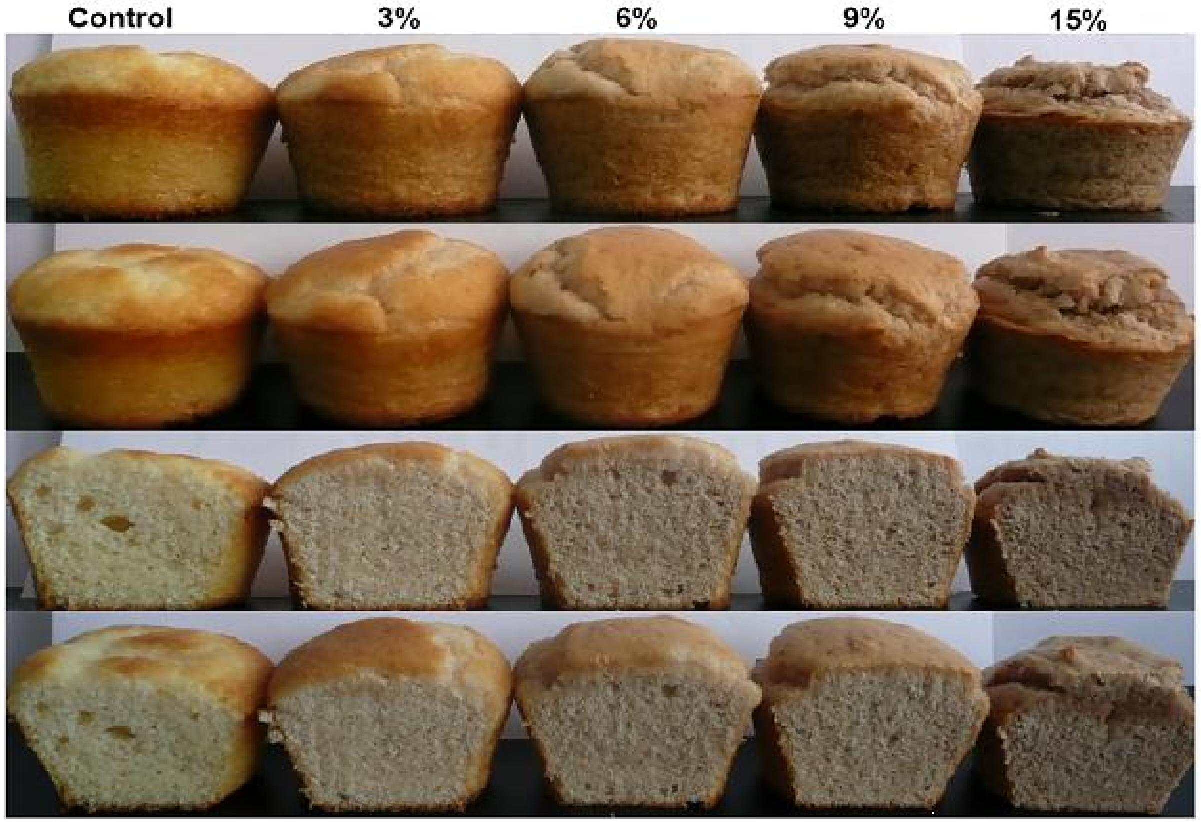

Figure 3.48 Pictures of cakes containing bran fiber based on 80 gr flour formulation: left to right, cake containing 0%, 3%, 6%, 9% and 15% bran fiber.

Figure 3.49 Pictures of cakes containing wheat bran based on 80 gr flour formulation: left to right, cake containing 3%, 6%, 9% and 15% wheat bran.

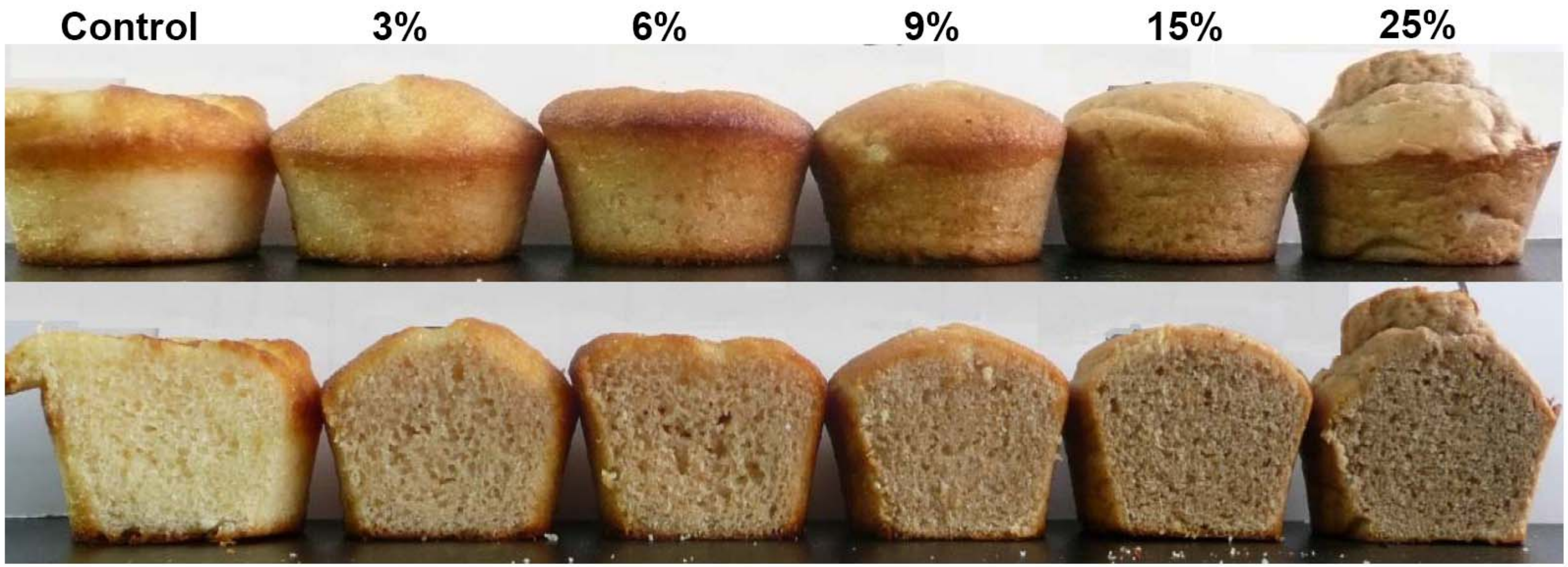

Figure 3.50 Pictures of cakes containing bran fiber based on 60 gr flour formulation: left to right, cake containing 0%, 3%, 6%, 9%, 15% and 25% bran fiber.

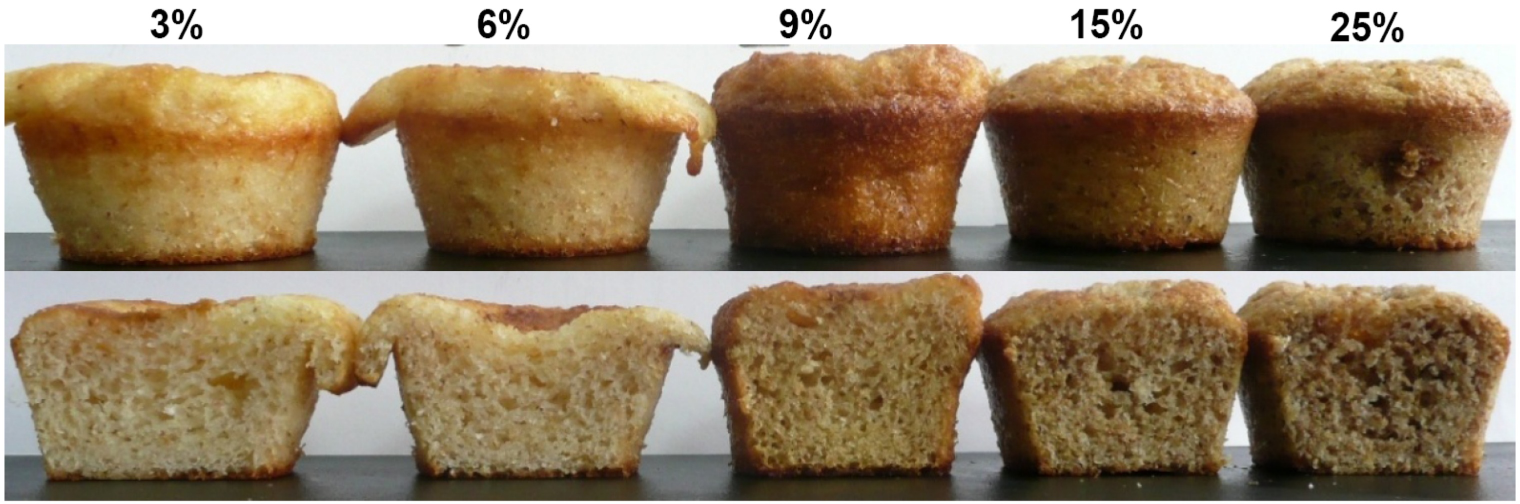

Figure 3.51 Pictures of cakes containing wheat bran based on 60 gr flour formulation: left to right, cake containing 3%, 6%, 9%, 15% and 25% wheat bran

Pore size and shape is important in cake manufacture, but when the flour decreased by %40 (to 60 g), the sizes of pores increased too much, and it continued to increase with the addition of wheat bran (Figure 3.51).

Cracking in the 25% bran fiber addition to the 60 gram flour formulation is because of the putting the sample to its container without flatten its surface before baking. Since the consistency of the cake batter in that sample was very high, it preserved its shape during baking as put into the oven. This is the case also in the 15 % bran fiber formulation in 80 gram flour batter.

Masoodi et al., 2002 demonstrated that a relationship exists between batter viscosity and cake structure. Thin batters were not viscous enough to hold air incorporated during mixing or the gas liberated by the baking powder. The consistency of batters is a very important physical property affecting the product quality as mentioned before. If the viscosity is too low, the bubbles in the batter which are incorporated into the batter during the mixing time can easily rise to the surface and are lost to the atmosphere during baking (Turabi et al., 2008). In rheological analysis of cake batter, it was seen how the viscosity values were higher in the cake samples prepared with wheat bran fiber than the samples prepared with wheat bran (Figure 3.38). As it can be seen from the Figures 3.49 and 3.50, while the cakes with wheat bran collapsed after baking, the samples with wheat bran fiber saved their structure during and after baking. Adding wheat bran fiber to the formulation increased the viscosity of cake batter and prevented collapse of the cakes in the oven.

In terms of pore diameter and their shape, it can be said that the samples with bran fiber had small and very uniform pore size distribution. On the other hand there are large voids in the formulations with wheat bran. These voids can be shown as the reason of that little volume increase (Figure 3.51).

3.B.3.2 Texture Profile of Cakes

Achieving the desired textural quality of food has important economic considerations.

The texture parameters play an important role on the acceptability of the cakes. Hardness, cohesiveness and gumminess are among most of the important textural parameters of cake. Therefore these parameters were measured using Texture Profile Analysis (TPA).

In the study, samples are stored in same conditions up to their relative humidity value became 80% for objective measuring and results of three major textural parameters (hardness, gumminess, chewiness) were taken.

Firmness of cakes was measured by considering both the cutting force and compression force. Therefore in the cutting experiment while the force to cut the cake sample was measured, in the compression experiment the force necessary to attain a predetermined penetration was measured. Other parameters such as cohesiveness and gumminess were measured during the compression test.

3.B.3.2.1 Cutting Experiment

Figure 3.52 Experimental setup for cake cutting experiment

Figure 3.52 shows the experimental setup for the cake cutting experiment.

3.B.3.2.1.1 Cutting Experiment of 100 g flour based cake formulation

Cutting forces required to cut the 100 gram flour cake formulations are shown in Figure 3.53. The lower force values were obtained for the cakes containing wheat bran. Increasing the concentration of wheat bran or bran fiber increased the cutting force (Figure 3.53). The increase was smaller in wheat bran than in bran fiber. While the control has around 350 g force, it became more than 3 times large in 15% bran fiber addition. The increase in cutting force indicates the increase in the hardness of the cake. That is the cake sample with 15% wheat bran fiber had the largest hardness value, while the control had the lowest. This result is expected after seeing the figures showing the Volume and Outer Surface of Cakes (Figure 3.46, 3.48, and 3.50). The pores become smaller and density became larger resulting in harder cakes in bran fiber formulations. Wheat bran did not have a significant effect.

Figure 3.53 Cutting experiment results obtained from 100 gram flour formulations

3.B.3.2.1.2 Cutting Experiment of 80 g flour based cake formulation

The 80 gram flour formulation was also showed similar trends in terms of wheat bran fiber addition with the formulation of 100 gram flour. Again the cutting force increased with the wheat bran fiber addition (Figure 3.54). However cutting forces were lower than the previous ones (100 gram flour formulation forces), since the decrease in the amount of flour resulted in softer texture.

The trend was not similar in wheat bran addition. The wheat bran addition to the formulation did not give a consistent result. Increasing the percentage of the wheat fiber firstly decreased the cutting force (% 3 percent wheat bran addition) but then the force began to increase in % 6 and % 9 formulations and finally decreased in % 15 wheat bran formulation (Figure 3.54). Only the % 9 formulation's cutting force was higher than the control's formulation. These results showed that the addition of wheat bran have not any dependable effect on texture of cake in terms of firmness, sometimes it lowered the firmness, sometimes increase, but all these effects were trivial, that it can be heeded.

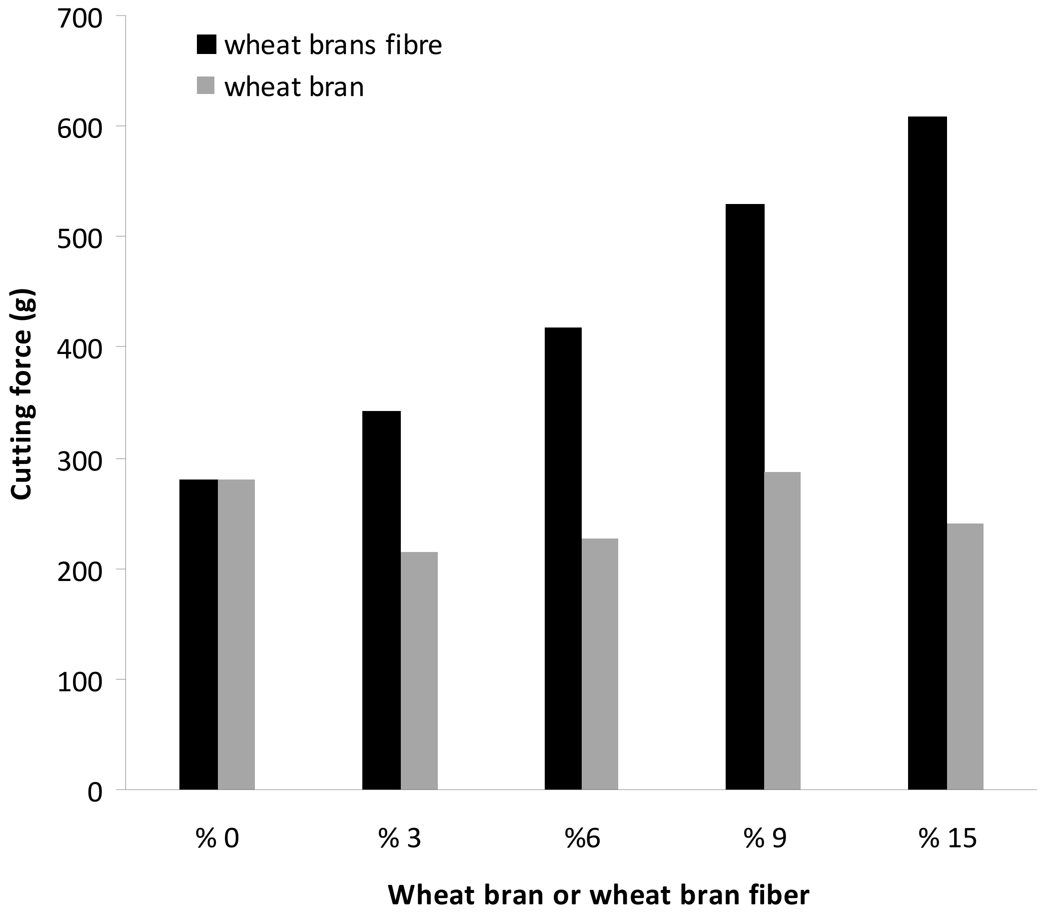

Figure 3.54 Cutting experiment results obtained from 80 gram flour formulations

3.B.3.2.1.3 Cutting Experiment of 60 g flour based cake formulation

One more time, it was showed that the cutting force increased depending on the percentage of wheat bran fiber, and wheat bran did not have any significant effect on the cutting force (Figure 3.55). Furthermore it was shown that as the amount of flour in the formulation decreased, the cutting force decreased dependingly.

As a conclusion from the three figures (Figures 3.53, 3.54 and 3.55), when 100 gram flour cake formulation with no wheat bran or wheat bran fiber taken as a reference, it is seen that the texture in terms of firmness can be meet by using 3 percent wheat bran fiber in 80 g flour and 3-6 percent in 60 gram flour. That it is possible to catch the same texture in the cake by decreasing the amount of flour, when the wheat bran fiber used in the formulation, but it can not be possible by using wheat bran.

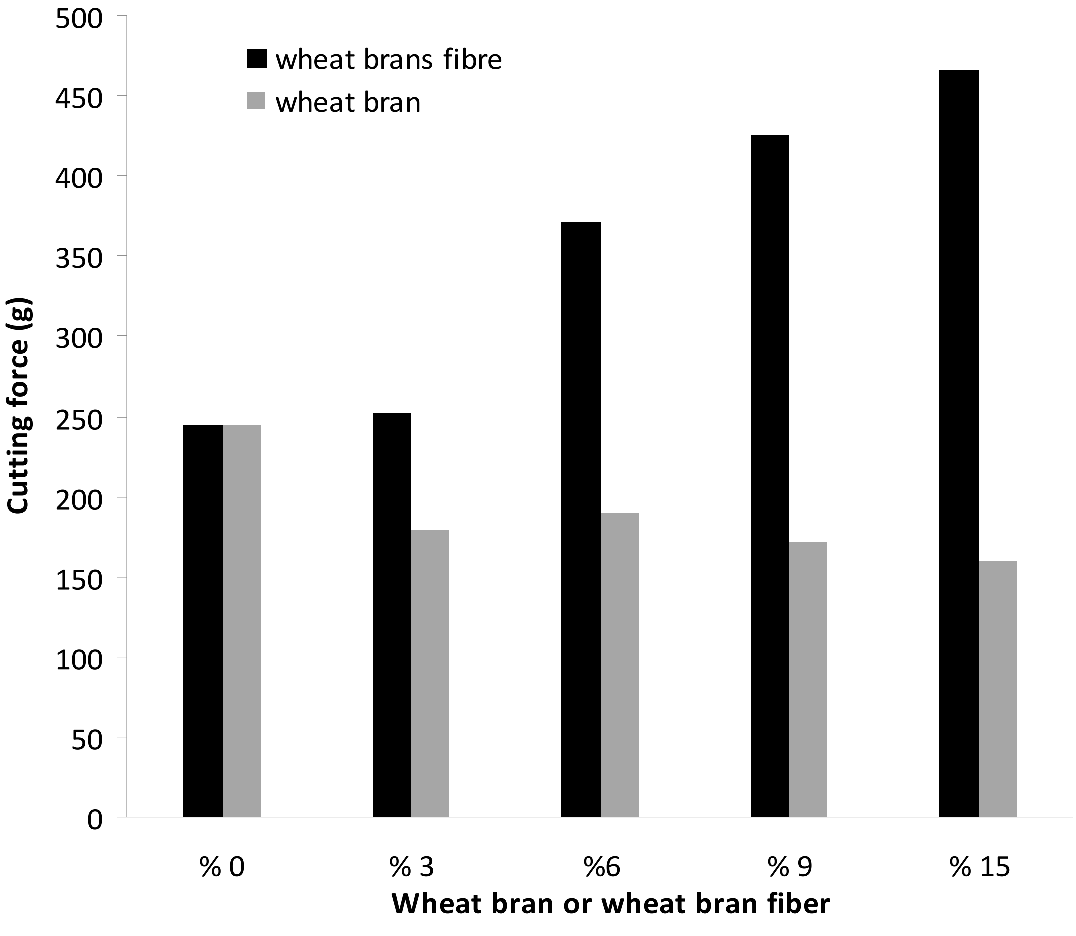

Figure 3.55 Cutting experiment results obtained from 60 gram flour formulations

3.B.3.2.2 Compression Experiment

In the compression experiment, squashing the sample enabled a number of textural properties to be evaluated, including hardness, cohesiveness, and gumminess.

Figure 3.56 shows the experimental setup for texture profile analysis.

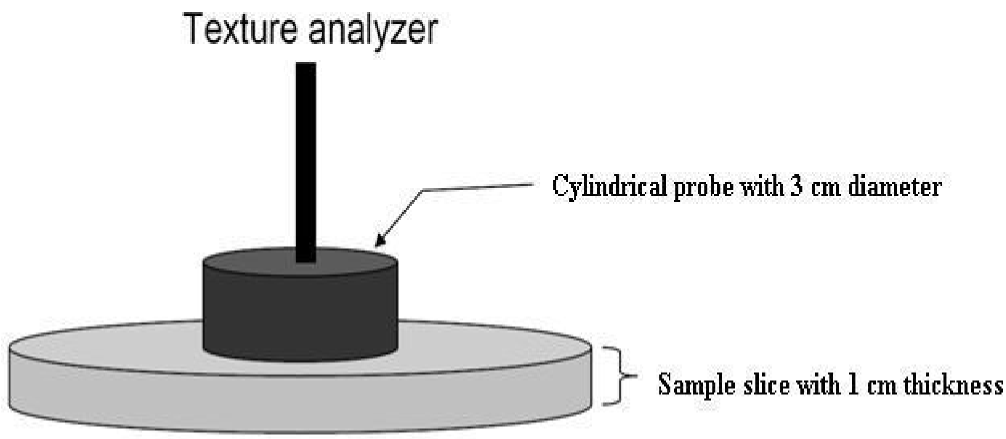

Figure 3.56 Experimental setup for texture profile analysis

Figure 3.57 shows the typical result for a texture profile analysis experiment.

Texture profile parameters were determined from:

Hardness : The maximum force during the first cycle of compression.

Cohesiveness: The ratio of the positive force area during the second cycle of compression to that of the first cycle (area of second peak / area of first peak).

Gumminess is defined as the product of hardness times cohesiveness.

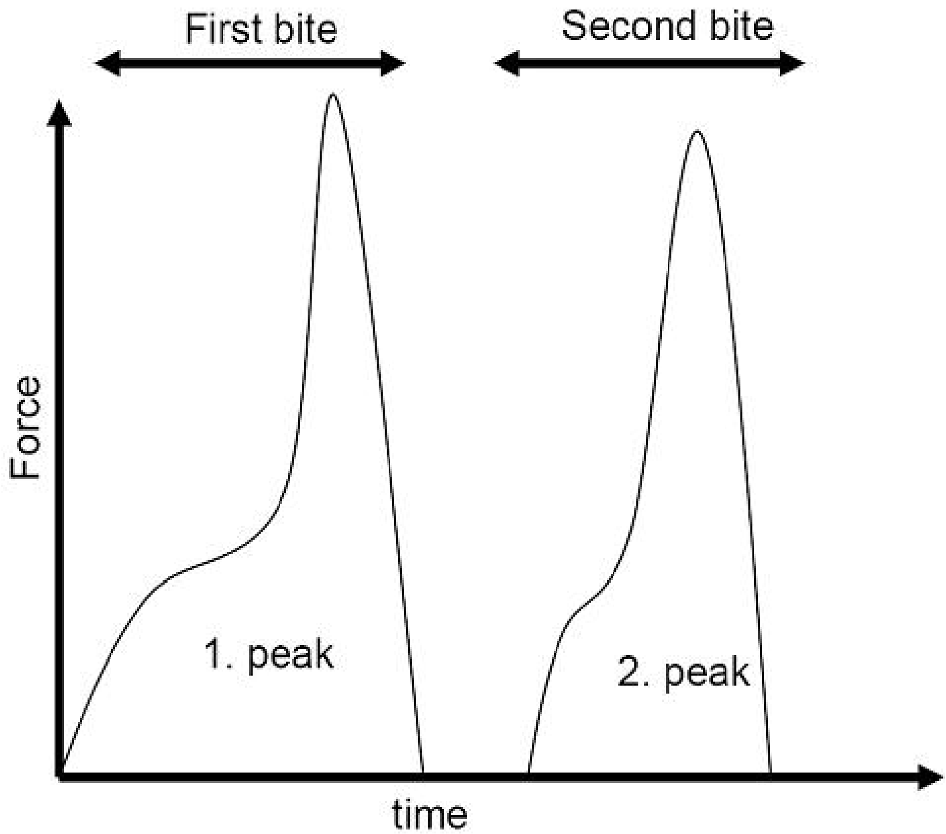

Figure 3.57 Typical result for a texture profile analysis experiment

3.B.3.2.2.1 Compression Experiment of 100 g flour based cake formulation

3.B.3.2.2.1.1 Hardness

The texture of the cakes measured using food texturemeter, showed that the cakes became harder with increasing levels of wheat bran fiber.

Figure 3.57 show the addition of wheat bran fiber to the formulation increased the hardness of the cake samples. This was an expected result since after seeing the results of cutting experiment and the results before. In the case of wheat bran addition there was not a significant results that can be reached because firstly addition of it increased the force but it gave a conflicting result in 15 percent addition by turning the rising trend to falling. However all the formulations with wheat bran or wheat bran fiber addition gave higher results in terms of hardness compared with control (the one containing neither bran nor bran fiber).

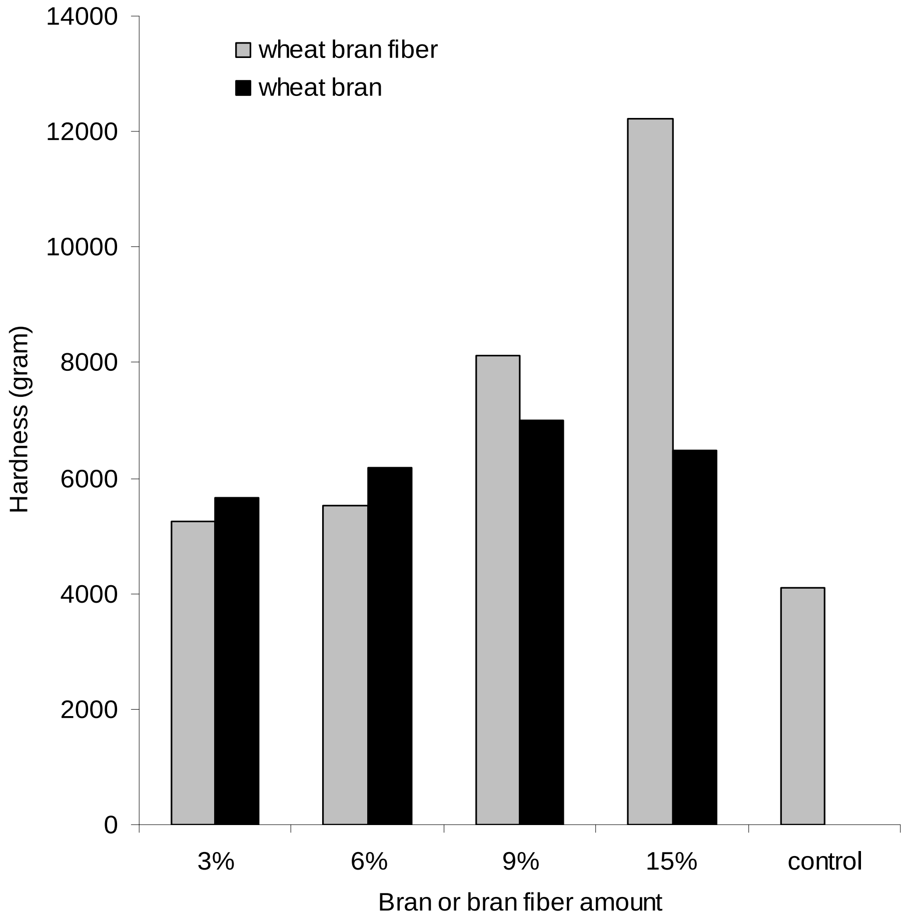

Figure 3.58 Hardness values obtained from compression experiment using 100 gram flour formulation

3.B.3.2.2.1.2 Cohesiveness

Cohesiveness determines the firmness and smoothness of cakes. Cake with good cohesiveness will be less crumbly and less fragile, resulting in a fresher feel (pleasant mouth feel) and making it easier to eat (no crumbs on shirt). Figure 3.59 shows how the wheat bran fiber addition increased the cohesiveness of the cake.

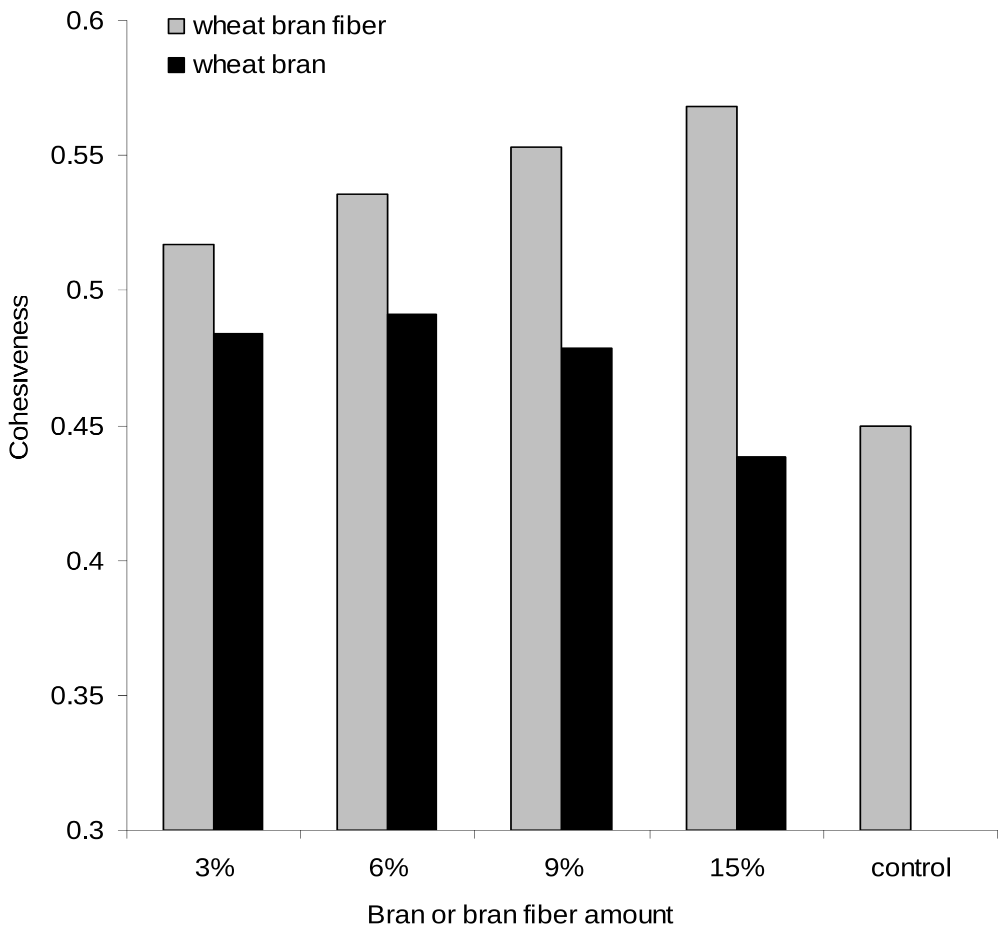

Figure 3.59 Cohesiveness values obtained from compression experiment using 100 gram flour formulation

The trend was same as in the hardness results. Cohesiveness increased parallel to the fiber addition.

3.B.3.2.2.1.3 Gumminess

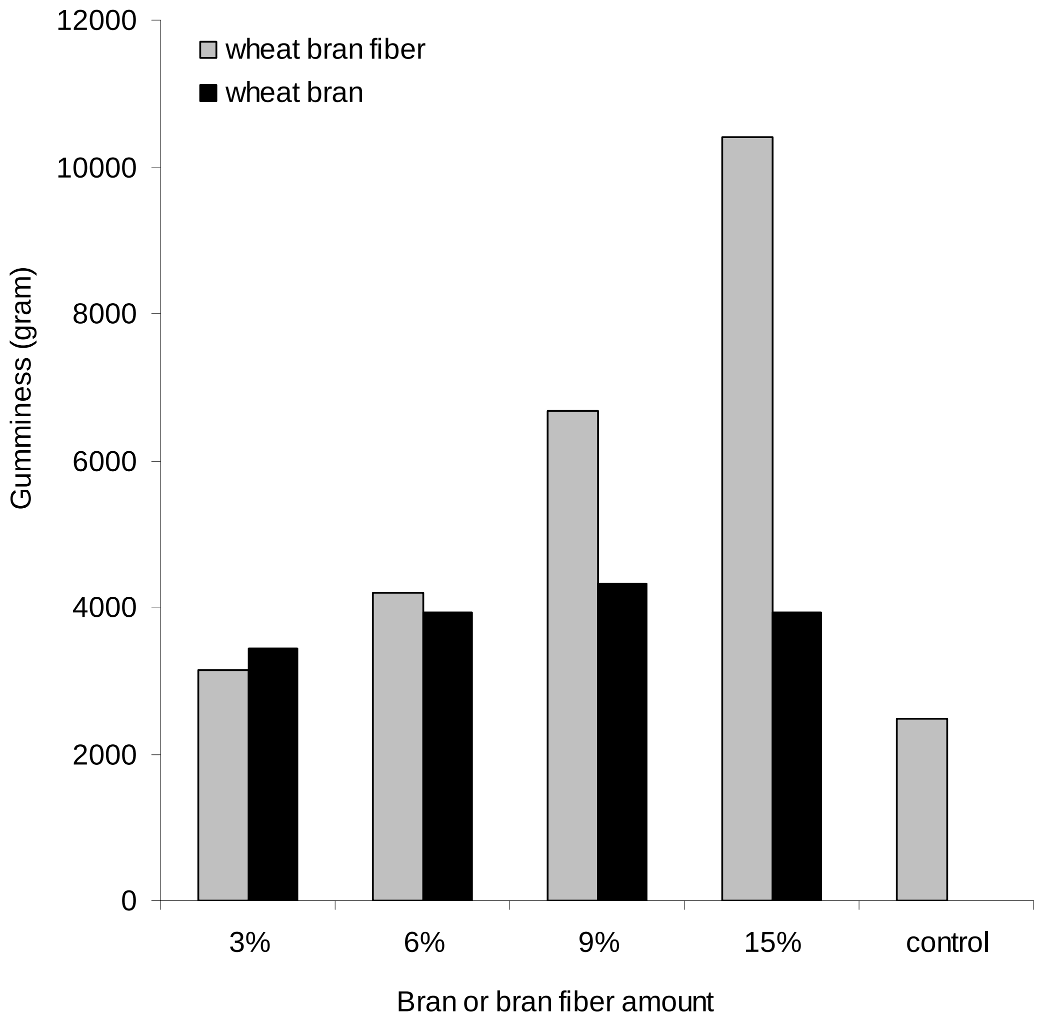

Figure 3.60 Gumminess values obtained from compression experiment using 100 gram flour formulation

Gumminess; another texture profile parameter, which is the product of hardness and cohesiveness values, showed almost similar trends with hardness; it again increased with bran fiber addition (Figure 3.60).

3.B.3.2.2.2 Compression Experiment of 80 g flour based cake formulation

3.B.3.2.2.2.1 Hardness

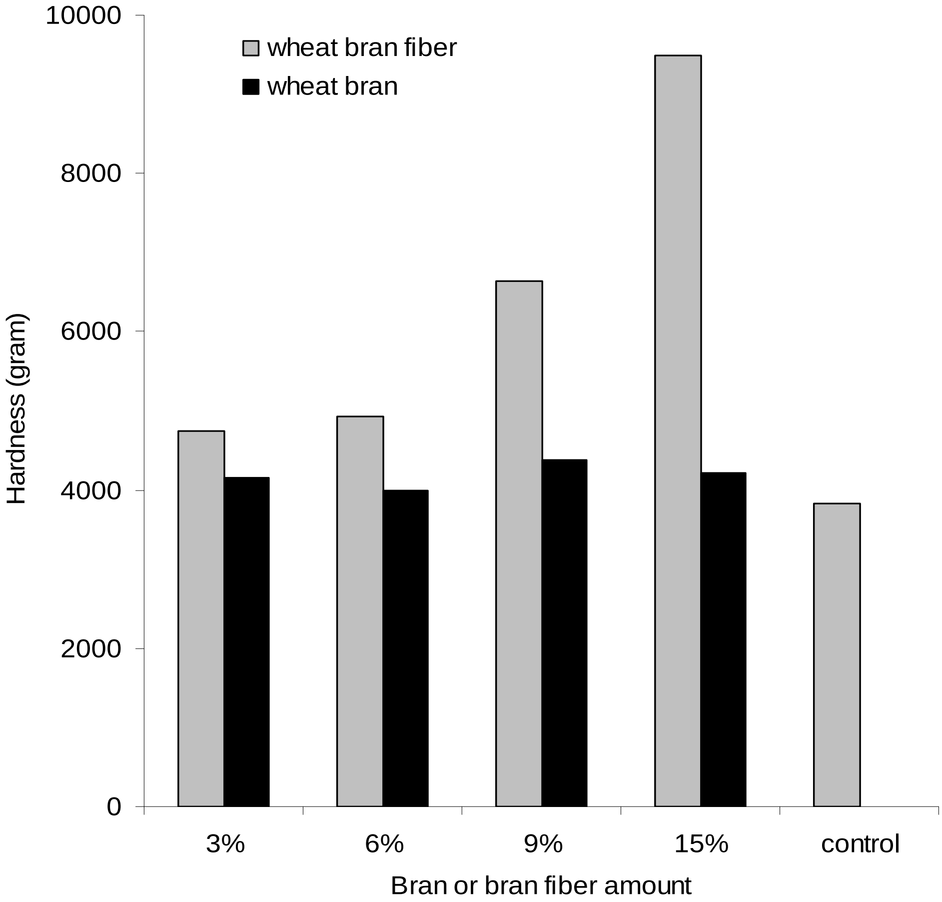

Figure 3.61 Hardness values obtained from compression experiment using 80 gram flour formulation

The highest hardness value was obtained for the 15 % wheat bran fiber containing cake. This hardness value was also significantly higher than the hardness value of the control cake. For bran fiber containing cakes, as the bran fiber concentration increased, the hardness values increased significantly (Figure 3.61). On the other hand, for wheat bran containing cakes, the concentration increase had no significant effect on the hardness values. The values for wheat bran samples were nearly the same with the control's. Furthermore, it can be shown from the Figure 3.61 that the hardness values are inversely proportional with the amount of flour. That is the hardness values in same concentrations are lower compared to the 100 gram flour formulations.

3.B.3.2.2.2.2 Cohesiveness

Figure 3.62 shows the effect of wheat bran and wheat bran fiber addition to cohesiveness values of the cake formulated with 80 gram flour. While the formulations with 3 percent and 6 percent bran fiber showed similar results with the 80 gram flour control cake sample, the one with 9 percent and 15 percent resulted in higher values of cohesiveness. On the other hand the one with wheat bran were found to be lower at all concentrations in terms of cohesiveness.

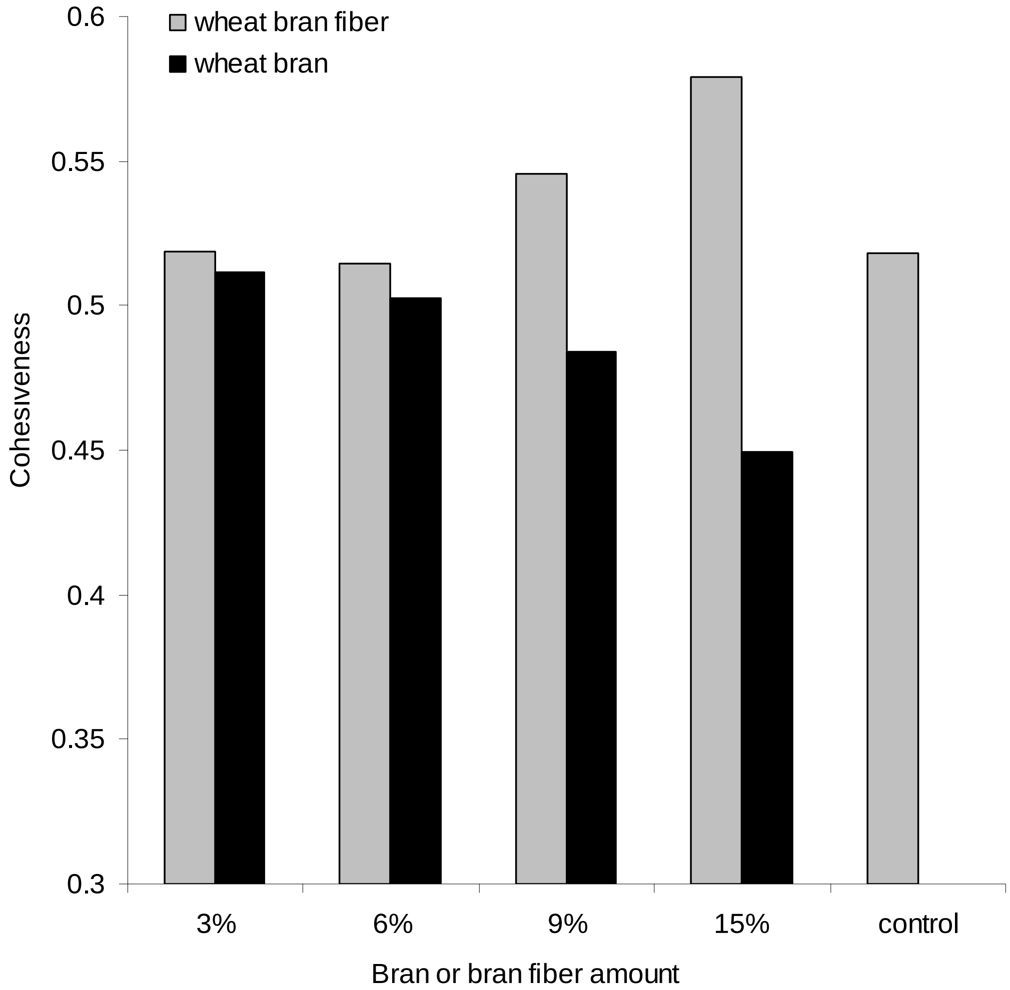

Figure 3.62 Cohesiveness values obtained from compression experiment using 80 gram flour formulation

3.B.3.2.2.2.3 Gumminess

It was found that for 80 gram flour formulation, the gumminess values are directly proportional to percentage of wheat bran fiber in the formulation (Figure 3.63) ; moreover decreasing the amount of flour resulted in decreased the gumminess values.

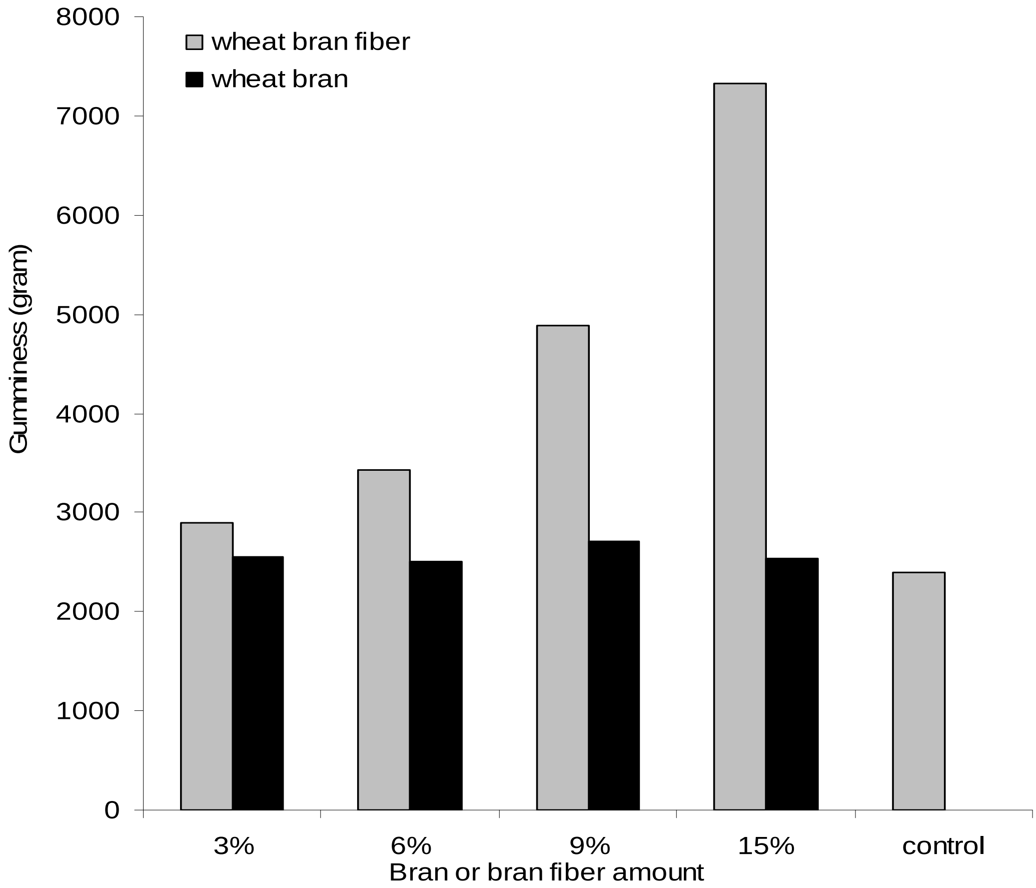

Figure 3.63 Gumminess values obtained from compression experiment using 80 gram flour formulations

3.B.3.2.2.3 Compression Experiment of 60 g flour based cake formulation

3.B.3.2.2.3.1 Hardness

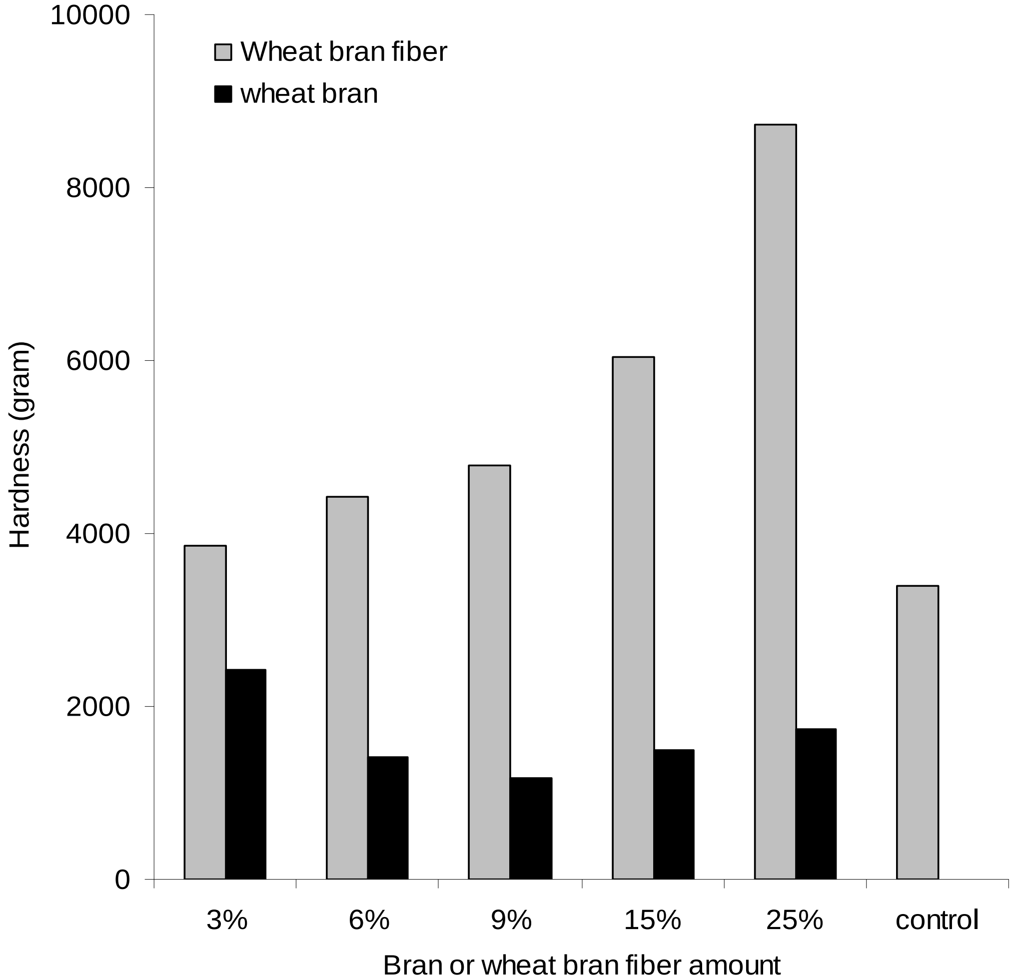

Figure 3.64 Hardness values obtained from compression experiment using 60 gram flour formulations

Increasing wheat bran fiber content of samples increased the firmness of the cake samples. While the addition of wheat bran had negative effect in terms of firmness, wheat bran fiber helps the samples to gain a texture. The addition of wheat bran reduced the firmness of all samples; the samples become softer giving less resistance to the applied force during analyses (Figure 3.64).

The results of the hardness of 100 g, 80 g and 60 gram flour formulations showed that it was possible to produce high quality cakes in terms of hardness by decreasing the amount of flour used (Figures 3.58, 3.59 and 3.60). Hardness is a term which is not preferred in cake manufacture, but it is also a term which is necessary to characterize the cake texture. Soft structure is not also acceptable for the good quality. To balance between soft and hard is the desired. Wheat bran fiber can be an ingredient to serve this aim; it can be a texture modifier. Decreasing the amount of flour results in low hardness values, then the cake can not save its structure and then collapse. Using wheat bran fiber provides cakes firmness so the stable structure can be preserved when the amount of flour decreased. This issue is clearly seen in 60 gram flour formulation. When the flour amount was decreased by 40 percent, the hardness values decreased significantly and cakes could not preserved its structure and collapsed but when wheat bran fiber was added to the formulation, its hardness values began to increase, and it gained its desired texture, while the wheat bran could not provide this.

3.B.3.2.2.3.2 Cohesiveness

Cohesiveness values in 60 gram flour formulations were higher for 15 and 25 percent wheat bran fiber formulations than the 60 gram control cake. Cohesiveness is the texture profile parameter which shows how well the product withstands a second deformation compared to its behavior under the first deformation. As another definition, it is the integrity of the product (Demirkol, 2007). As a conclusion it can be said that 15 and 25 percent wheat bran fiber formulations resulted in higher integrity in the cakes.

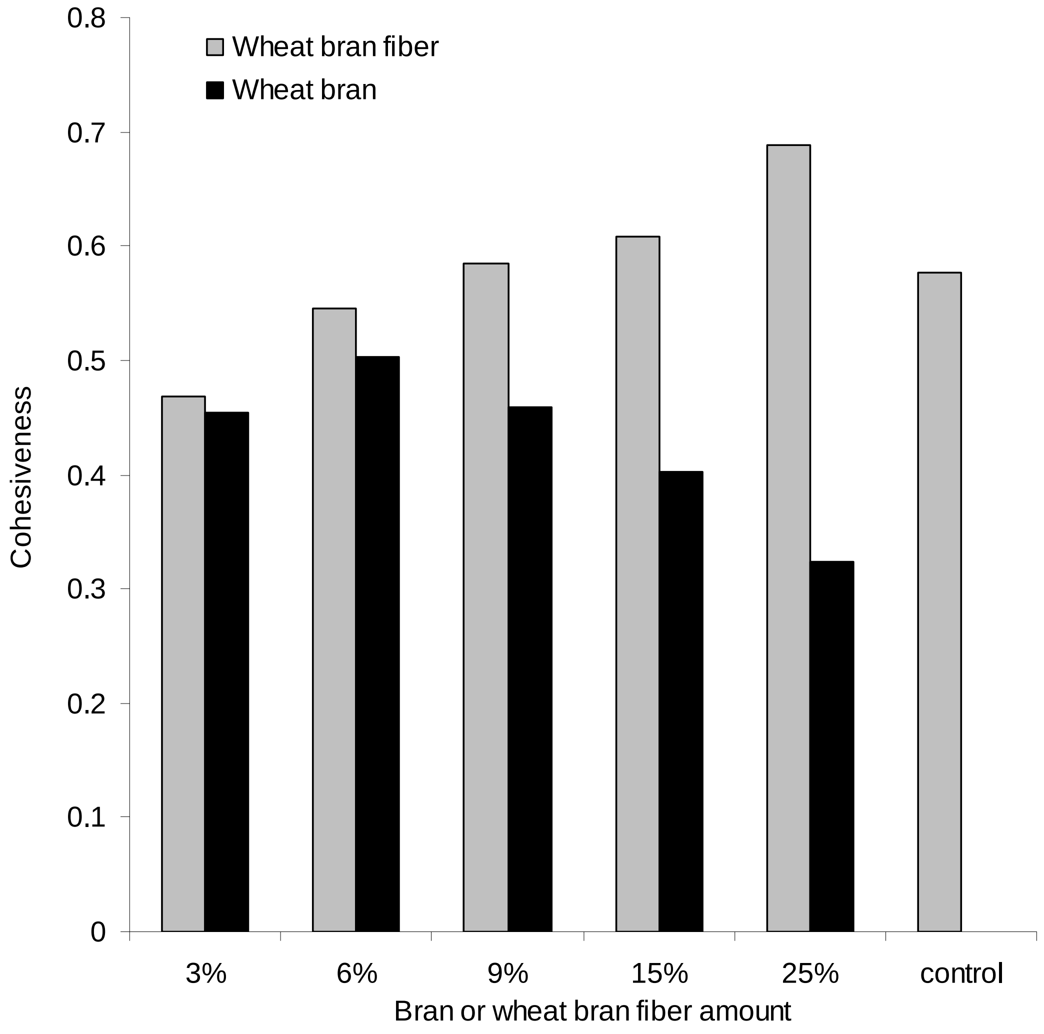

Figure 3.65 Cohesiveness values obtained from compression experiment using 60 gram flour formulations

Figures 3.59, 3.62 and 3.65 show that the cohesiveness values increased with the decrease in flour amount. In the cakes prepared using 0% wheat bran and bran fiber (control cakes), whereas the cohesiveness value in 100 gram formulation is around 0.45, it raised above 0.5 and nearly to 0.6 in 80 gram flour and 60 gram flour formulation respectively. The effect of the wheat bran was sometimes in positive trend but sometimes in negative trend. While the cohesiveness increased to around 0.6 in 60 gram flour formulation, it decreased to nearly 0.3 when 25 percent wheat bran was used. When compared with 100 gram flour control, all the samples prepared with wheat bran fiber showed higher cohesiveness values and so higher integrity results.

3.B.3.2.2.3.3 Gumminess

Figure 3.66 shows that increasing wheat bran fiber content of samples increased the gumminess values especially at addition levels of 15% and 25% .However the addition of wheat bran to the formulation reduced the gumminess at all concentrations.

Figures 3.60, 3.63 and 3.66 show that the gumminess values were increased when wheat bran fiber was added to the formulations, this result is valid for all 100 gram, 80 gram and 60 gram flour formulations at all concentrations of bran fiber. Gumminess did not change when the amount of flour was decreased by 20 %, but it decreased when it was decreased by 40 %. However for both 20 and 40 % reduced formulations, the gumminess values began to increase directly with the bran fiber addition, whereas the effect of wheat bran was changeable.

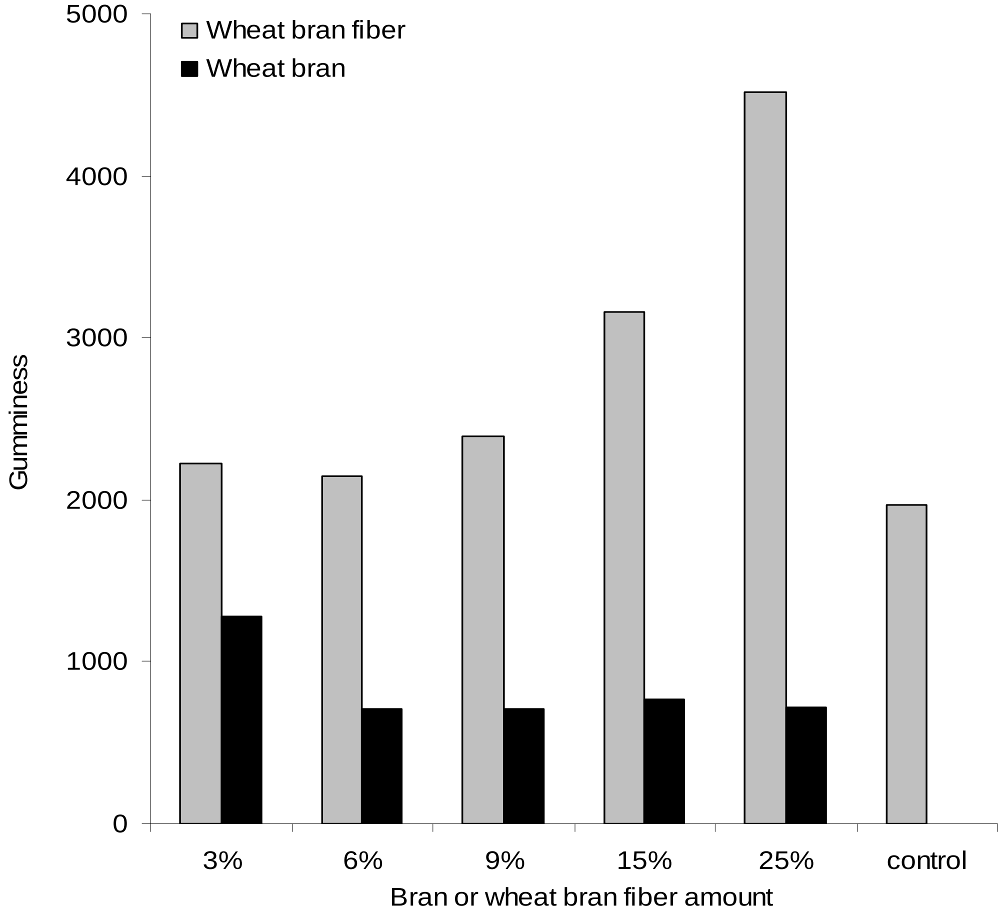

Figure 3.66 Gumminess values obtained from compression experiment using 60 gram flour formulations

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

Tomato pulp/pomace at present is a waste product of tomato industry. However it is very valuable that it should not be left as a waste and should need to be evaluated. Moreover it should be reused since the use of food processing wastes means using a fixed amount of food for more people and less environmental damage. The results obtained in the study showed that the tomato pulp/pomace is one of the valuable wastes that need to be evaluated. The rheologic data on the samples with and without the tomato fiber showed that the tomato fiber could be used instead of other hydrocolloids or thickeners in the formulation of tomato ketchup or by using it, the amount of tomato used in the ketchup production can be decreased. After investigating the samples with tomato fiber and tomato powder and compared with the results of the ketchups sold in the market (Tamek, Tukas, Calve, Heinz, Tat, and Bizim), it was concluded that using tomato fiber in 6 % will be enough to catch the flow characteristics of tomato ketchup sold in the market, while in terms of powder this ratio will be about % 20. The fiber showed to be a good candidate for improving the rheological properties of products with similar color and flavor i.e. the present study showed that tomato fiber can be used to improve quality of ketchups by behaving as rheology modifier. Moreover this result verified with the stability measurements data.

From the experimental results obtained it was concluded that the trend was same in cake samples in terms of rheology modification. The fiber addition to the formulations increased the viscosity and yield stress of samples. The effect was striking and valuable as the amount of flour decreased.

When the textures of cakes prepared were investigated in terms of volume, outer surface, hardness, cohesiveness and gumminess, it was seen that addition of wheat bran fiber increased hardness, cohesiveness and gumminess; on the other hand wheat bran did not have any significant effect on them. Moreover, all three values decreased as the amount of flour decreased. It was concluded from the results that cakes with a charming crust and crumb color can be obtained with bran fiber. Bran fiber behave as texture modifier as the amount of flour decreased by avoiding collapses, undesired pores and shapes in the cake. It saved the structure of the cake, prevented it from undesired shapes and also helped to cake to rise. Also bran fiber addition prevented large voids and uniformity in the inner part of cake that was seen in wheat bran formulations in decreased flour formulations. It was seen that it was possible to produce good quality cakes which would be healthier even in a 40% decrease in flour amount.

It can be concluded that using bran fiber can provide healthier cakes with decreased amount of flour without sacrificing from quality (in terms of both rheology and texture). Furthermore, the cakes with fiber will be healthier since the amount of flour can be decreased; the calorie value will be decreased too, and also will include dietary fiber. In addition to all, addition of bran fiber in cake making can avoid the addition of other flavouring ingredients as the cakes prepared with it had pleasant flavour.

As future work, the effects of other fruits' and (or vegetables') and/or their waste products may be studied in terms of fiber composition and function to obtain the improved product quality with healtier and environmental results. As an example apple pomace fiber may be studied in biscuit production. Since the biscuits have a wide range in terms of color and taste, lots of other alternatives can be tried, such as lemon pomace fiber, pumpkin fiber, wheat bran fiber, and so on. Those alternative sources may also be used in the cake formulation to obtain improved quality with different aromas and colors.

In addition to these, different fruits/vegetables and/or their pomaces may be used in emulsions and foams in order to obtain impoved stability so improved quality. It should not be forgetton that there are lots of valuable components in wastes taht are waiting to be evaluated.

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