PRODUCTION OF CACAO MICRO AND NANO FIBERS AND UTILIZATION IN CAKES

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PRODUCTION OF CACAO MICRO AND NANO FIBERS AND UTILIZATION IN CAKES

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ABSTRACT

PRODUCTION OF CACAO MICRO AND NANO FIBERS AND UTILIZATION IN CAKES

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The main objective of this study was to investigate micro and nano cacao fibers and their effects on quality, texture and staling of cakes.

In the first part of the study, rheological properties of cake batter with different concentrations (0 %, 3 %, 6 %, 9 %, 12 %) cacao micro and nano fiber, and cacao powder were determined. Cake batter was found to show shear thinning and time independent behavior for all formulations and fit the Power Law model. The viscosity increased as the percentage of fiber increased. Both G′ and G″ values increased with oscillatory frequency and percentage of fiber.

In the second part of the study, physical properties (specific volume, texture, color and weight loss), sensory properties of cakes and textural changes during storage were determined. Addition of micro and nano cacao fibers to the cake formulation decreased specific volume, weight loss and L* values. It increased hardness, springiness, chewiness, resilience and elastic recovery values and minimized textural changes during storage. Fiber addition also improved the cake acceptability of the cakes in terms of odor, taste and color.

Keywords: Cacao fiber, Cacao powder, Rheology, Texture, Cake

ÖZ

MİKRO VE NANO KAKAO LİFLERİNİN ÜRETİLMESİ VE KEKLERDE KULLANILMASI

Duman, Burcu
Yüksek Lisans, Gıda Mühendisliği Bölümü
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Bu çalışmanın amacı mikro ve nano kakao liflerinin keklerin kalitesi, tekstürü ve bayatlaması üzerine etkilerini araştırmaktır.

Çalışmanın ilk aşamasında kek hamurunun reolojik özellikleri incelenmiştir. Keklerde değişik oranlarda (0 %, 3 %, 6 %, 9 %, 12 %) kakao tozu ve kakao mikro ve nano lifi kullanılmıştır. Kek hamuru örneklerinin kayma ile incelen bir yapı gösterdiği, reolojik açıdan zamandan bağımsız olduğu ve Power Law modeline uyduğu belirlenmiştir. Hamurun vizkozitesinin lif yüzdesi arttıkça arttığı gözlenmiştir. G′ ve G″ değerleri artan salınım frekansıyla ve lif yüzdesiyle birlikte artmıştır.

Çalışmanın ikinci aşamasında keklerin fiziksel (özgül hacim, tekstür,renk ve ağırlık kaybı), ve duyusal özellikleri ile keklerin depolama sürecinde tekstür değişimleri incelenmiştir. Mikro ve nano kakao liflerinin keklere eklenmesi, keklerin özgül hacmini, ağırlık kaybını ve L* değerlerini azaltmıştır.Lif kekin sertliğini, çiğnenebilirliğini, elastikiyetini ve elastik toparlanma yeteneğin arrtırmış ve depolama sürecince tekstürel değişiklikleri azaltmıştır. Lif eklenmesi ayrıca keklerin koku, tat ve renk açısından kabul edilebilirliğini arttırmıştır.

Anahtar sözcükler: Kakao lifi, Kakao tozu, Reoloji, Tekstür, Kek

To My Family

ACKNOWLEDGEMENTS

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Finally, I would like to express my deepest gratitude to my family, my father, Güven Duman, my mother Zekiye Duman, for their love, endless patience and belief. With love I dedicate this work to them.

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LIST OF ABBREVIATIONS

DF	Dietary Fiber
G′	Storage Modulus
G″	Loss Modulus
n	Flow Behavior Index
RDA	Recommended Daily Allowance
SEM	Scanning Electron Microscope
TPA	Texture Profile Analysis
WHC	Water Holding Capacity
WBC	Water Binding Capacity

CHAPTER 1

INTRODUCTION

1.1. History of Dietary Fiber

History of dietary fiber goes back to the ancient history. In 450 B.C. Ancient Greek physician Hippocrate advised people to eat whole wheat bread for its laxative effects on bowel. Roman athletes believe eating whole grain bread make them stronger and healthier. 1000 years later in 9th century A.D. the Persian physician Hakim repeated Hippocrates' observation about laxative effects of whole wheat. During medieval and middle ages in Mesopotamia, Greece, and Rome and in European countries diets based on high fiber containing cereal, vegetables fruits (Dreher 2001).

In 18th century with industrial revolution white flour, meat, high sugar and fat containing foods became more available. At the turn of the century, a major change took place in the pattern of the Western diet. Fiber-rich diets started to change through fat and sugar-rich diets (Walker 1993).

In 19th century Burne and Graham indicated laxative effect of whole grain and their positive effects on health. Until 1950 few publications were made but this subject could not draw enough attention. In those years concept that group of substances practically indigestible by human gastrointestinal enzymes could be important to health did not seem right to nutritionists, physiologists, and physicians (Spiller 2001).

In 1950s Cleve hypothesized that most of the western disease were caused by high consumption of refined carbohydrates and lack of 'bulk' food. After publication of Refined Carbohydrate Foods and Disease by Burkitt and Trowell in 1975, fiber gained momentum. Nowadays dietary fiber is one of the most research fields as a food component (Dreher 2001).

1.2. Definition of Dietary Fiber

In 1953 dietary fiber term was used by Hipsley as a shorthand term of non-digestible components of plant cell wall. Between 1972 and 1976, Burkitt et al. (1972), Trowell (1972*a*,*b*, 1974) and Painter (1975) expanded the definition as include cellulose, hemicelluloses, lignin, gums, modified celluloses, mucilage, oligosaccharides and pectin, and associated minor substances such as waxes, cutin and suberin (Anderson et al. 2009).

Through the years the term has been updated several times. More recently, the definition of dietary fiber has been broadened to include oligosaccharides, such as inulin, and resistant starches (Anderson et al. 2009).

1.3.Physicochemical and Functional Properties of Dietary Fiber

1.3.1. Hydration Properties

Hydration properties of fibers are described by 4 parameter. Water-holding capacity (WHC), water-binding capacity (WBC), swelling and solubility.

WHC can be defined as the quantity of water that is bound to fiber without external forces except atmospheric pressure or gravitational force. WBC is quantity of water that remains bonded to fiber after application of external forces like centrifuge or pressure (Thebaudin et al. 1997).

Fibers are divided into two categories according to their solubility as soluble and insoluble fibers. Solubility is a major factor functional property of fibers. Soluble fibers play a role prevention of cardiovascular diseases by influencing to lipid metabolism and lower the level of total and LDL (low-density lipoprotein) cholesterol, and also lower or control sugar level in blood (Guo 2009).

Insoluble fibers have laxative effect, contribute to fecal bulk, decrease transit time and helps prevent colon cancer, diverticulosis and hemorrhoids (Staniforth et al. 1991, Oakenfull 2001).

Solubility and swelling properties connected to each other. First step of polysaccharide solubility are swelling by absorbing water. Water moves into solids structure and disperse completely in macromolecules. This can lead to solubility (Thebaudin et al. 1997).

Fibers have a high water holding capacity. This helps to retard staling by controlling moisture migration. It also increase freeze-thaw stability and reduce weeping or syneresis (Nelson 2001).

1.3.2. Binding of Small Molecules and Ions

In addition to binding water fibers have ability of binding bile acids, carcinogens and mutagens. Fibers decrease cholesterol level and help prevent colon cancer by binding with bile acids (Blackwood et al. 2000).

Fibers also reduce mineral ability and electrolyte absorption due to binding metal ions and minerals. They bind with minerals mostly iron, zinc and calcium. Absorption of zinc and iron are actually enhanced to phytate level in fibers. It could be eliminated by removing phytate from fiber (Oakenfull 2001,Thebaudin et al. 1997).

It has been stated that dietary fiber has limiting effect in bioavailability of some vitamins mostly E and D vitamins (Thebaudin et al. 1997).

1.3.3. Viscosity

Viscosity is defined as the ratio of the shear stress to the shear rate or more simply the resistance of the fluid to flow. Fibers are able to increase the viscosities of food systems because of their high water holding capacity and gel-forming capacities. There are many factors effecting contribution of the fibers on viscosity such as temperature, pH, concentration of fiber, shear condition. In general as the molecular weight and fiber length increase, the viscosity increases (Nelson 2001).

1.3.4. Oil- Binding Capacity

Fibers also have ability to bind oil. The ability of binding oil is a function of porosity of the fiber structure more than an affinity of the molecule for oil. The lengths of molecules also play a role in oil-binding capacity. Presoaking fiber with water reduces fat intake because pores are occupied by water before oil. This can help to reduce uptake oil during frying and reduce fat content of the product (Nelson 2001).

1.4. The Role of Dietary Fiber in Human Health

1.4.1. Dietary Fiber and Cardiovascular Disease

It’s stated that soluble dietary fiber effect lipid metabolism, thus have potential to reduce total and LDL cholesterol level. Dietary fibers prevent accumulation of cholesterol, decrease level of VLDL(Very-low-density lipoprotein) and inhibit the transformation of VLDL to LDL (Guillon and Champ 2000).

Leontowicz et al.(2001) found that sugar beet pulp fiber and apple pomace fiber have hypolipidemic properties. They stated that total cholesterol and plasma lipids of rats cholesterol fed are increased but when sugar beet pulp fiber or apple pomace fiber are added to the diets of rats LDL cholesterol, triglyceride and total cholesterol level stay stable.

15 g/day supplemental water-soluble dietary fiber (WSDF; a mixture of psyllium, pectin, guar gum, and locust bean gum) added to diets of hypercholesterolemia men and women and after 8 weeks the WSDF mixture make 6.4% and 10.5% reductions in mean plasma total and low-density lipoprotein cholesterol concentrations, and they were sustained at 16 and 24 weeks (Jensen et al. 1997).

In a six-year prospective cohort of middle-age health women an inverse relationship was observed between both soluble and insoluble dietary fiber intake and cardiovascular disease risk and myocardial infarction (Liu et al.2002).

It's proposed that binding of bile acid with dietary fiber leading the cholesterol loss from body. Increasing bile acid excretion cause homeostatic imbalance and results in bile acids synthesis from cholesterol. Decreasing in bile acid also cause inhibits formation of micelle which absorbs fat and cholesterol in intestine (Robertfroid 1993, Schneeman 1998).

1.4.2. Dietary Fiber and Glucose Metabolism and Diabetes

Diabetes is a major health problem throughout the world. In 1997 approximately 124 million people have diabetes in the world. There are 23.6 million diabetes in the USA only in 2008 (Dreher 2001).

There are two types of diabetes; type-1 (insulin-dependent diabetes) and type-2 (non-insulin-dependent). Type-2 diabetes is the most common form of diabetes; affecting 97 % of all people with the disease and 80 % of these people are obese. The one of the major factors in increasing the number of people with diabetes are wrong diet which is poor in fiber and rich in sugar, and obesity (Anderson 2009).

The hypothesis about dietary fiber can be protective against development of non communicable diseases began with the Dr. Cleave. He claimed that many modern diseases were caused by diets which are rich in refined flour and sugar, and poor in fiber. Later Burkitt and Trowell developed the famous dietary fiber hypothesis that a major cause of western diseases is high consumption of refined carbohydrates which are lack of fiber. This led us to understand the role of dietary fiber in diabetic, obesity and diverticular disease (Anderson 2009).

Fast digestible carbohydrates accelerate glucose absorption rate and cause blood sugar level to rise. Fiber-rich foods by decreasing absorption of glucose effect the carbohydrate mechanism and maintaining balanced Blood Sugar Levels.

Fiber slows the gastric emptying, decreases α-amylase activity and slows the rate of glucose absorption. These are leading to decreased in blood sugar level, reduce postprandial insulin level and anti-diabetic drug requirements (Roberfroid 1993, Spiller 2001).

Studies indicate that people which are consuming more fiber compare to the ones with the lowest intake have a 29% reduced risk for developing diabetes and people with the highest intake of dietary fiber have 6 %4 reduced risk to prediabetes turn into diabetes over 4-year period (Anderson 2009).

Fibers reduce the need for insulin intake decreased by 25% to 50% and improve glycemic control in patients with diabetes type 1. In patients with type 2 it reduce diabetes drug needed 50%-100 and often eliminate the need of drug at all. In obese people it provides glycemic control without using antidiabetic medicine (Spiller 2001).

1.4.3. Dietary Fiber and Colon Cancer

Dietary fiber can act as a protective factor in colon cancer by increasing fecal bulk, thereby lower concentration of fecal carcinogens. In addition to this it shortens the transit time, thus decreases the time that carcinogenic agents in the digestive tract interact with cells lining the colon (Burkitt 1975, Roberfroid 1993).

It inhibits the production of carcinogenic substances by decreasing amount of bacteria in the colon. Dietary fiber increases butyric acid production which inhibits the formation of abnormal cells in the colon and promotes production of intestinal epithelial cells (Nyman and Svanberg 2002).

1.4.4. Dietary Fiber and Weight Control

Fiber increases chewing leading to promoting production of caliva and gastric juice. Thus it increase empting time of stomac, and provide full feeling and increase satiety. It also decrases the absobtion efficiency of small intensine. There is a theory about humans may consume constant amount of food. Fiber-rich diets consist less energy comparing the high-fat foods in the same amount, thereby this can lead to weight loss (Slavin 2005).

Studies show that there is a strong reverse relationship between dietary fiber consumption and obesity. People with the highest level of fiber consumption have a reduced 0.77 risk of developing obesity compared to those with the lowest fiber intake level. Studies indicate that high dietary fiber consumption reduce obesity risk approximately 30 % (Anderson 2001).

1.5. Recommendations for Total Dietary Fiber (TDF) Intakes

Although positive effect of fibers on human health is widely known, average consumption of dietary fiber is lower than recommended daily intakes in western countries. Average consumption of dietary fiber in the USA is about 11 to 15 g per day which is the lowest value in the western countries.

There is not a agreement about recommendation for TDF intakes. Minimum 20 g dietary fiber intake per day is recommended by promotion groups and government agencies. American Diabetes Association recommends 20-35 g of dietary fiber per day. American Heart association's recommended is 20 to 30 g and according to National Cancer Institute (NCI) daily intake of fiber should between 25 and 35 g per day (Dreher 2001).

1.6. Dietary Application in Food Industry

1.6.1. Dietary Fiber Application in Baked Foods

Among all the categories baked products are the most common fiber-enriched products. High fiber baked products are widely available and consumed all over the world. Adding fibers to a baked product can be intimidating because fiber has a major effect on rheological properties of batter or dough. Fiber uses reduce tolerance to over mixing, reduced extensibility and increase or decrease the resistance to extension depend on which fiber used. It also affects viscosity and stickiness. It inhibits ice crystal formation in frozen foods, decreasing oil uptake in fried foods (Nelson 2001).

Consumers find the texture and flavor of fiber rich product unpleasant. However new development have allowed to producers to formulate products accepted by consumers. Breads, cakes cookies and crackers are one of the most fiber used baked product (Nelson 2001).

1.6.2. Beverage Applications

Even it is not common as baked products, fibers are used in beverages industry. Using fibers in beverages industry became more popular after the trend in development of functional foods which have positive effect on health. Currently, Japan, Europe and the United States have shown the greatest interest in ‘functional foods. Teas, shakes, smoothies are the one of the most fiber added beverages in order to produce healthy beverages (Nelson 2001).

Soluble fibers are more common to use due to its high water disperse ability, insoluble fiber also can be used. However several formulations may be necessary for insoluble ones such as changing the particle size or choosing the shorter fiber length. Otherwise it may cause gritty mouth feel. Both adding soluble and insoluble fibers increase total dietary fiber content of the product. It increases the stability of system by decreasing the droplet or cell size. It also influences the texture and flavor (Dreher 2001).

1.6.3. Dairy Applications

There are several applications in dairy products such as ice cream, milk cheese, yogurt and their related product. In diary products mostly insoluble fibers are used due to their high water binding ability and low delectability in product. They help to reduce fat and calorie content of dairy products, modify the texture and mouthfeel, influence on consistency and improve the visual appearance of the product (Dreher 2001).

1.6.4. Meat Applications

Fiber is suitable for meat products preparation because of its water retention property, decreases cooking loss and neutral flavor. High-fiber ingredients can provide several benefits such as modifying texture, managing water migration and improving the marketability of the meat products. Fruit and vegetable are more preferred due to its high water and oil binding capacity, colonic fermentability, lower energy and phytic acid content. It is a valuable extender, binder and fat-replacement ingredient in the manufacture of various meat products (Biswas et. al 2011).

1.7. Cacao Powder

Cacao beans are the fruit from the plant Theobroma cacao L., a plant tree originated in the rain forests of America which culture has extended to equatorial areas of Africa and Asia. Cacao powder manufacture includes fermentation, drying, roasting and the Dutch process. During the first two steps, the flavor precursors are generated and the flavor compounds are formed during roasting through maillard browning. The correct fermentation and drying of cacao beans is essential to the development of suitable flavours and flavour precursors (Lecumberri et al. 2007).

After fermentation, the beans are placed in shallow trays to dry. After fermentation and drying, the cacao beans should have moisture content of ca. 5±7%. Roasting produces Maillard (non-enzymatic) reactions and generates the aromatic compounds of cacao (Bonvehi 1996).

Dutch or alkalizing is carried out to modify the color and flavor of cacao. Cacao in its natural form is slightly acidic, with a nominal pH ranging from 5.0 to 5.6. The alkalization or Dutch process neutralizes the normal cacao acidity, raises the pH to 7–8 Depending on the degree of alkalization, the flavor of cacao becomes milder and less harsh, and the color becomes darker (Li et al. 2012).

Cacao beans, as well as cacao derived products, present a rich source of polyphenols. Three groups of polyphenols can be distinguished: catechins or flavan-3-ols (37%), anthocyanins (4%) anproanthocyanidins (58%). Reports on the polyphenolic content of cacao products vary greatly in the literature, with values ranging from 3.3 to up to 65 mg/g in cacao powder (Lecumberri et al. 2007).

The polyphenols in cacao beans are stored in the pigment cells of the cotyledons.During fermentation of cacao beans, polyphenols diffuse with cell liquids from their storage cells and undergo oxidation to condensed high molecular mostly insoluble tannins. These reactions are both non-enzymatic and catalysed by the enzyme polyphenol oxidase, During the fermentation process, anthocyanins are hydrolysed to anthocyanidins. The latter compounds polymerise along with simple catechins to form complex tannins. Cacao beans are roasted to develop further the chocolate flavour (Wollgast et al. 2000).

It should also be noted that cacao and cacao products are not only rich in polyphenols, but are also rich in methylxanthines. In cacao powder, they are caffeine (1,3,7-

trimethylxanthine) and caffeine-relatives theobromine (3,7-dimethylxanthine) (Belscak et al. 2009).

Besides flavonoids, cacao is rich in other component of remarkable nutritional interest such as dietary fibre (DF) (Lecumberri et al. 2007).

As an important ingredient, cacao powder is used in a wide range of food manufacture. The cacao component is unique to impart both flavor and color to the end products (Bonvehi 1996) Cacao powder is also used as ingredient in baked chocolate goods such as cookies, chocolate cakes, etc.

There are two types of unsweetened cacao powder: natural cacao and Dutch-process cacao. Natural cacao has lighter color and strong chocolate flavor. It is commonly used in bakery industry. It is used with baking soda, creates a leavening action that allows the batter to rise during baking. Dutch-process cacao is processed with alkali to neutralize its acidity but this process destroys its natural flavor. It has a milder taste and with a darker color. It generally used in chocolate drinks (Cauvain 2006).

CHAPTER 2

MATERIALS AND METHODS

2.1. Materials

For cake batter preparation cacao powder, cake flour and egg white powder obtained from Ulker Biscuit Industry Co. Inc. Salt, shortening, baking powder de-fatted and de-sugared milk powder was bought from local markets.

2.2. Methods

2.2.1. Production of Micro and Nano Cacao Fibers

Microfluidizer equipment (M-110Y, Microfluidics, USA) was used for producing nano and micro cacao powder fibers from cacao powder. This process was performed in two stages. In first stages cacao powder sample was soften with water in reservoir. Later, this slurry-like product are introduced microfluidization which pumps it at a very high pressure through filters of 300-100μm pore size and collected in the output reservoir (Figure 2.1).

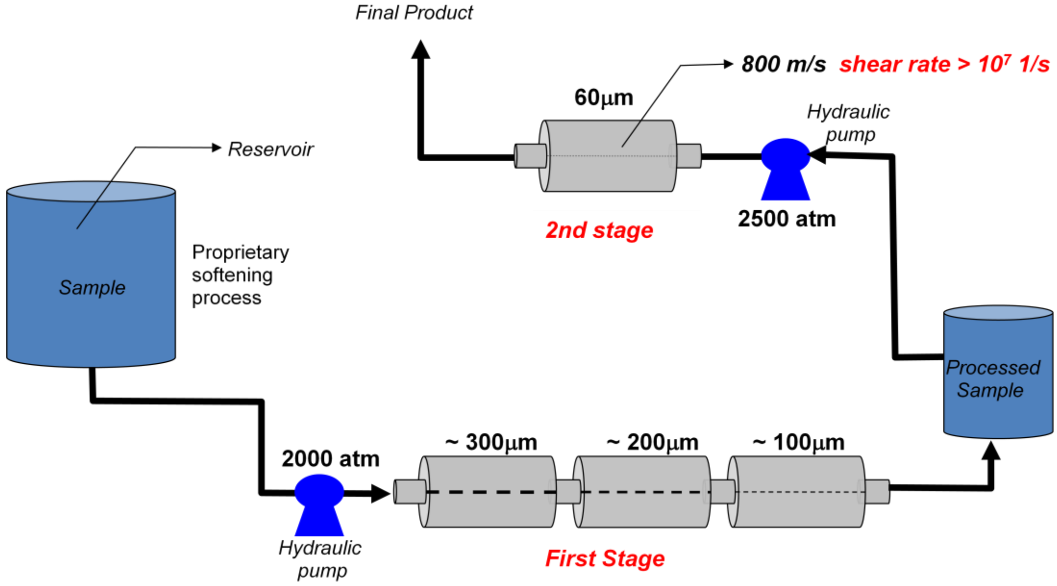

Figure2.1. Production of cacao fiber from cacao powder

Our processed sample was introduced again to the system by hydraulic pump but with higher pressure to pass through filters of 60µm pore size. At the second stage slurry velocity was 800 m/s and shear rate was above 10000000 1/s. When product was forced pass through filters, cacao powder granules broke down into fibers. Finally, slurry-like product was frozen and dried by freeze drier (Power Dry LL 1500, Heto,USA).

2.2.2. Preparation of Cake Batter

Cake batter recipe contained 100 % flour, 100 % water, 80 % sugar, 50 % shortening,12 % milk powder, 8 % egg white powder, 6 % baking powder and 1.5 % salt (All percentages are given to flour basis). Cacao and cacao fiber were added formulation 0 %, 3 %, 6 %, 9 %, 12 % concentration on flour basis.

8 g egg white powder and 56 g water were mixed together for minute by a mixer (Krups) and obtained a fluffy cream texture. 80 g sugar was added. Sugar and fluffy cream were mixed for 30 second. Dry ingredients (flour, baking powder, milk powder, salt and cacao or cacao fiber) and 44 g water were added and mixed for 1 minute and the 50 g melted shortening was added and mixed for 2 minutes.

2.2.3. Baking and Storage

Cake batter was poured into the cake pan with portion of 65 g and baked for 17 minutes at 175 °C.

After baking, cakes were left for 1 hour at room temperature for cooling and packed in plastic bags, stored at room temperature for different period of storage times (1d, 3d, 5d, 7d).

2.2.4. Analysis of Cake Flour

Wet gluten, dry gluten, farinogram values, protein, ash content and moisture content was determined with ICC Standard Method No: 106/2 (ICC 2002), Özkaya and Özkaya (2005), ICC Standard Method No: 115/1 (ICC 2002), AACC(American Association of Cereal Chemistry) Approved Method No: 46-12 (Anonymous, 1990) , ICC Standard Method No: 104/1 (ICC 2002), ICC Standard Method No: 110/1 (ICC 2002) , respectively.

2.2.5. Rheological Analysis

Rheological properties of produced fibers cake batters were examined using a rheometer (AR 2000ex Rheometer) at 20 C. Parallel plates with 40 mm diameter were used during experiments. The gap was adjusted either 2.0 cm. The tests were performed in duplicated.

Flow properties; viscosity, shear rate, viscoelastic properties were measured as the representative rheological properties.

2.2.6. Texture Profile Analysis

Texture Profile Analysis of the cake samples were determined with a Texture Analyzer (The TA.XT*Plus*) by using modified version of the method develop by Bourne (1978). For this procedure the cake samples were cut into slices with 2mm. The cake slices were compressed twice using 40% strain rate by the 36 mm diameter aluminum plate (P/36R). Finally the results were analyzed in terms of hardness, springiness, resilience, and chewiness.

2.2.7. Elastic Recovery

Elastic recovery was measured a using a Texture Analyzer (The TA.XT*Plus*). For this procedure the cake samples were cut into slices with 2mm. Elastic recovery was measured by compressing a strain of 25% of the original height for 60 s.

The compression was performed using a 36 mm diameter aluminium plate (P/36R). The elastic recovery was measured as:

$$\frac{F60}{Fmax} \times 100 = \%\ recovery$$

where Fmax is the maximum force and F10 is the force after 60 s (Baixauli 2008).

2.2.8. Specific Volume

Volume was determined by the rape seed replacement method (AACC, 1990). Specific volume was calculated by volume and weight.

2.2.9. Color Measurement

The surface crumb and crust color were measured by using Minolta Color Reader (Minolta CR-10, Osaka, Japan). CIE *L**, *a**, *b** color scale was used for measurements. The L* value indicates darkness (0-black)/ lightness (100-white), the a* value indicates reddness (+a)/ greenness (-a) and the b* value indicates yellowness (+b) / blueness (-b).

2.2.10. Weight Loss

Percent baking loss (BL %) was calculated by using the weight of cake sample (W_{cake}) and weight of cake batter (W_{batter}).

BL (%)=$\left[\frac{Wbatter-Wcake}{Wbatter}\right] \times 100$

Percent weight loss during storage (WL%) was calculated by using the weight of cake on 1st , 3rd, 5th, 7th day.

WL (%) =$\left[\frac{W(n+2)th\ day-Wnth\ day}{Winitial\ weight}\right] \times 100$

2.2.11. Sensory Evaluation

Sensory evaluation of the fresh cakes were carried out by 8 untrained panelists on a five point hedonic scale (1 dislike extremely, 5 like extremely) for different parameter such as color, appearance, texture, taste, odor and overall acceptability.

CHAPTER 3

RESULTS AND DISCUSSION

In this study effects of cacao fiber concentration (3 %,6 %,9 % and 12 %) on the quality parameters (baking loss, specific volume, textural properties, crust and crumb color and sensory properties) of cakes were investigated. In addition, staling of the cakes was investigated by different methods (weight loss, textural properties) during storage. For the sake of comparison, cacao powder was used in the same concentration.

3.1. Properties of Cake Flour

Table 3.1 Rheological, chemical and physicochemical properties of cake flour

	Cake Flour
Moisture (%)	12.5
Ash (% dry basis)	0.46
Protein (% dry basis)	8.5
Wet Gluten (%)	22.1
Dry Gluten (%)	7.2
Farinogram Values	
Water Absorption (%)	54
Development Time (min)	1.0
Stability (min)	2.4
Mixing Tolerance Index (BU)	80
Softening Degree (BU)	112

As it can be seen in Table 3.1 moisture content was 12.5 % and ash content was 8.5 %.Protein content, wet and dry gluten were 8.5%, 22.1% and 7.2 , respectively. Soft wheat flour is generally used in cake industry. This type of flours has a low protein content compared to other flours (8 to 10%) and the proteins are weak in strength (Matz 1992). Development time, stability, mixing tolerance index and softening degree were 1 min, 2.4 min, 80 BU and 112 BU , respectively. These values can be regarded as appropriate for cake making.

3.2. Rheology of Cake Batter

The determination of rheological properties of flour-based products is essential because its major effects in final product quality. Cacao fiber differs from cacao powder due to its high water holding capacities (WHC). The appearance of cacao powder and fiber aqueous solution which contained 21% solid content can be seen in Figure 3.3. Processing with microfluidizer improved the viscosity of cacao fiber significantly. As shown in Figure 3.1 even they contain same amount of solid, cacao fiber is more viscous than cacao powder aqueous solution. This can be explained with higher WHC of cacao fiber. WHC is higher in cacao fiber because of higher surface area due to the smaller particle size of cacao fiber and its branched structure, which is shown in Figure 3.2.

Figure 3.1 Cacao powder 21% dry matter (on the left) and **c**acao fiber 21% dry matter (on the right)

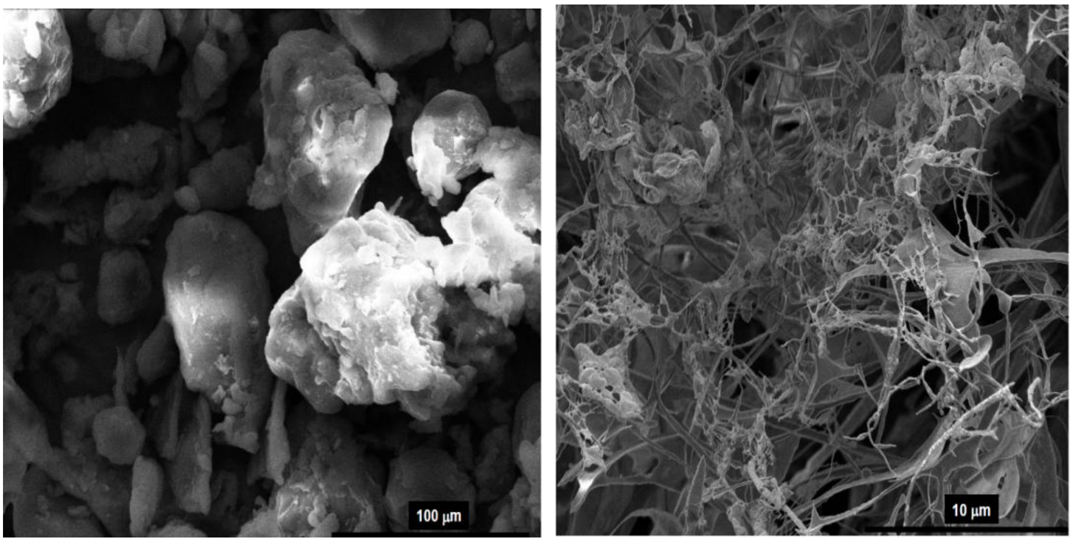

Figure 3.2 SEM pictures of cacao powder- 100µm (on the left) and cacao fiber- 10µm (on the right)

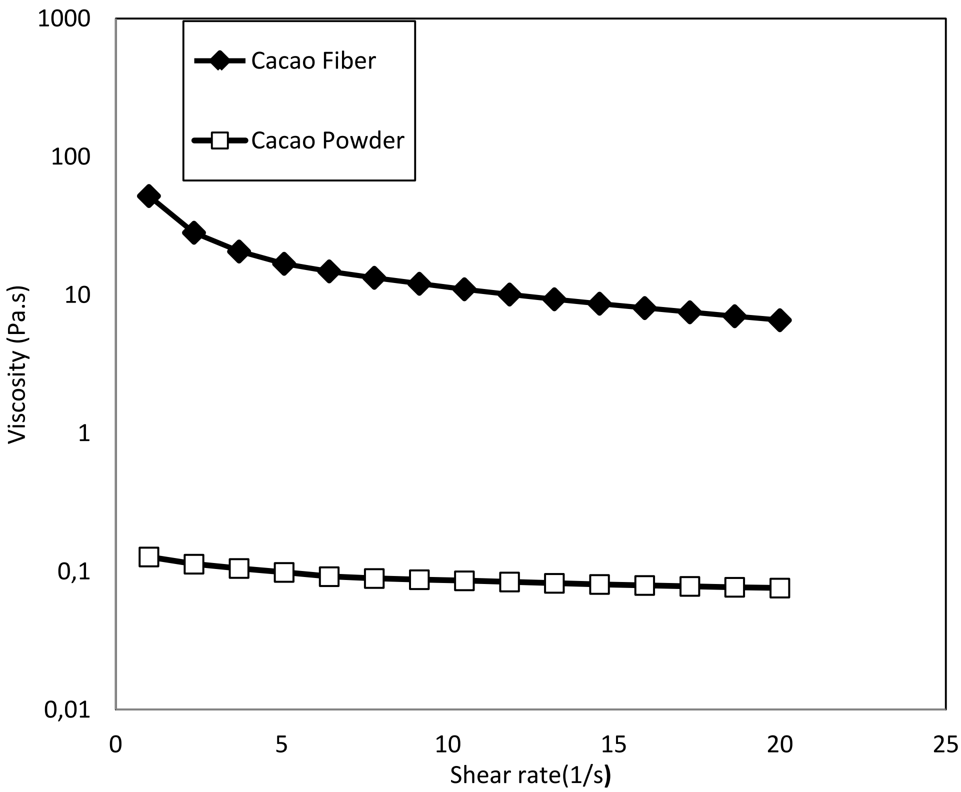

Figure 3.3 Shear rate (1/s) versus viscosity (Pa.s) values of cacao powder and fiber used cake batter

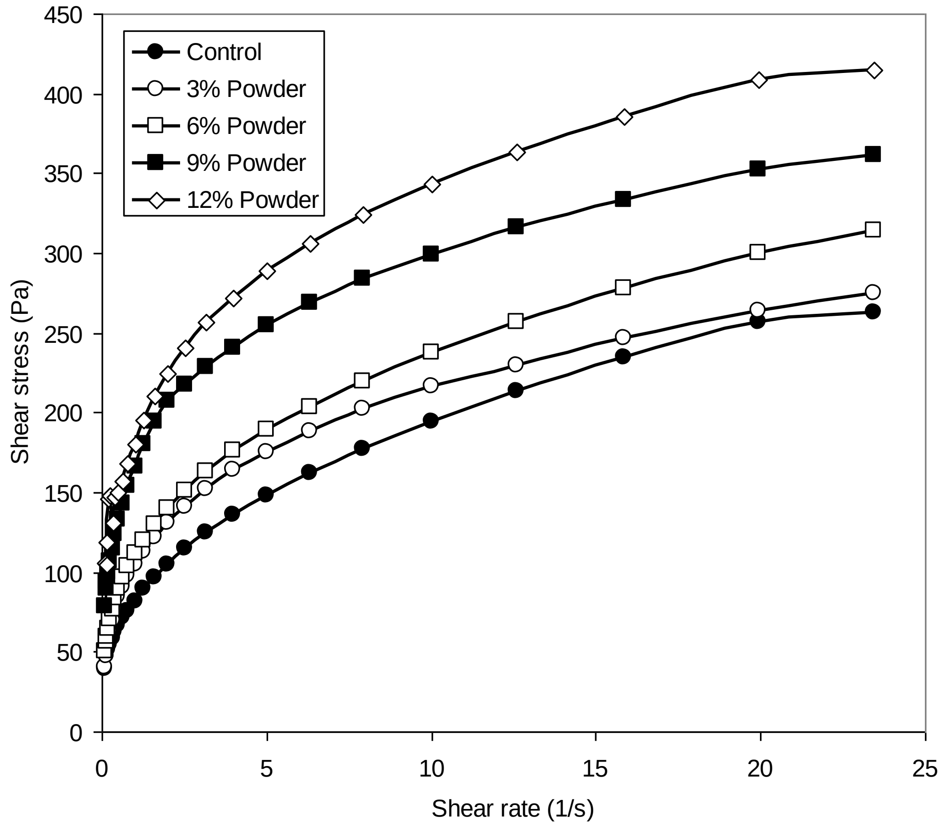

Figure 3.4 Shear rate (1/s) versus shear stress (Pa) values of cacao powder used cake batter

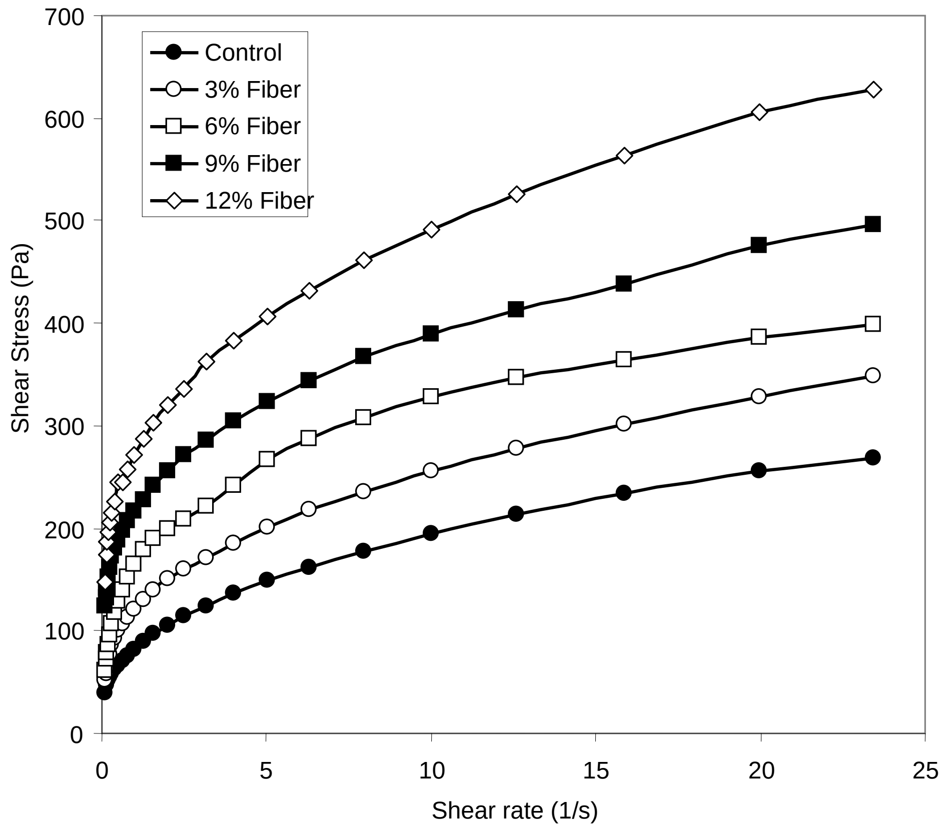

Figure 3.5 Shear rate (1/s) versus shear stress (Pa) values of cacao fiber used cake batter

All cake batter formulation fits the Power-Law Model,

$\tau = k (\delta)^n$

where τ is the shear stress, δ the shear rate, K the consistency and n the flow behavior index (Steffe 1996).

Table 3.2 Rheological properties of cake batter

Samples		K ($Pa.s^n$)	n	R^2
Control		86.58	0.34	0.99
Cacao Powder (%)	3	100.40	0.34	0.99
	6	111.12	0.33	0.99
	9	130.10	0.30	0.99
	12	145.87	0.28	0.99
Cacao Fiber (%)	3	126.39	0.33	0.99
	6	152.83	0.33	0.99
	9	169.48	0.24	0.99
	12	185.94	0.24	0.99

Flow behavior index (n) measures the degree to which the fluid is shear-thinning or shear-thickening. If it is 1, then the model reflects Newtonian behavior.

$n < 1$ Shear thinning
$n > 1$ Shear thickening
$n = 1$ Newtonian fluid

Flow behavior index (n) of all cake batters ranged from 0.24 to 0.34. Since for all cake formulations n values were less than 1, it can be concluded that cake batter showed a shear thinning behavior. It was also observed that the higher the fiber percentage resulted in higher consistency values (K). Behavior index (*n*) values decreased with increasing cacao powder content. The decrease in *n* values was not observed with cacao fiber. However, the highest n values belongs to control cake, the lowest n value belongs to 9% and 12% cacao fiber cake.

Handleman et al. (1961) found that layer cake batters possessed shear-thinning behavior. Elevation of the K value was also found by Martínez-Cervera et al. (2011) when soluble cacao fiber was added in a batter cake. As expected increasing the fiber content lead to higher consistency value (K) and the lower the shear-thinning index (n). These findings were in agreement with results published by Gomez et al. (2010).

The batter consistency is one of the important parameters studied in this study as it is related to the capacity of retaining air and controlling factor for the final cake volume. In fact, there is an optimum consistency of cake batter to achieve cakes with high volume. Lakshminarayan et al. (2006) stated that low batter consistency gives cakes of low volume however; the excessive consistency could also diminish cake quality since it could limit the batter expansion (Gularte et al., 2011).

Viscosity increases with increasing cacao and fiber content of the cakes sample. When same amount of cacao fiber and cacao powder used in the formulation viscosity of cacao fiber cake batters are higher than cacao powder batter. Control cake batter had the lowest the 12% fiber cake batter had the highest viscosity value. Inglett et al. (1997) showed that the incorporation of oat fiber increased the batter viscosity The higher viscosity of the cacao fiber-incorporated batters might have been due to water absorption by the fiber.

Elastic modulus (G′) is measured deformation energy stored by the sample during the shear process. After reload is removed, energy is completely available. It represents elastic behavior of the sample. Loss Modulus (G″) is measured deformation energy used by sample during the shear process and afterwards it is lost for product. It represents viscous behavior of the sample (Mezger 2006). Storage modulus (G′) is high for elastic materials, and loss modulus (G″) is high for viscous materials. Cake batter displays both viscous (the continuous phases) and elastic properties (the bubble phases) and is known as a viscoelastic material (Sumnu, 2008).

The effects of cacao fiber and cacao powder on the visco-elastic behavior of cake batters are presented in Figs 3.6, 3.7, 3.8 and 3.9 showing elastic modulus (G′) and viscous modulus (G″) as function of frequency. Higher G′ and G′ 'values were obtained with increase in angular frequency. It is observed that the G′ is always greater than G″ indicating that the batters had a solid, elastic-like behavior under the testing conditions. In addition to that it was observed that when the fiber and powder percentage increased, the G′ and G″ values also increased. It could be concluded that cacao fiber attributed elastic and viscous behavior of the cake batter. However, the increase in G′ and G″ of cacao fiber used samples is higher than cacao powder used samples.

These results were consistent with those obtained by Gomez et al. (2009) who observed higher G′ and G″ values when the different kind of fiber (wheat bran, oat bran, cellulose microcrystalline) was added to layer cake batter.

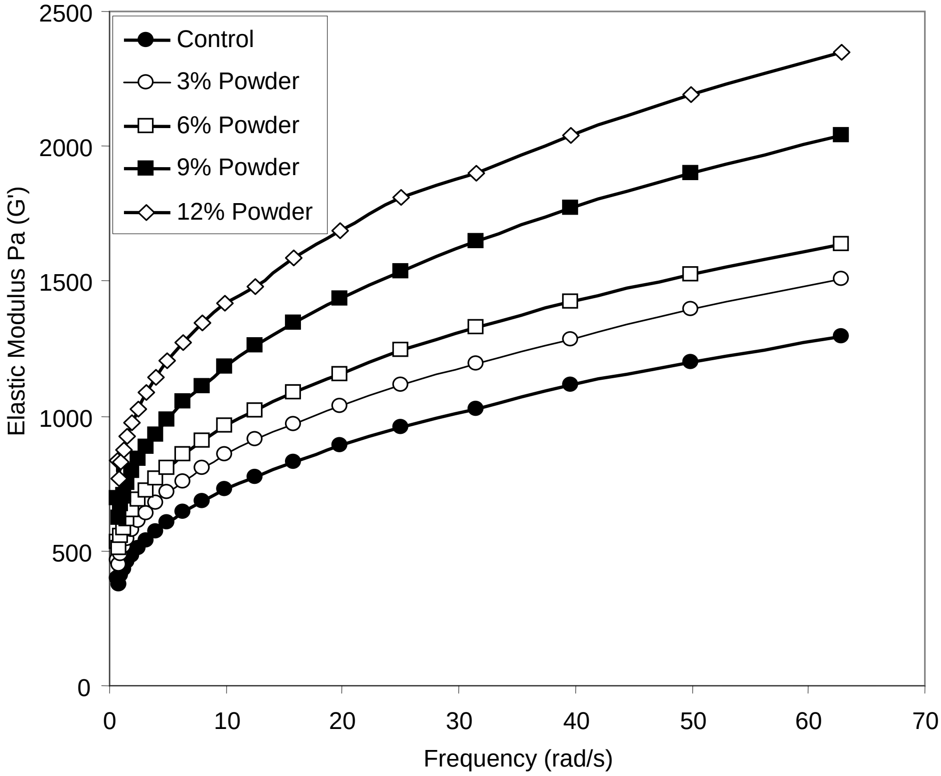

Figure 3.6 Frequency (rad/s) versus elastic modulus (G′) (Pa) of cacao powder used cake batter

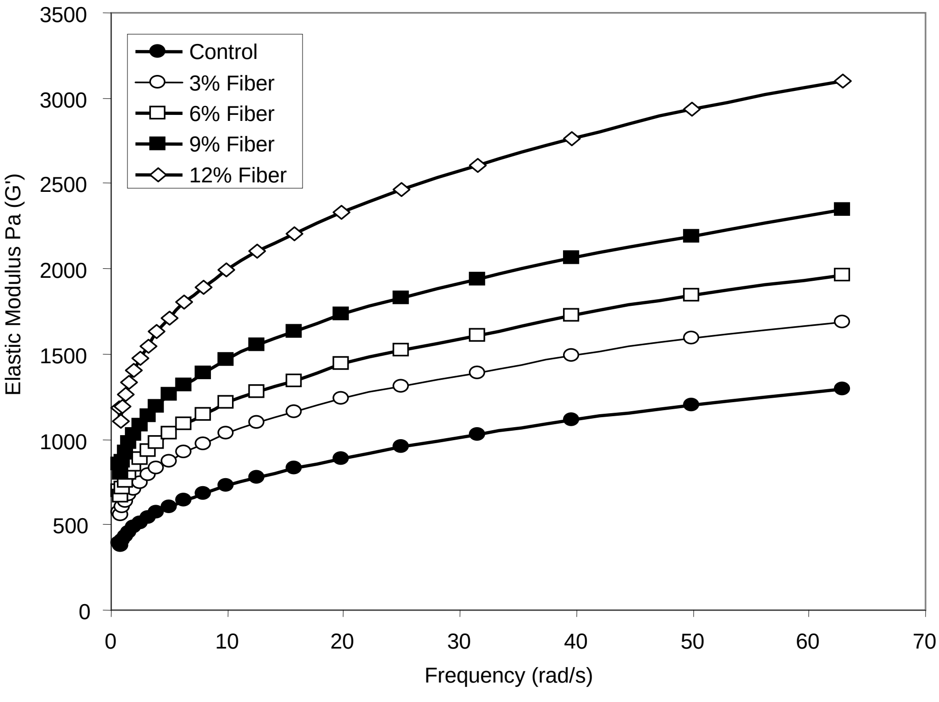

Figure 3.7 Frequency (rad/s) versus elastic modulus (G′) (Pa) of cacao fiber used cake batter

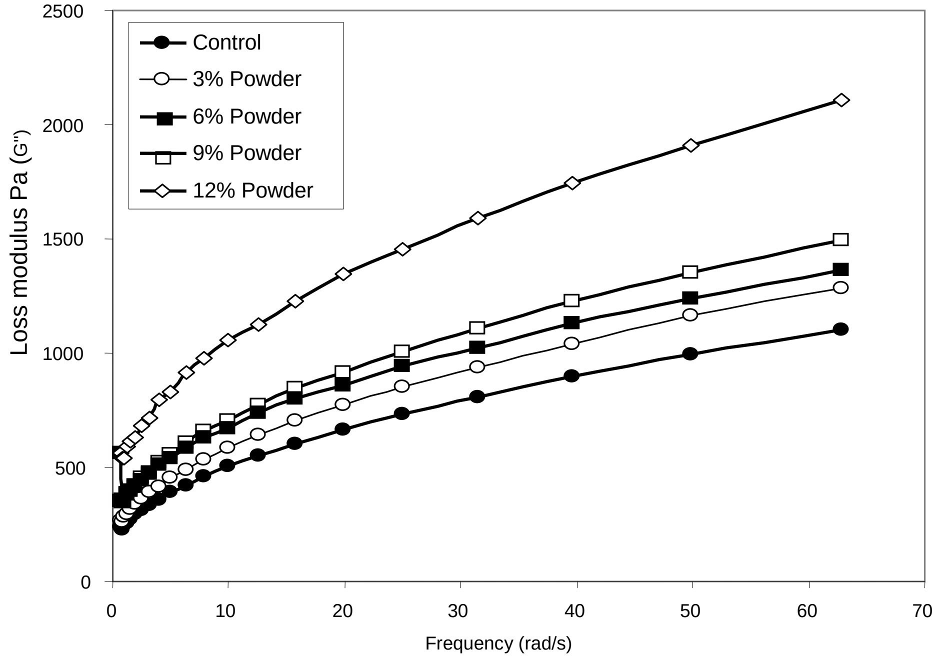

Figure 3.8 Frequency (rad/s) versus loss modulus (G'') (Pa) of cacao powder used cake batter

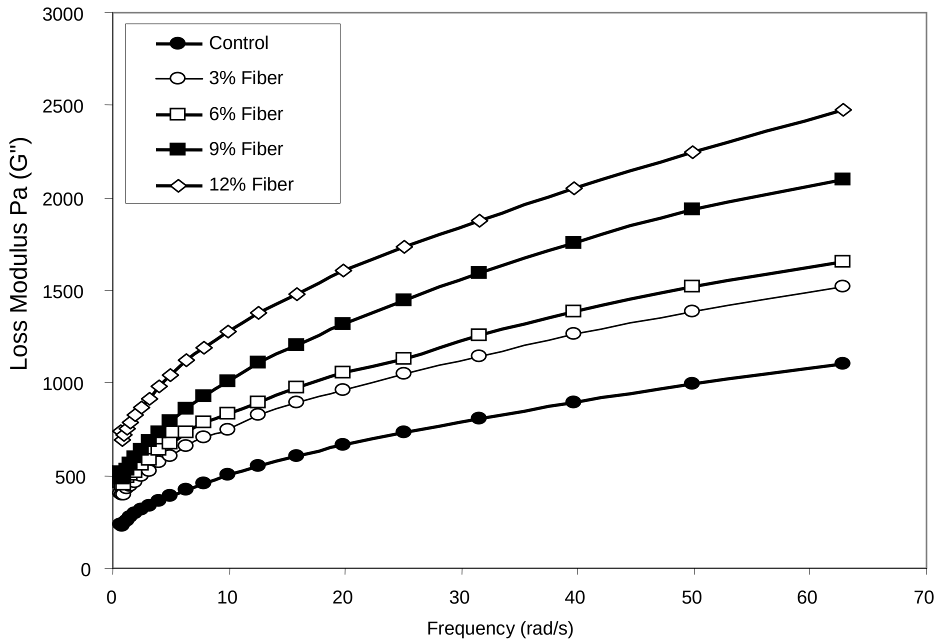

Figure 3.9 Frequency (rad/s) versus loss modulus (G'') (Pa) of cacao fiber used cake batter

Table 3.3 Textural properties of cake samples

Samples		Hardness (g force)	Springiness (%)	Resilience (%)	Chewiness (g force)	Elastic Recovery (%)
Control	0	1458.9	93.9	25.3	1202.8	47.7
CacaoPowder(%)	3	1571.0	93.2	24.5	1212.2	46.5
	6	1590.1	93.5	23.7	1173.4	45.4
	9	1625.3	93.2	24.4	1168.6	45.3
	12	1756.7	93.4	24.3	1464.9	44.0
Cacao Fiber(%)	3	1863.9	95.4	27.9	1306.6	49.0
	6	1900.7	95.4	27.7	1310.2	49.5
	9	1926.7	95.6	28.3	1359.4	49.5
	12	2105.4	95.7	29.9	1662.3	50.0

3.3. Textural Properties

Hardness is defined as force necessary to attain a given deformation (Szczesniak 2011). The effects of cacao powder and fiber concentration on hardness can be seen in Figure 3.10.The texture profile analysis, the measured hardness of samples showed that the cakes became harder with increasing levels of cacao fiber. Hardness value of control sample were determined as 1458 g force and it increased with increasing both cacao powder and fiber ratio When same amount of cacao powder and fiber used in the samples hardness of containing cacao fiber samples were higher than with cacao powder samples. Increment in viscosity and consistency index could cause increase in hardness value. This was an expected result since the control cake was the softest cake.

Grigelmo-Miguel et al. (1999) also observed an increase in muffins firmness when dietary fiber was added to the formulation.

Kamel and Rasper (1988) noted that the firmness of cake was directly related to the density of tested materials. Cakes containing 12% fiber showed the highest hardness, which might be related to the decrease of specific volume besides the low weight loss induced by the presence of fiber. Thus, the increase in hardness was related to the density of the cake samples.

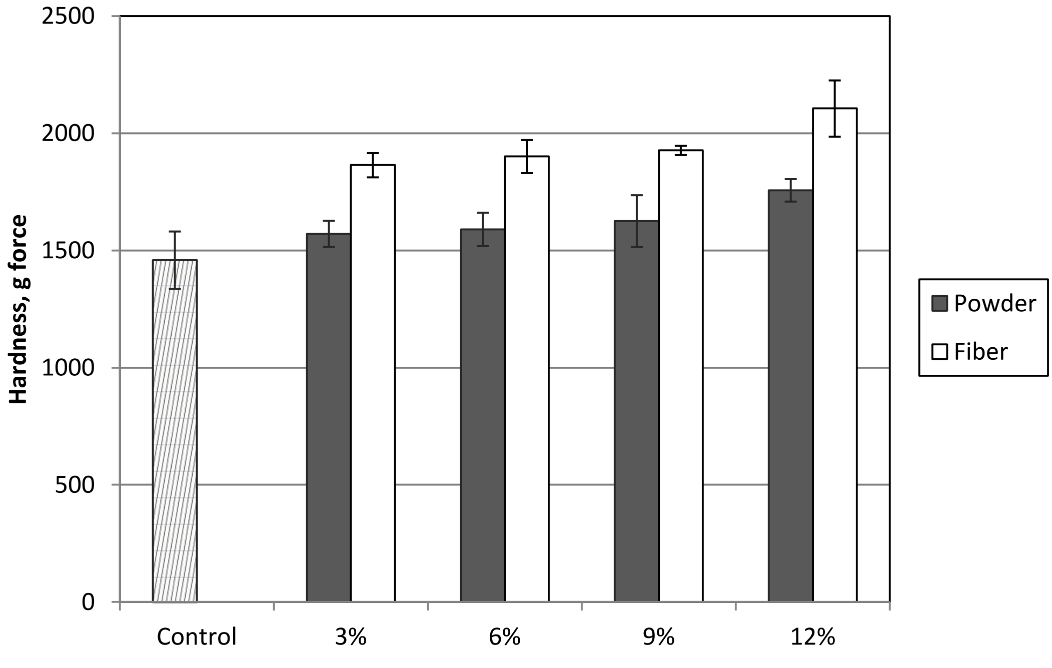

Figure. 3.10 The effects of cacao powder and fiber concentrations on hardness of cake samples

Springiness is defined as food shape recovery between the end of the first bite and the beginning of the second one (Szczesniak 2011). The effects of cacao powder and fiber concentration on springiness can be seen in Figure 3.11.Springiness value of control sample were determined as 93%. Springiness value was same in cacao powder containing samples and it was not changed with increasing cacao powder. Cacao powder had no effect on springiness value. When cacao fiber used in the samples springiness value were measured as 95%. Higher springiness values were observed with fibers used cake than with powder used cake. However, no significant differences were observed in springiness between the ratio of fiber and powder.

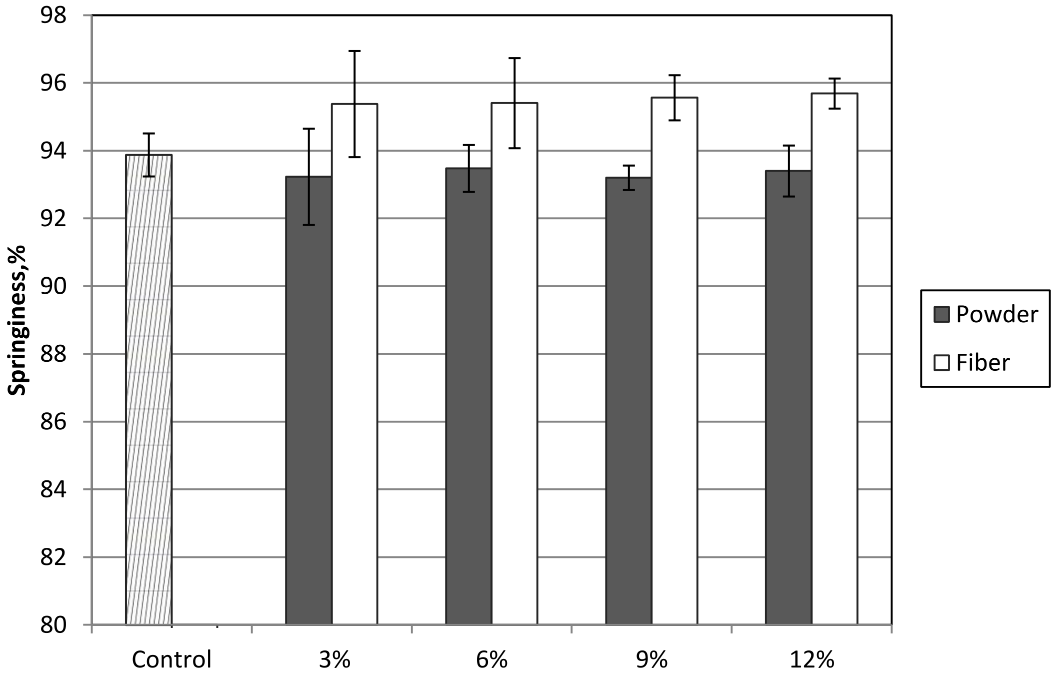

Figure 3.11 The effects of cacao powder and fiber concentrations on springiness of cake samples

Resilience is defined as measurement of how a sample recovers from deformation in relation to speed and forces derived (Szczesniak 2011). The effects of cacao powder and fiber concentration on resilience can be seen in Figure 3.12. Resilience value of control samples and cacao powder was 25% and 24% respectively. When cacao fiber used in the samples resilience value of samples were measured as between 27% and 29%. Similar results were obtained with the springiness results. Higher resilience values also were observed with fibers used cakes than with powder used cakes. However, no significant differences were observed in resilience between the ratio of fiber and powder.

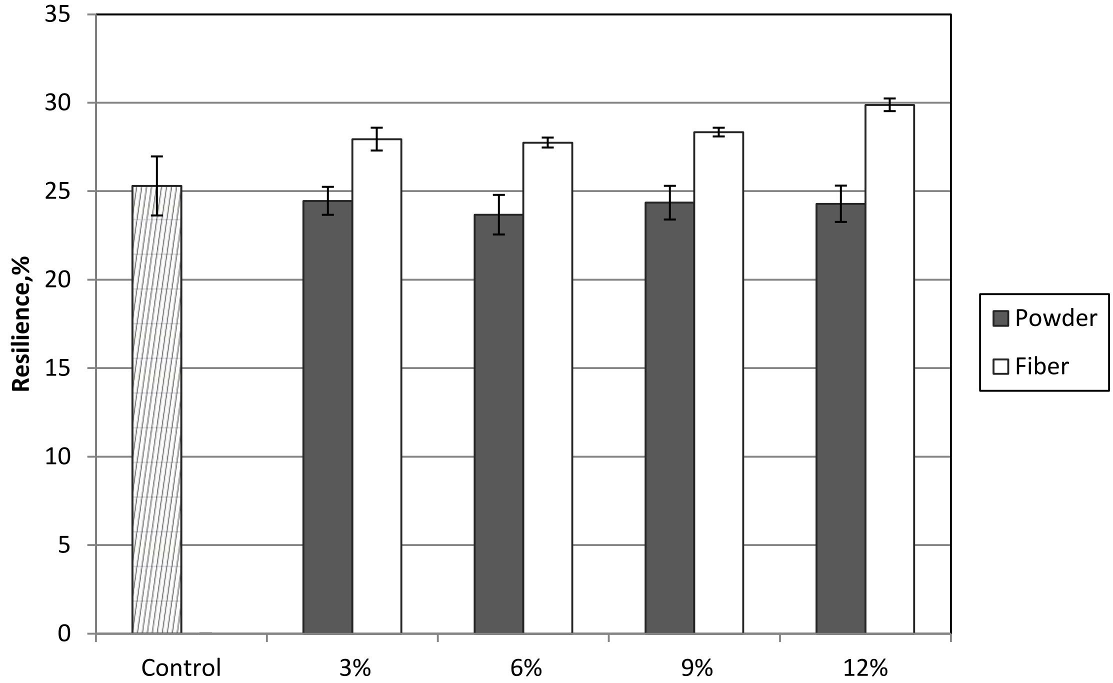

Figure 3.12 The effects of cacao powder and fiber concentrations on resilience of cake samples

Chewiness is defined as energy required masticating a solid food to a state ready for swallowing. It is calculated by multiplying gumminess and springiness which equals hardness x cohesiveness x springiness (Szczesniak 2011). The effects of cacao powder and fiber concentration on chewiness can be seen in Figure 3.13. Chewiness value of control sample was 1202 g force. Chewiness value increased with increasing cacao powder and cacao fiber. When cacao powder used in the samples chewiness was about 1100 g force. However, when 12% powder was used chewiness increased 1464 g force. These values were determined as approximately 1300 when 12% fiber used in the samples chewiness increase 1662 g force. The measured chewiness of cake samples showed that the chewiness values became higher increasing levels of cacao fiber. When the percentage of fiber increased, chewiness increased. When same amount of cacao powder and fiber used in the samples chewiness of cacao fiber samples were higher than with cacao powder samples.

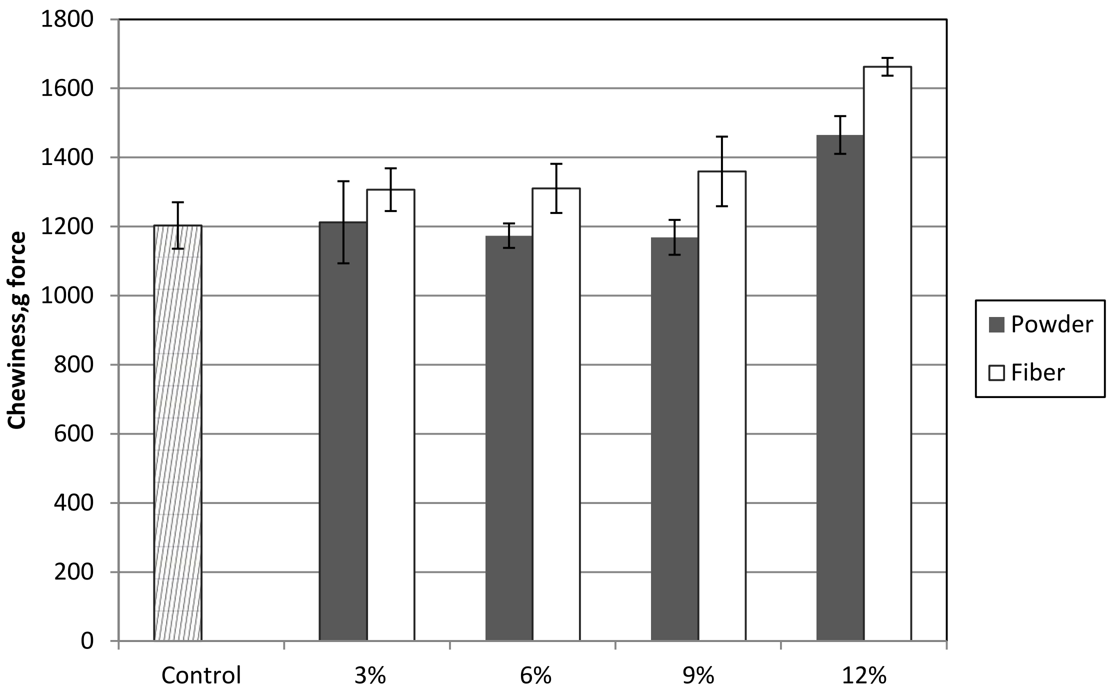

Figure 3.13 The effects of cacao powder and fiber concentrations on chewiness of cake samples

The effects of cacao powder and fiber concentration on elastic recovery can be seen in Figure 3.14. Elastic recovery value of control sample was determined as 47.67%. When cacao powder increased from 3% to 12% elastic recovery value decreased from 46.5% to 44.02%. Elastic recovery value of cacao fiber samples were about 49%. Cakes containing fiber showed a more elastic structure. However, no significant differences were observed in elastic recovery between the ratios of fiber.

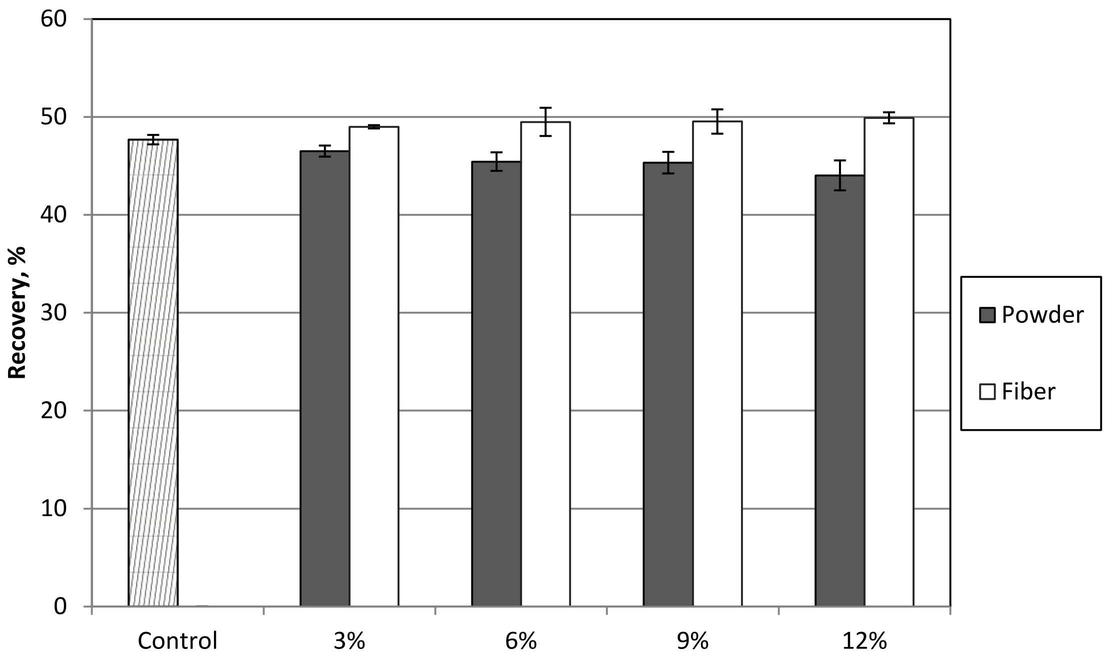

Figure 3.14 The effects of cacao powder and fiber concentrations on elastic recovery of cake samples

Table 3.4 The effects of storage time on textural properties of cake samples

		Day 1	Day 3	Day 5	Day 7
Hardness (g force)					
Control		1458.9	2305.7	2459.5	2740.8
Cacao Powder (%)	**3**	1571.0	2470.3	2688.1	2718.9
	6	1590.0	2530.7	2827.2	2921.3
	9	1625.3	2669.4	2971.3	3250.8
	12	1756.6	3035.4	3357.8	3655.2
Cacao Fiber (%)	**3**	1863.8	2679.1	2818.4	2823.9
	6	1900.7	2792.1	3001.5	3071.3
	9	1926.7	2999.0	3148.1	3357.3
	12	2105.4	3099.8	3344.6	3701.0
Springiness (%)					
Control		93.9	91.2	90.3	89.3
Cacao Powder (%)	**3**	93.2	91.9	90.5	89.5
	6	93.5	91.7	90.8	89.4
	9	93.2	91.7	90.2	89.4
	12	93.4	91.1	89.8	89.3
Cacao Fiber (%)	**3**	95.4	94.4	94.1	94.0
	6	95.4	94.1	94.0	93.6
	9	95.6	94.1	93.7	93.5
	12	95.7	94.9	94.8	94.7
Resilience (%)					
Control		14.6	23.1	24.6	27.4
Cacao Powder (%)	**3**	15.7	24.7	26.9	27.2
	6	15.9	25.3	28.3	29.2
	9	16.3	26.7	29.7	32.5
	12	17.6	30.4	33.6	36.6
Cacao Fiber (%)	**3**	18.6	26.8	28.2	28.2
	6	19.0	27.9	30.0	30.7
	9	19,3	30,0	31,5	33,6
	12	21,1	31,0	33,4	37,0
Chewiness (g force)					
Control		1202,9	1689,7	1797,2	1959,5
Cacao Powder (%)	**3**	1212,2	1743,7	1815,6	2006,8
	6	1173,4	1857,7	2004,0	2097,5
	9	1168,6	1864,2	2104,9	2393,1
	12	1464,9	2114,2	2324,0	2598,7
Cacao Fiber (%)	**3**	1306,6	2004,0	2064,8	2119,7
	6	1310,2	2074,1	2331,9	2433,2
	9	1359,4	2262,7	2443,0	2571,4
	12	1662.2	2315.8	2687.1	2747.7

3.4. Textural Changes During Storage

The textural properties of the cakes were evaluated over a 7-day storage period. This study shows the textural changes in the samples prepared with different cacao powder and fiber levels that took place during storage.

The value for the ‟hardness” parameter of the cakes with cacao powder and fiber over 7 days of storage can be seen in Figures 3.15, 3.16, 3.17 and 3.18. Hardness value of all samples increased with increasing storage time. Hardness value of control sample was measured as 2740 g force end of the 7th day. Hardness value of 3 %,6 %,9 % and 12 % cacao powder samples were 2718, 2921, 3250 and 3655 g force respectively. Hardness value of 3 %,6 %,9 % and 12 % cacao powder samples were 2823, 3071, 3357 and 3700 g force, respectively. Most of the hardness increment occurred in the 7th day for all samples. It was observed that the cake with cacao fiber showed lover hardness increase than cacao powder although the initial hardness values were much higher than those of cakes with cacao powder.

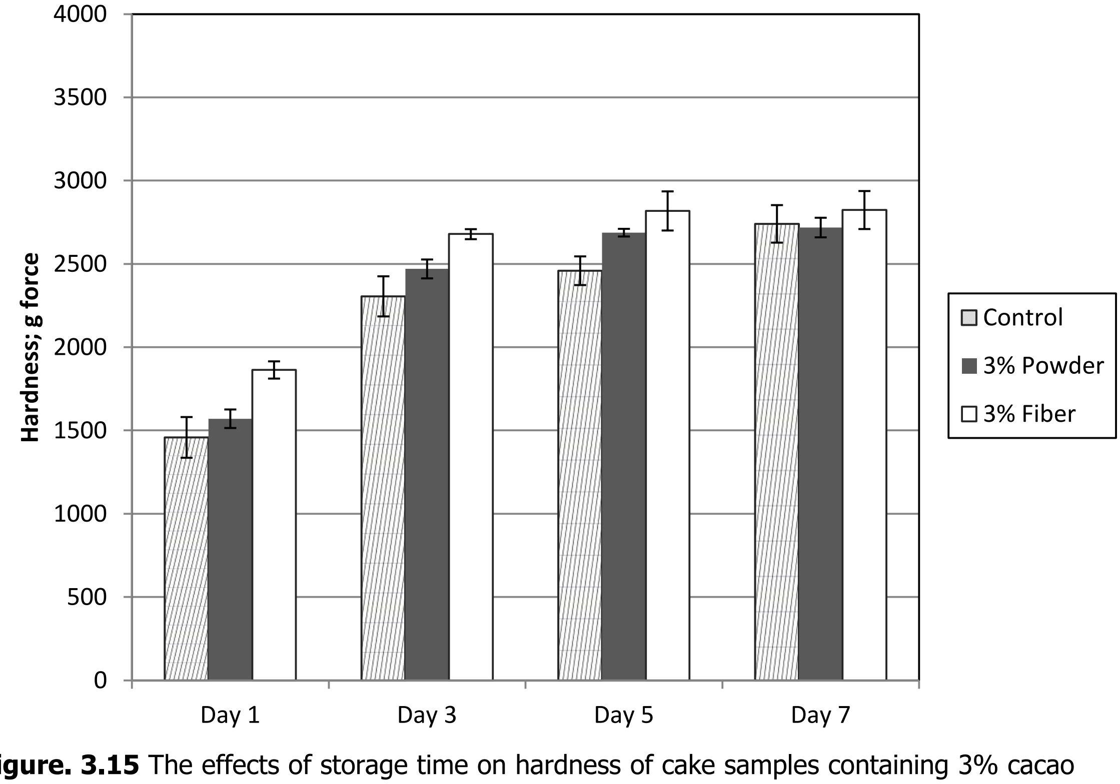

Figure. 3.15 The effects of storage time on hardness of cake samples containing 3% cacao powder and fiber

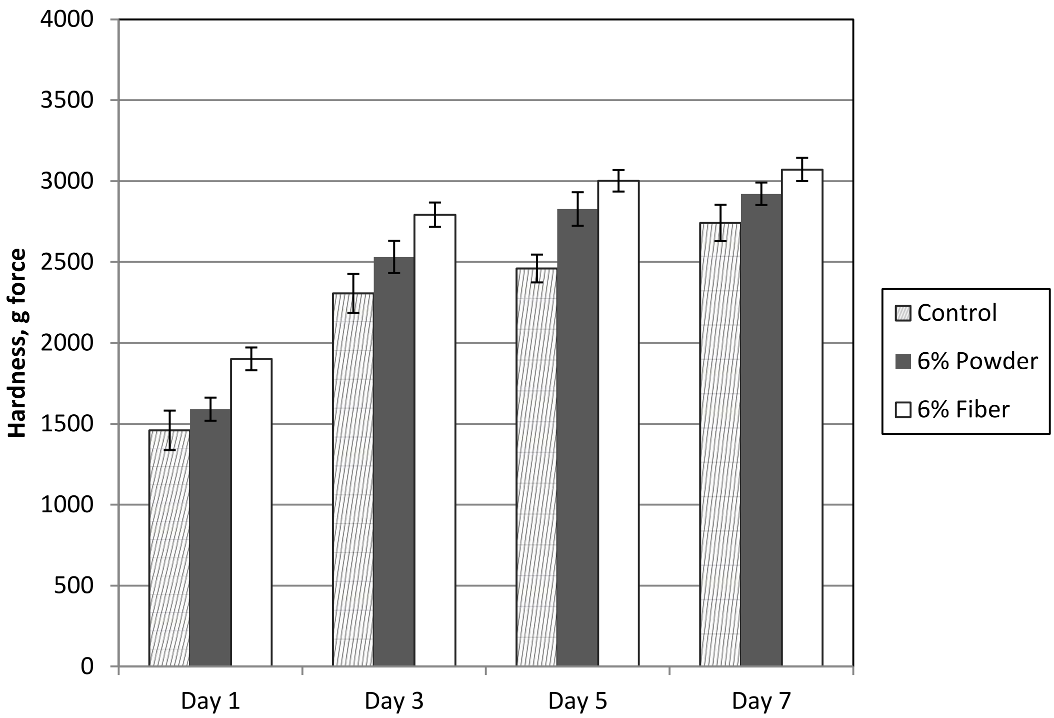

Figure 3.16 The effects of storage time on hardness of cake samples containing 6% cacao powder and fiber.

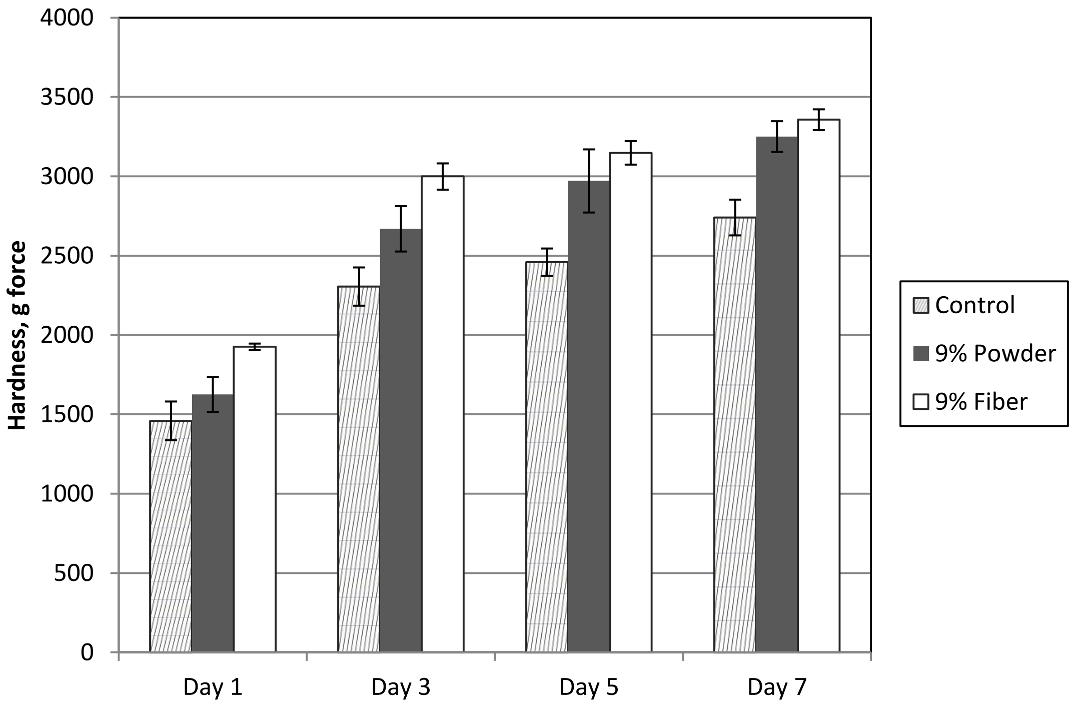

Figure 3.17 The effects of storage time on hardness of cake samples containing 9% cacao powder and fiber

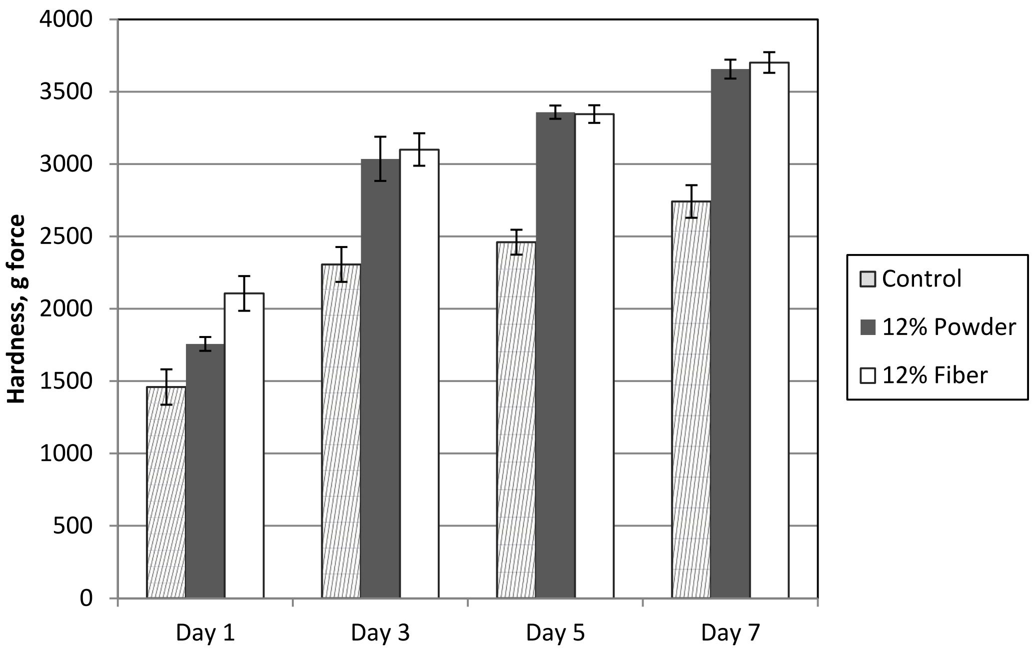

Figure 3.18 The effects of storage time on hardness of cake samples containing 12% cacao powder and fiber.

During 7days of storage, a decrease in springiness over the storage time can be seen in Figures 3.19, 3.20, 3.21 and 3.22. Springiness value of control sample and samples prepared with cacao powder decreased from 93% to 89% in the end of the 7th day. Springiness value of samples prepared with cacao fiber decreased from 95 % to 94 % in the end of the 7 th day. Decrement was 1 unit in the samples with cacao fiber. However this decrement was 4 units for cacao powder samples. Fiber increased springiness value and it also slow the increment rate during 7 day of storage.

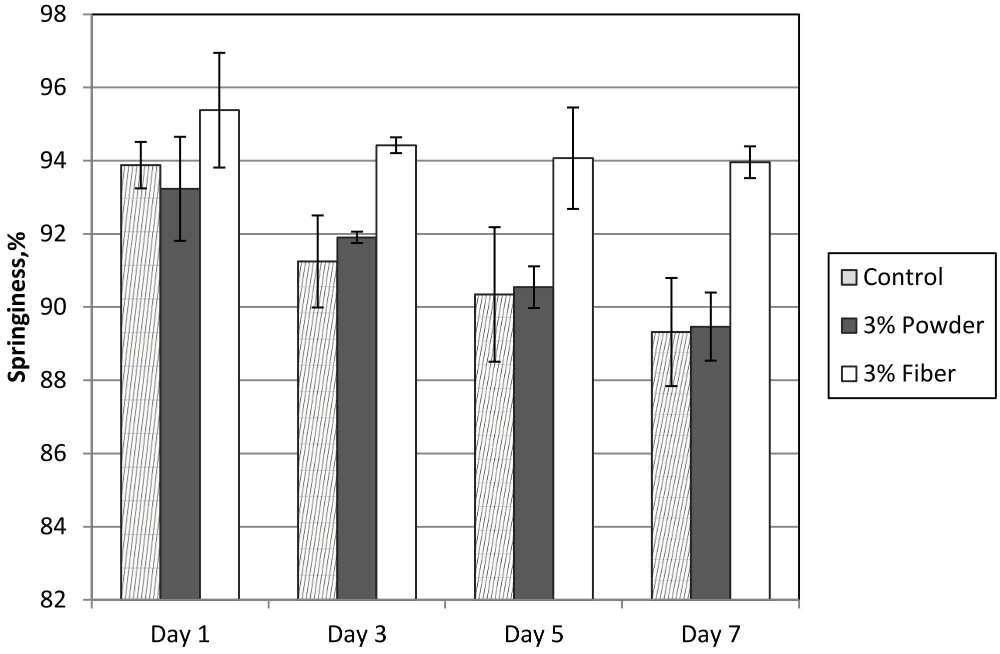

Figure 3.19 The effects of storage time on springiness of cake samples containing 3% cacao powder and fiber

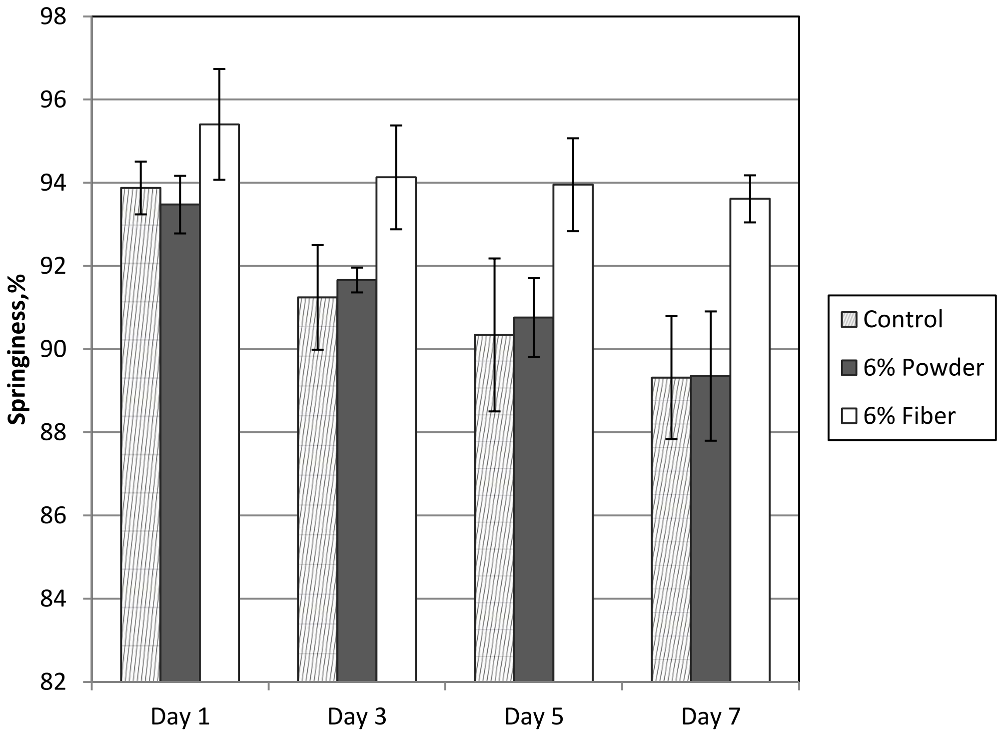

Figure 3.20 The effects of storage time on springiness of cake samples containing 6% cacao powder and fiber

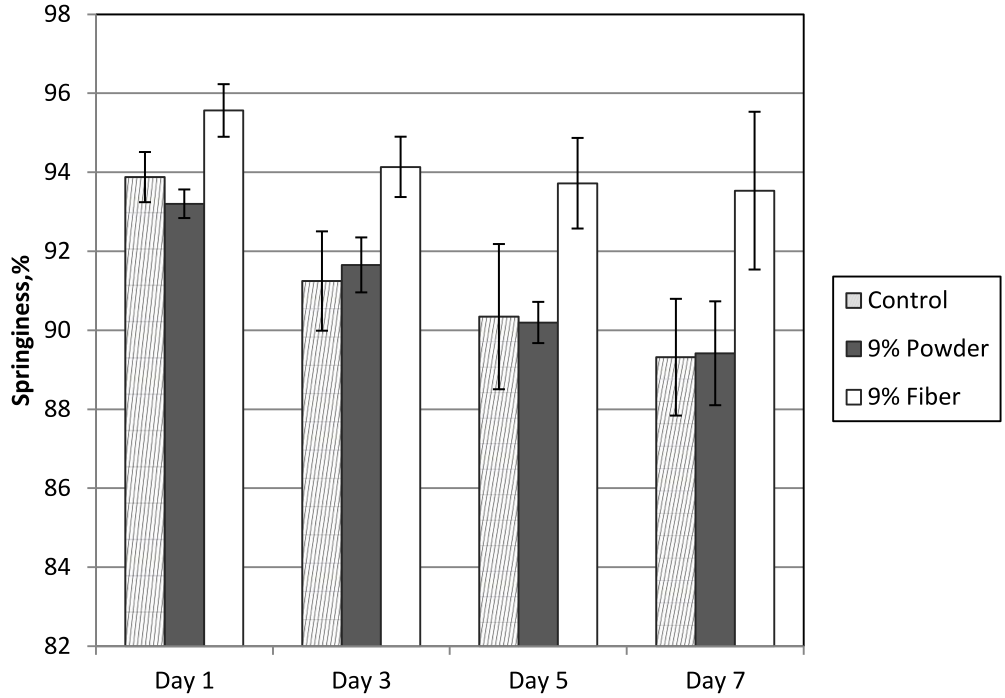

Figure 3.21 The effects of storage time on springiness of cake samples containing 9% cacao powder and fiber

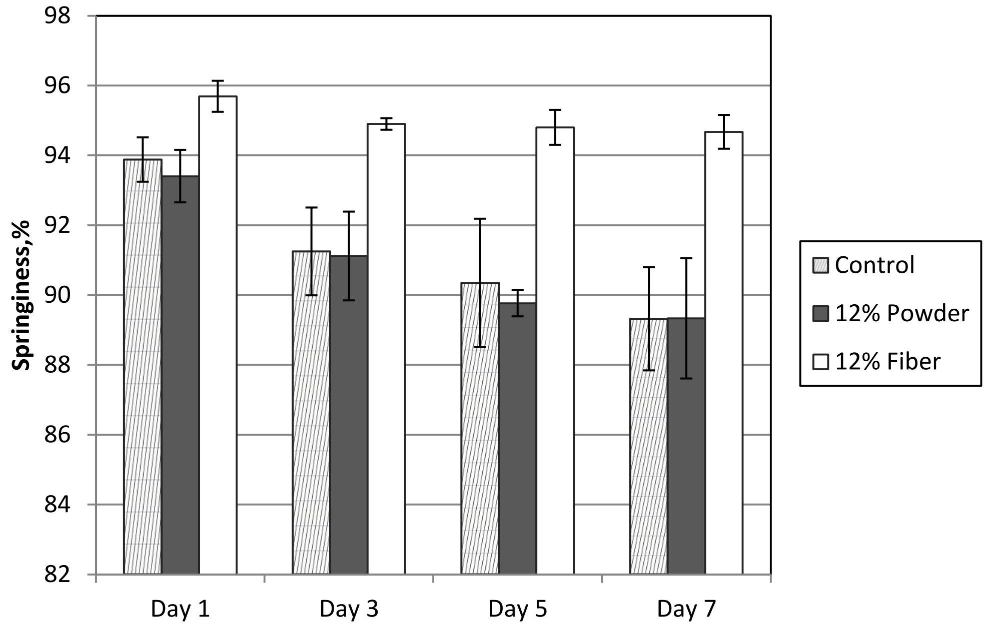

Figure 3.22 The effects of storage time on springiness of cake samples containing 12% cacao powder and fiber.

During 7days of storage, a decrease in resilience over the storage time can be seen in Figure 3.23, 3.24, 2.25 and 3.26. Resilience value of control sample and samples with cacao powder were between 25 % and 23 %. It was determined as 19 % after 7 days later. Resilience values of samples with cacao fiber were between 29 % and 26 %. It decreased to 26 % after 7 days later. Decrement was 2 units in the samples with cacao fiber. However this decrement was 5 units for cacao powder samples. Fiber increased resilience value and it also slow the increment rate during 7 day of storage like the springiness value. Results coincided with that Gomez et al.(2010) found a positive correlation between the initial springiness and resilience and also their evolution during storage.

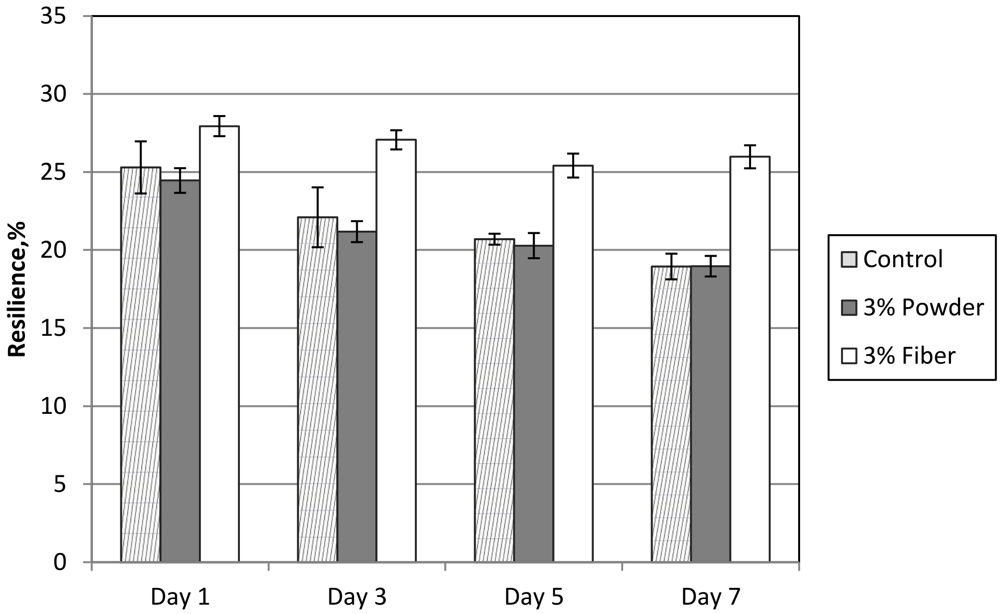

Figure 3.23 The effects of storage time on resilience of cake samples containing 3% cacao powder and fiber.

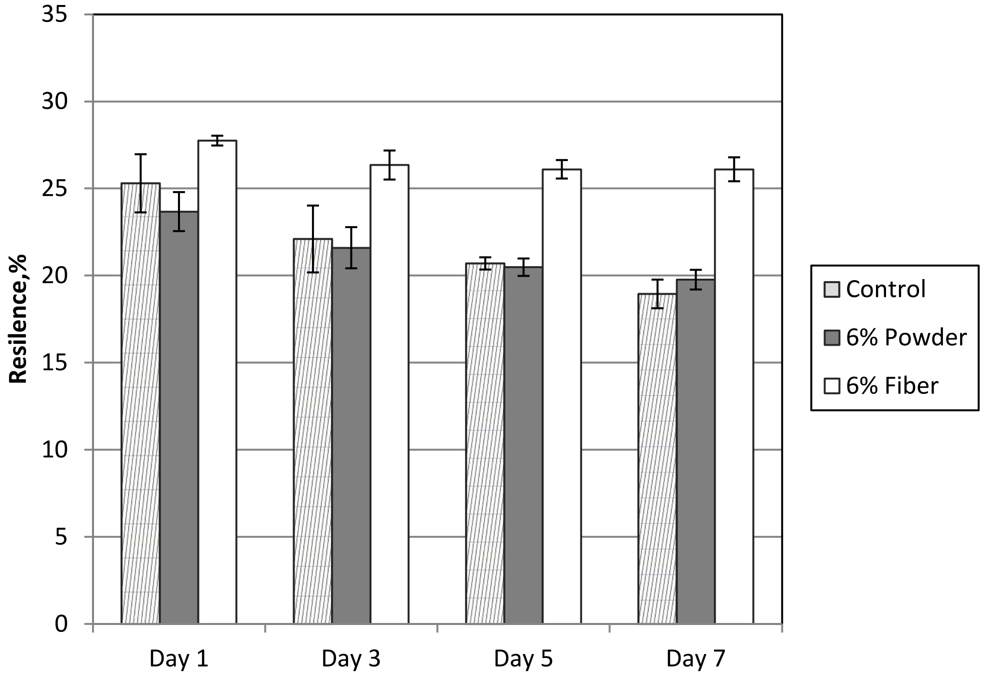

Figure 3.24 The effects of storage time on resilience of cake samples containing 6 % cacao powder and fiber.

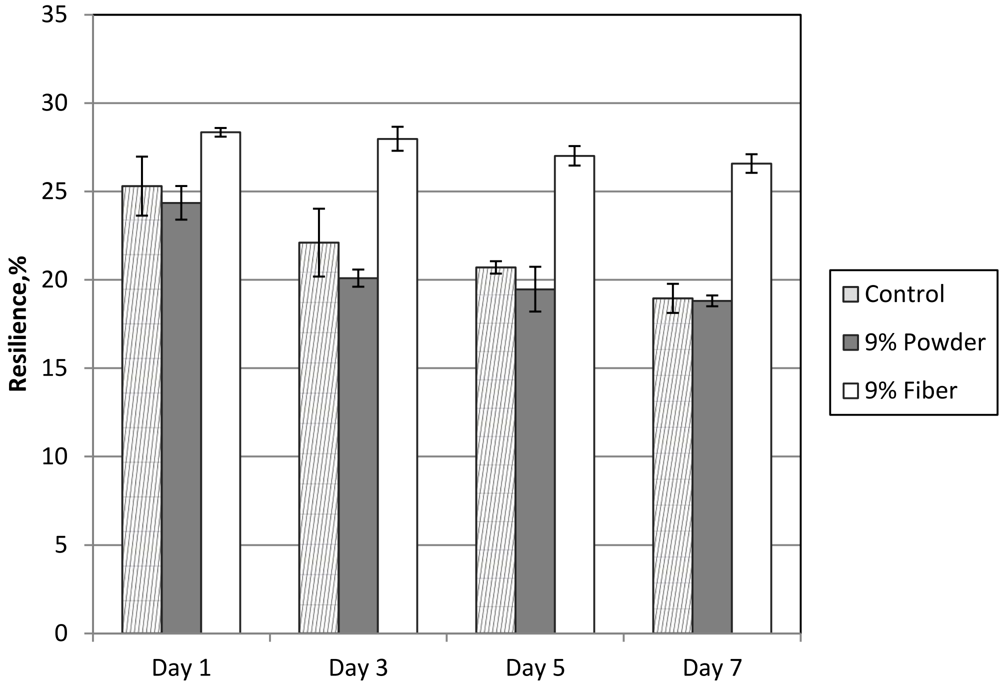

Figure 3.25 The effects of storage time on resilience of cake samples containing 9% cacao powder and fiber.

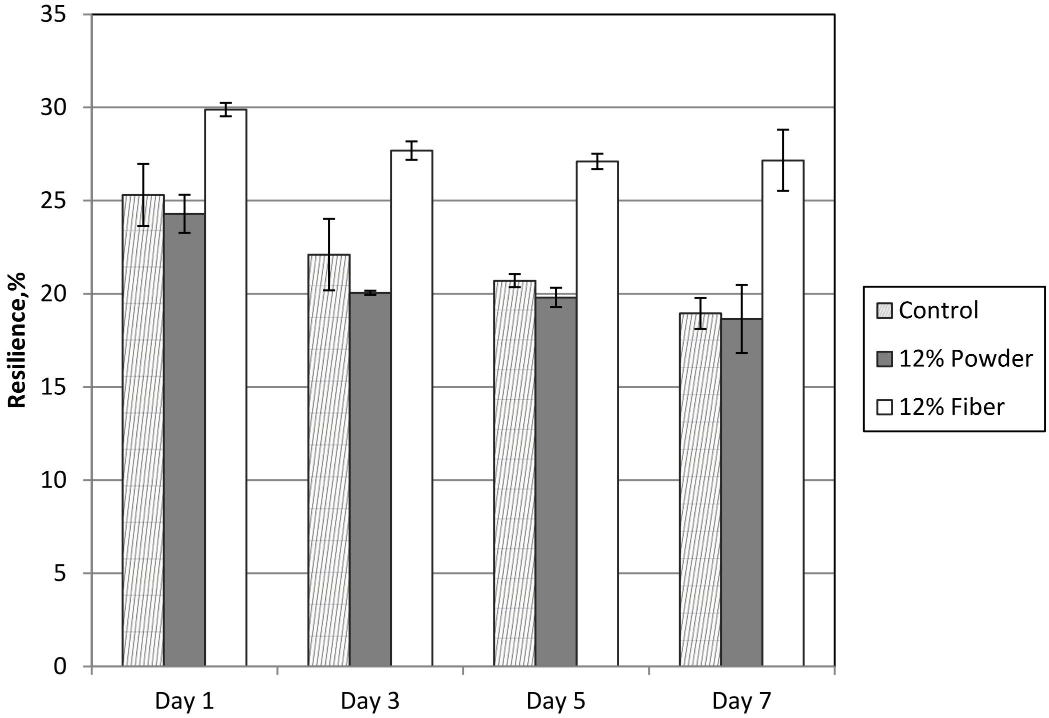

Figure 3.26 The effects of storage time on resilience of cake samples containing 12 % cacao powder and fiber.

The value for the ‟chewiness" parameter of the cakes with cacao powder and fiber over 7 days of storage can be observed in Figures 3.27, 3.28, 3.29 and 3.30. Chewiness value of all samples increased with increasing storage time. Chewiness value of 3%,6 %,9 % and 12 % cacao powder samples were 2006, 2097, 2393 and 2598 g force respectively. Chewiness value of 3%,6%,9% and 12% cacao powder samples were 2119, 2433, 2571 and 2747 g force, respectively. Chewiness value was lowest for the control cake and it increased with increasing cacao powder and fiber content. However, Chewiness increment was higher in the samples with cacao fiber. Fiber had no significant effect on chewiness change during 7 days of storage.

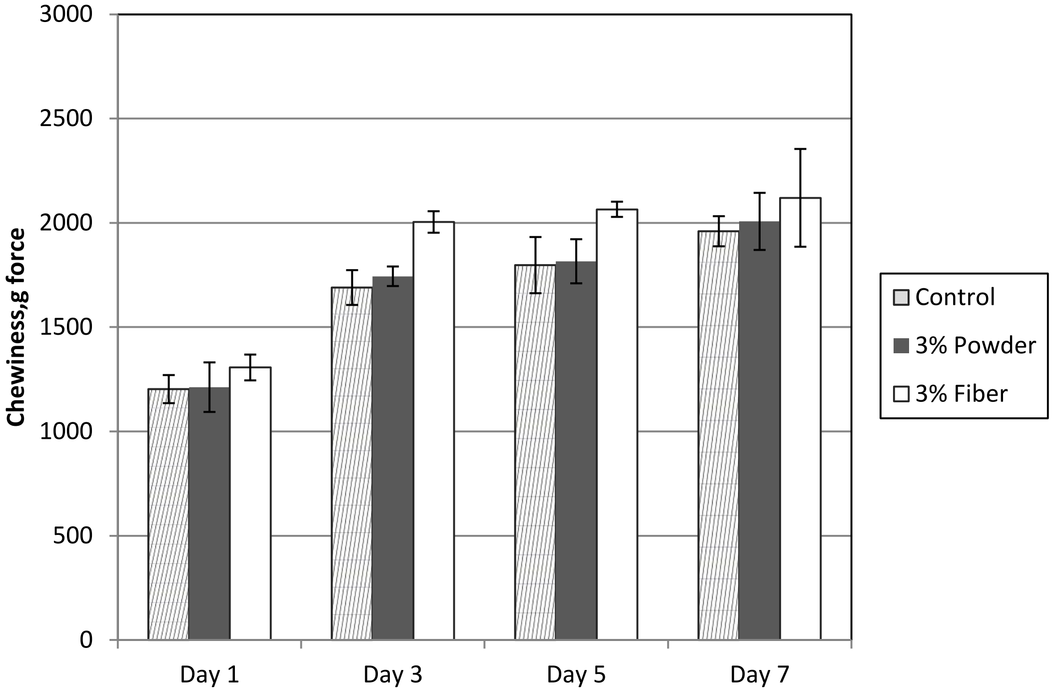

Figure 3.27 The effects of storage time on chewiness of cake samples containing 3 % cacao powder and fiber.

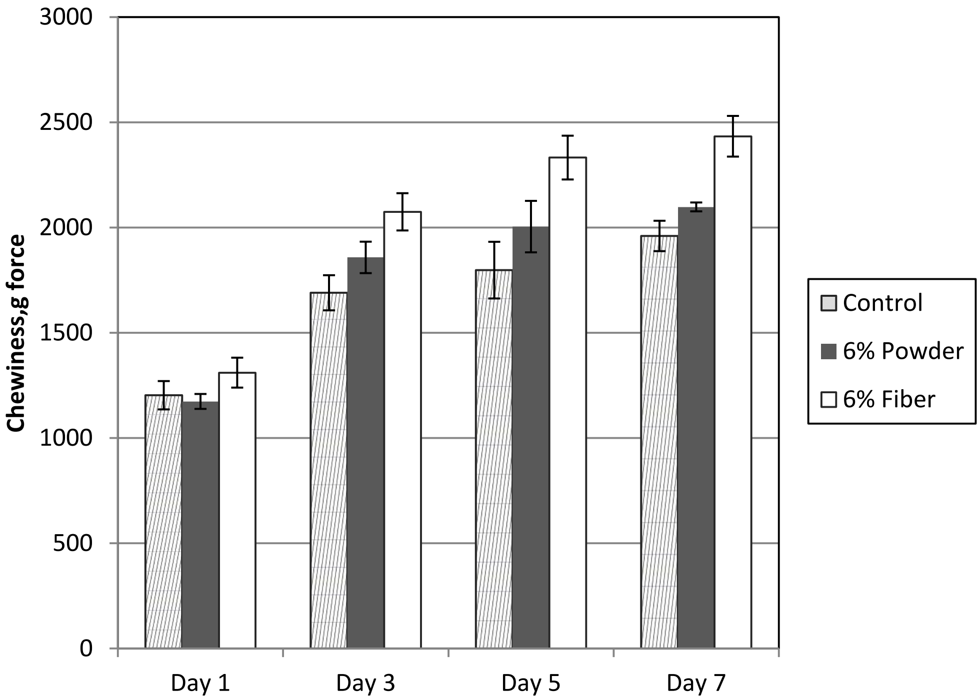

Figure 3.28 The effects of storage time on chewiness of cake samples containing 6 % cacao powder and fiber.

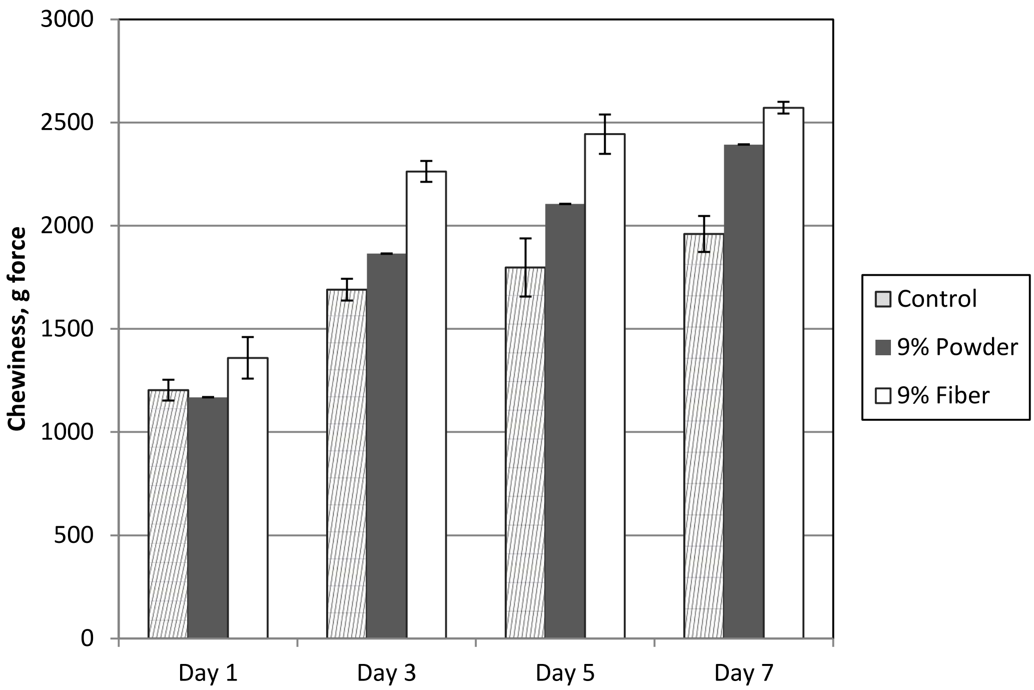

Figure 3.29 The effects of storage time on chewiness of cake samples containing 9 % cacao powder and fiber.

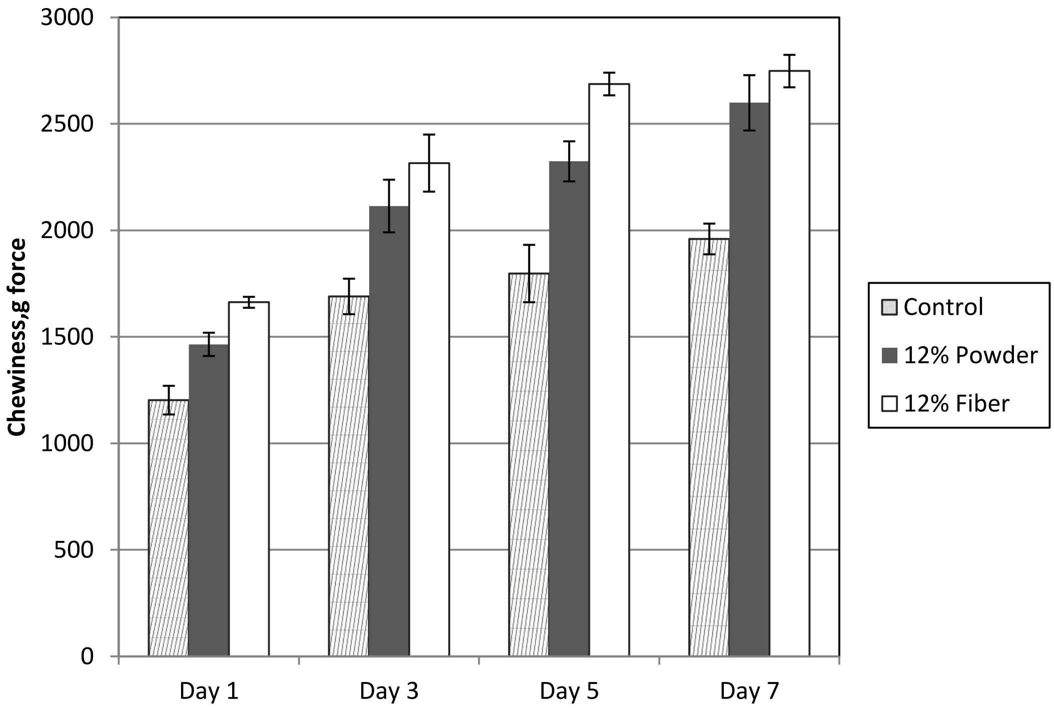

Figure 3.30 The effects of storage time on chewiness of cake samples containing 12 % cacao powder and fiber.

Baixauli et al. (2008) observed that the addition of resistant starch reduced textural changes in muffins during storage, being more evident with the highest dose. In bread studies Gómez et al. (2003) also observed that small quantities of fiber also reduced textural changes during storage. The fiber minimized the changes in hardness, springiness and resilience during storage.

During 7days of storage, a decrease in elastic recovery over the storage time can be seen in Figures 3.31, 3.32, 3.33 and 3.34. Elastic recovery value of control sample decreased from 47 % to 39% at the end of the 7th day. Elastic recovery value of samples with cacao powder decreased from 45 % to 39 % and in cacao fiber samples decreased from 49 % to 44 %. Decrement was 5 units in the samples with cacao fiber. However this decrement was 6 units for cacao powder samples. The fiber minimized the changes in elastic recovery during storage.

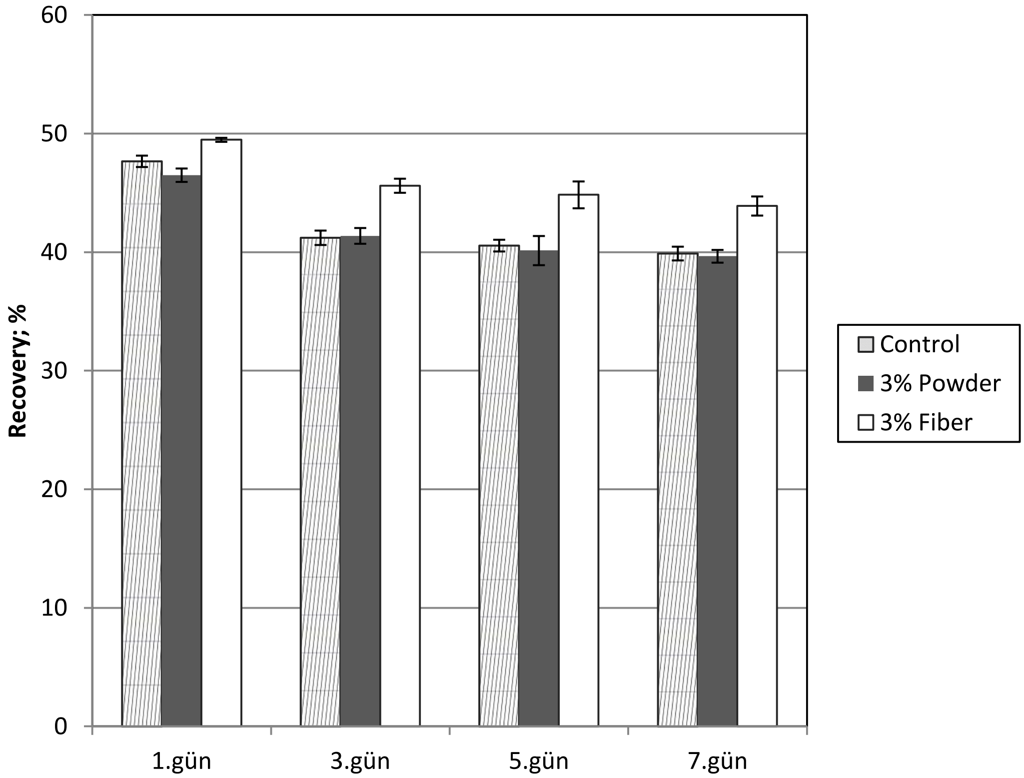

Figure 3.31 The effects of storage time on elastic recovery of cake samples containing 3 % cacao powder and fiber.

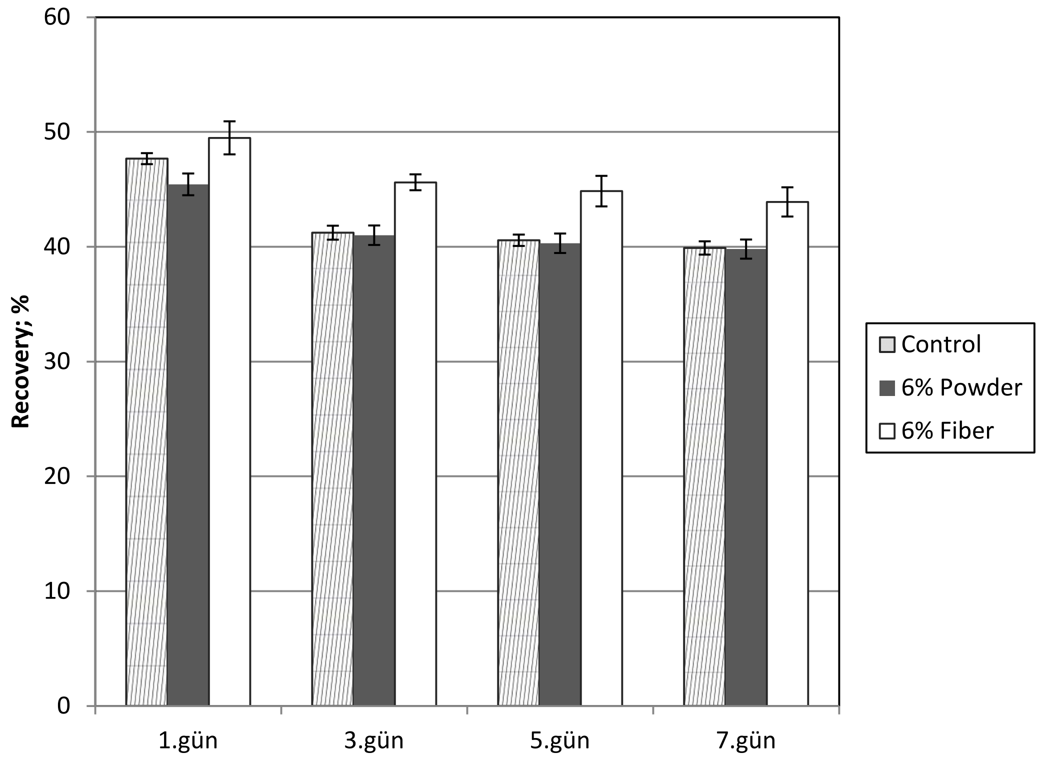

Figure 3.32 The effects of storage time on elastic recovery of cake samples containing 6 % cacao powder and fiber.

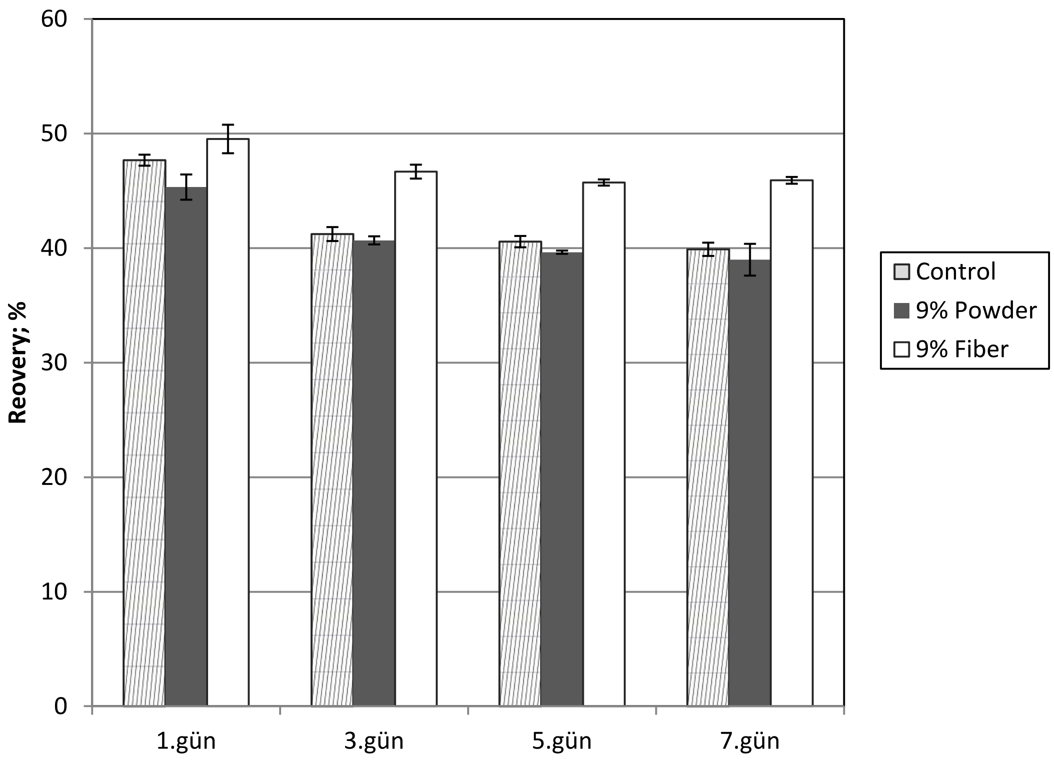

Figure 3.33 The effects of storage time on elastic recovery of cake samples containing 9 % cacao powder and fiber.

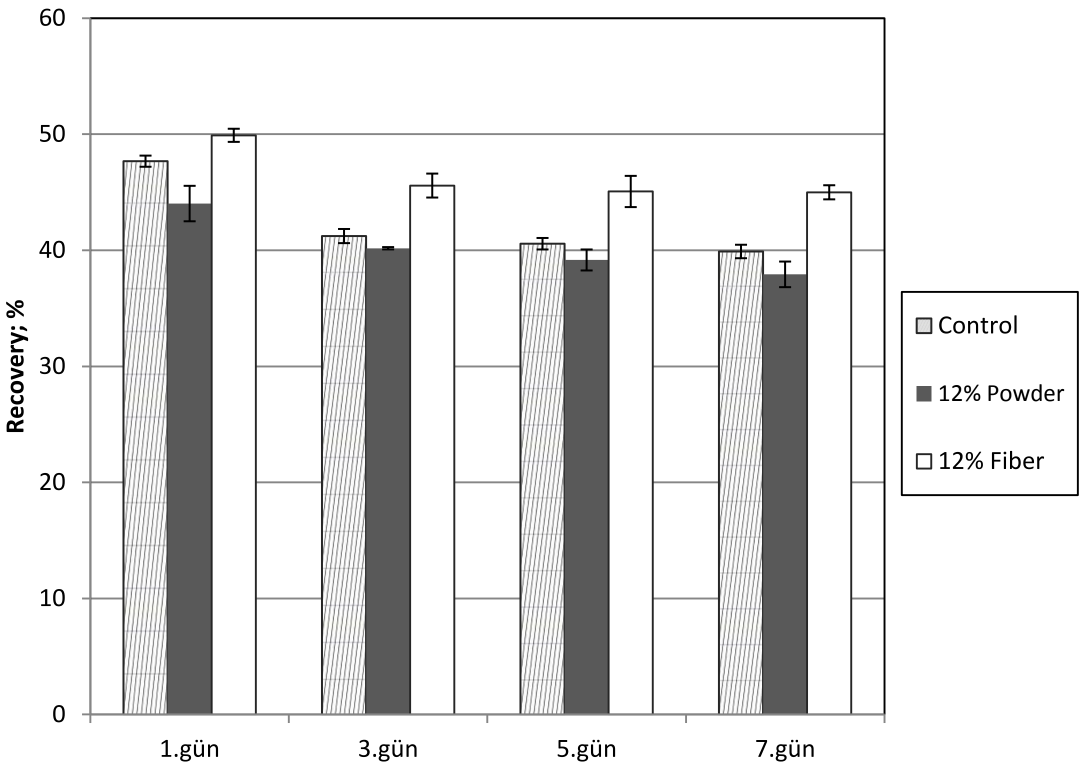

Figure 3.34 The effects of storage time on elastic recovery of cake samples containing 12 % cacao powder and fiber.

3.4. Specific Volume

The effects of cacao powder and fiber concentration on specific volume and volume can be seen in Figure 3.35 and Figure 3.36, respectively. Addition of 3 % fiber increased specific volume and volume. However, as the concentration of cacao fiber increased from 3 % to 12 %, the specific volume of the cake decreased from 1. 05 mL/g to 0.91mL/g and the density of the cakes increased from 0.96 /mL to 1.09 g/mL. Cakes containing 12 % fiber showed the lowest specific volume.

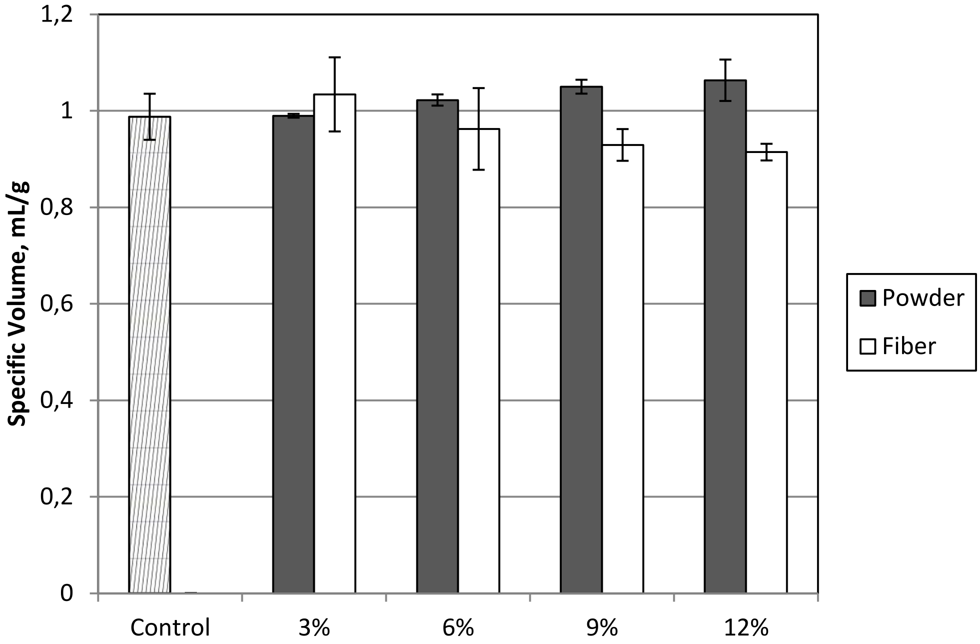

Figure 3.35 The effects of cacao powder and fiber concentrations on the specific volume of cakes

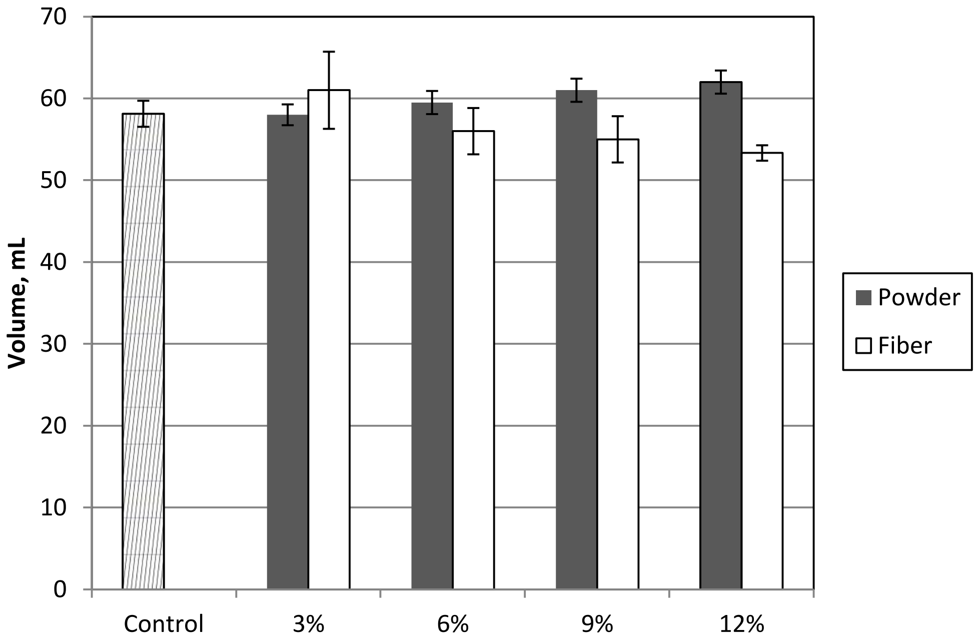

Figure 3.36 The effects of cacao powder and fiber concentrations on the volume of cakes

It is stated that guar gum could improve the cake volume when added at low levels (1%) (Gomez et al. 2007). Some authors reported a decrease in the cake volume when fibers from different fruits were incorporated (Grigelmo-Miguel et al. 1999).

It is known that the batter viscosity must be adequate in order to retain the air incorporated during mixing and the air produced by the baking powder during baking (Stauffer, 1990). Thus, a small increase of batter viscosity observed could help to retain gases, and increase cake volume when low fiber percentages added and a high increase of batter viscosity could reduce cake volume(as the one produced by high fiber percentages).

3.5. Baking Loss and Weight Loss

The effects of cacao powder and cacao fiber concentration on baking and weight loss of the cake samples are presented in Figure 3.37, 3.38, 3.39 and 3.40.

Baking loss of control sample and cacao fiber samples were 9% and 10% , respectively. Baking loss of 3 %,6 %,9 % and 12 % cacao fiber samples were measured as 10.5 %, 10 %, 9.5 % and 9 %, respectively. Cacao fiber addition resulted in a decrease in the baking weight loss (%) as compared to with cacao fiber samples. In addition to that baking loss decreased with increasing cacao fiber. The lowest baking weight loss (%) values were obtained when the cacao fiber at a higher concentration (12.0 %) was added to the cake formulation. Baking loss is important because it decreases the shelf life of products.

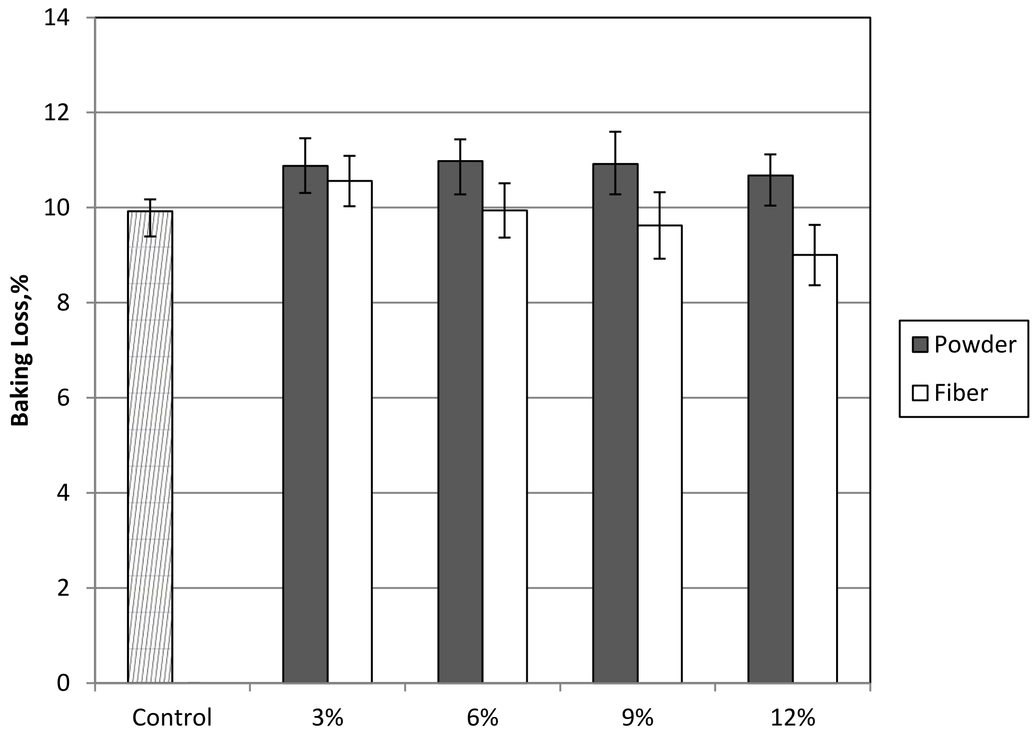

Figure 3.37 The effects of cacao powder and fiber concentrations on the baking loss of the cakes

It can be seen from the figure that for each type of cake formulation, the weight loss (%) increased, as the storage time increased for all samples. Weight loss of control cake was measured as 1.2 % in the 7^{th} day. Weight loss of cacao powder and fiber were measured as 1.2 % and 0.9 %, respectively. Weight loss decreased with increasing cacao fiber ratio during storage. Decrease in baking loss and weight loss may be explained with the high water holding property of the cacao fiber.

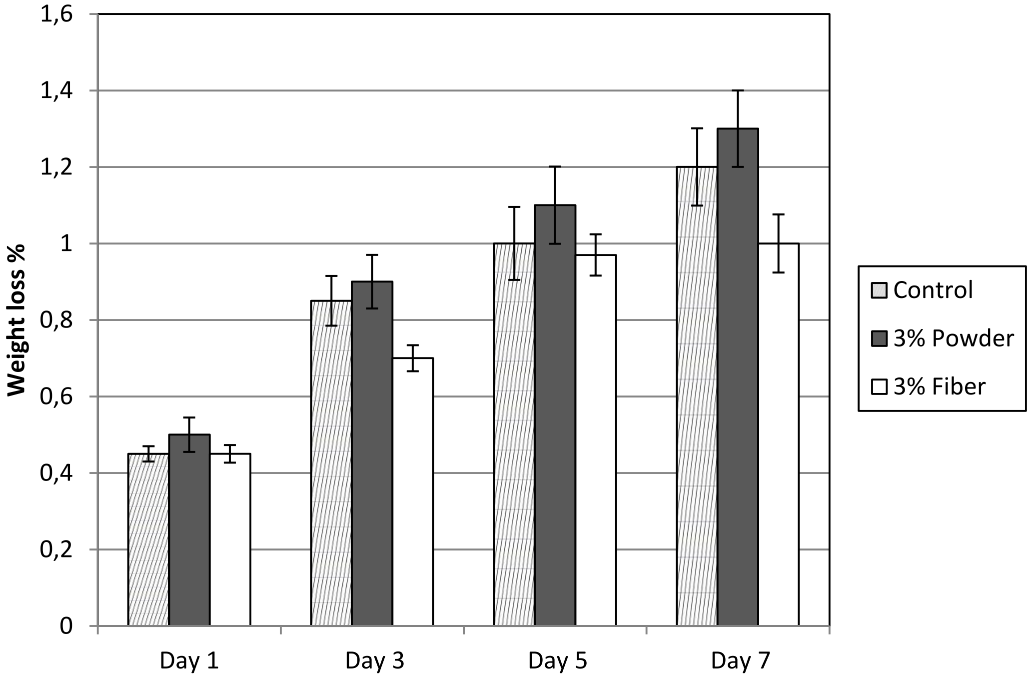

Figure 3.38 The effects of storage time on the weight loss of 3 % cacao powder and fiber containing cakes

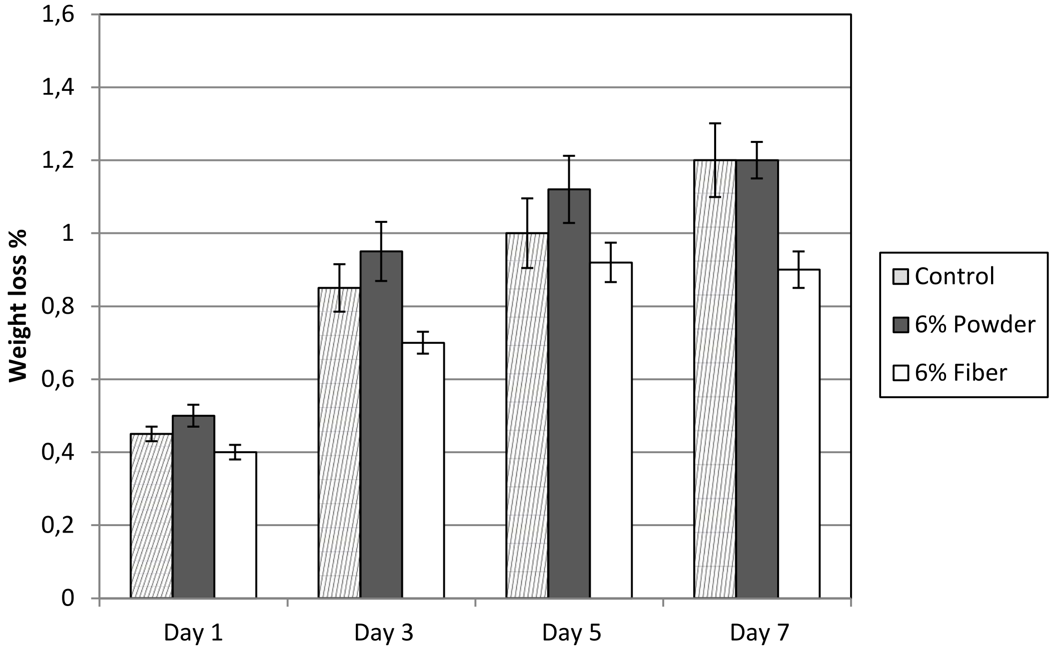

Figure 3.39 The effects of storage time on the weight loss of 6 % cacao powder and fiber containing cakes

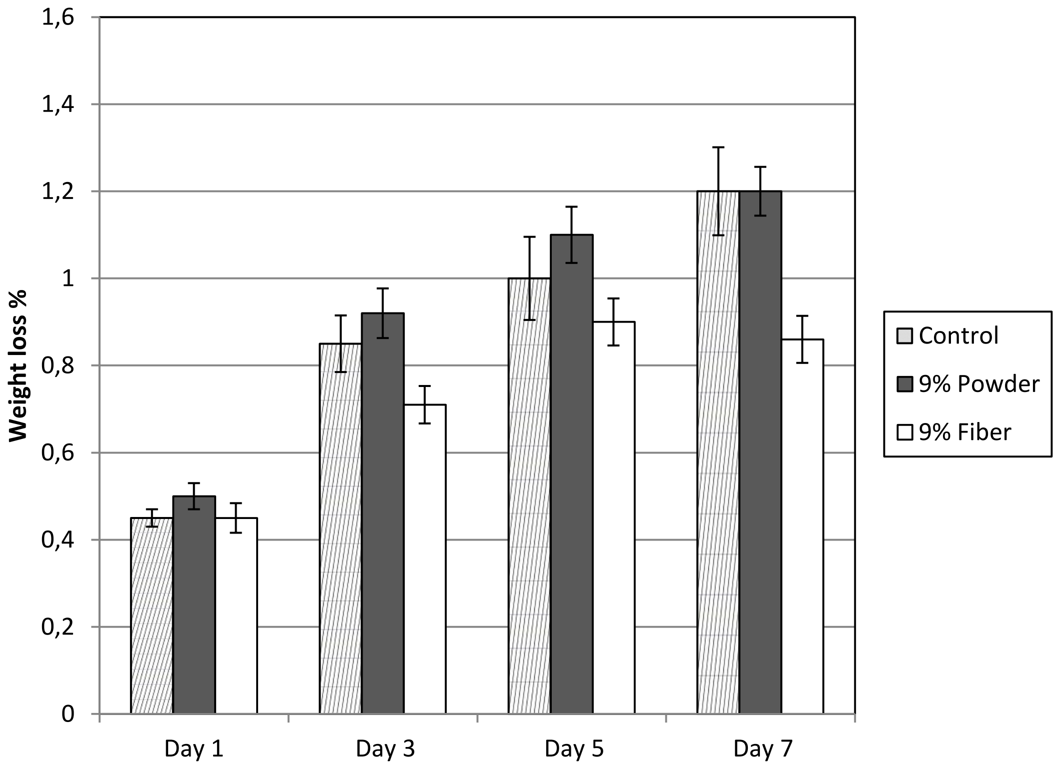

Figure 3.40 The effects of storage time on the weight loss of 9 % cacao powder and fiber containing cakes

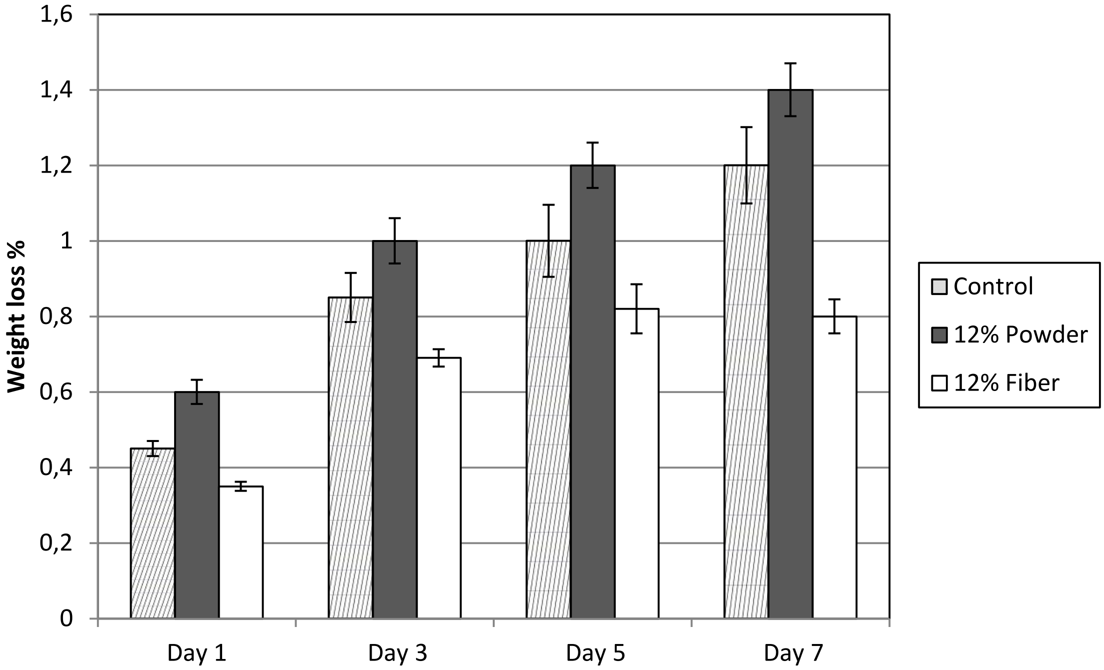

Figure 3.41 The effects of storage time on the weight loss of 12 % cacao powder and fiber containing cakes

3.6. Color

Crust color became darker (lower L* values), more reddish (higher a* values) and lower yellowish (lower b* values) when fiber was added. However, as the concentration of cacao fiber increased from 6 % to 12 %, a* value decreased.

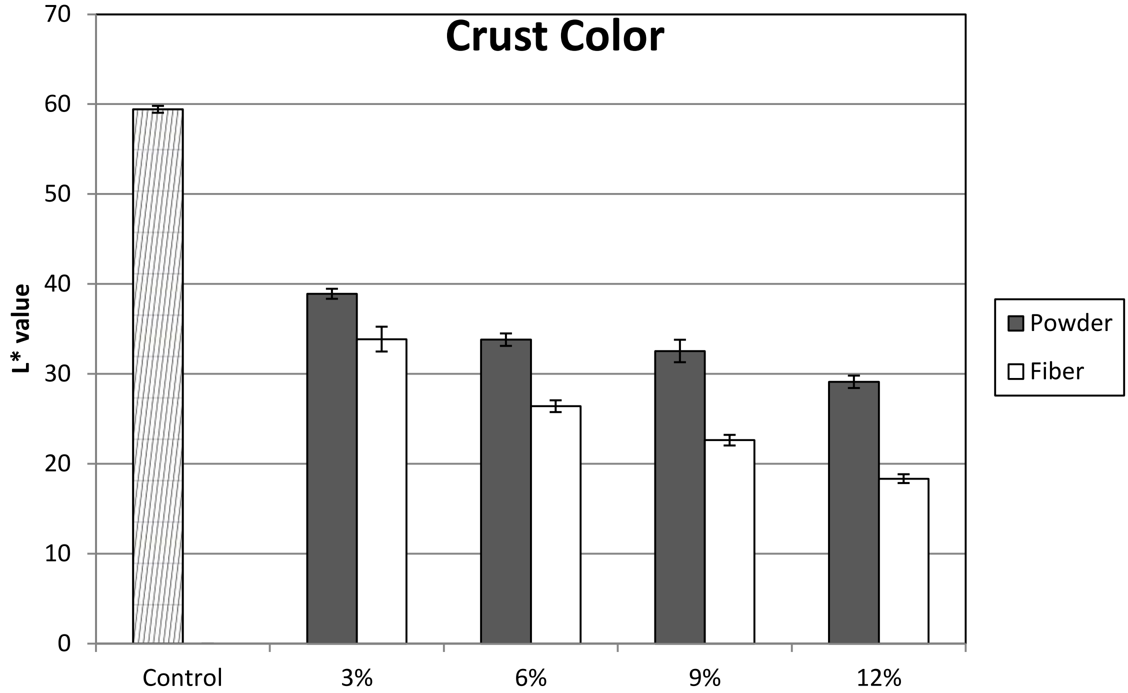

Figure 3.42 The effects of cacao powder and fiber concentration on the L* values of crust color

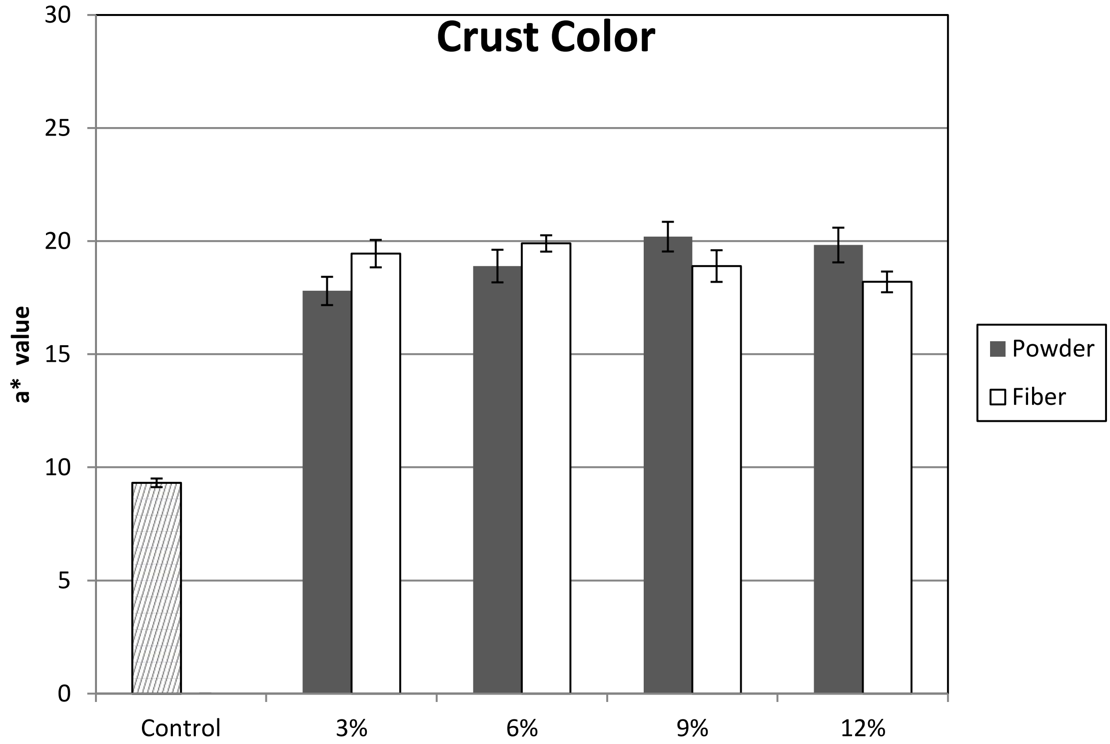

Figure 3.43 The effects of cacao powder and fiber concentration on the a* values of crust color

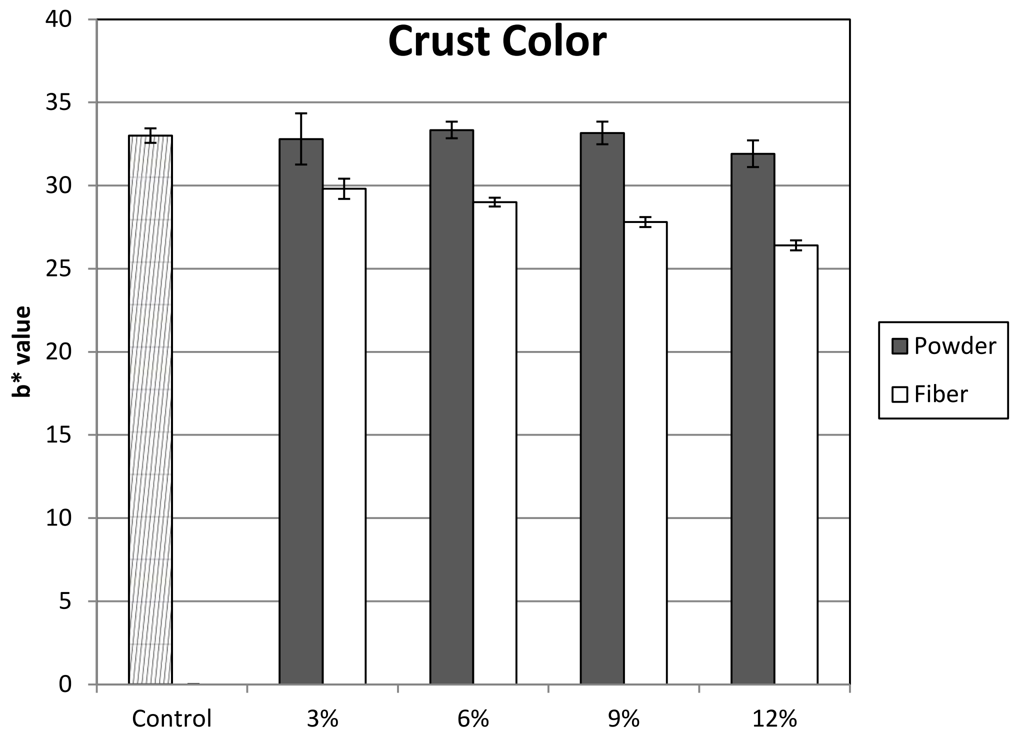

Figure 3.44 The effects of cacao powder and fiber concentration on the b* values of crust color

The effects of concentrations of cacao powder and cacao fiber on the L*, a* and b values of crumb color can be seen in Figure 3.45, 3.46 and 3.47.Increase in ratio of fiber decreased crumb *L** values, increase a* values and *b** values, However , after 6 % fiber content a and b values started to decrease. Cakes formulated with 6 % of cacao fiber gave the highest *a** and *b** crust color values.Both the crust and the crumb color were darker with addition of cacao fiber to the cake samples. Even 12 % cacao fiber used cakes have lighter crumb and crust color than samples with 3 % cacao fiber.

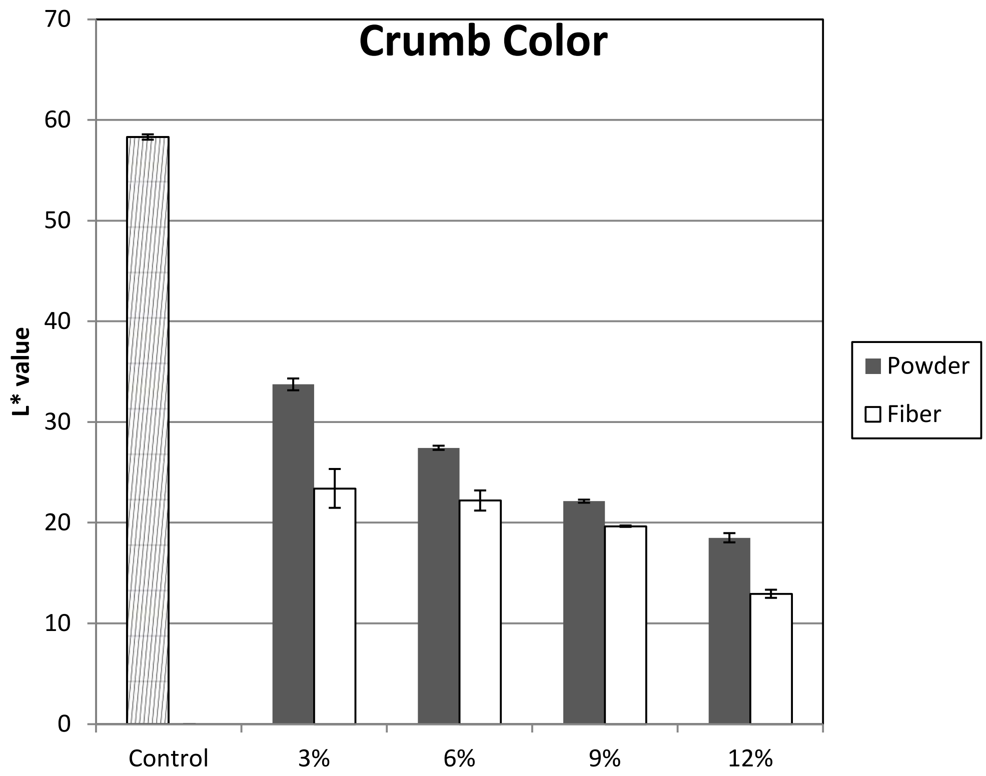

Figure 3.45 The effect cacao powder and fiber concentration on the L* values of crumb color

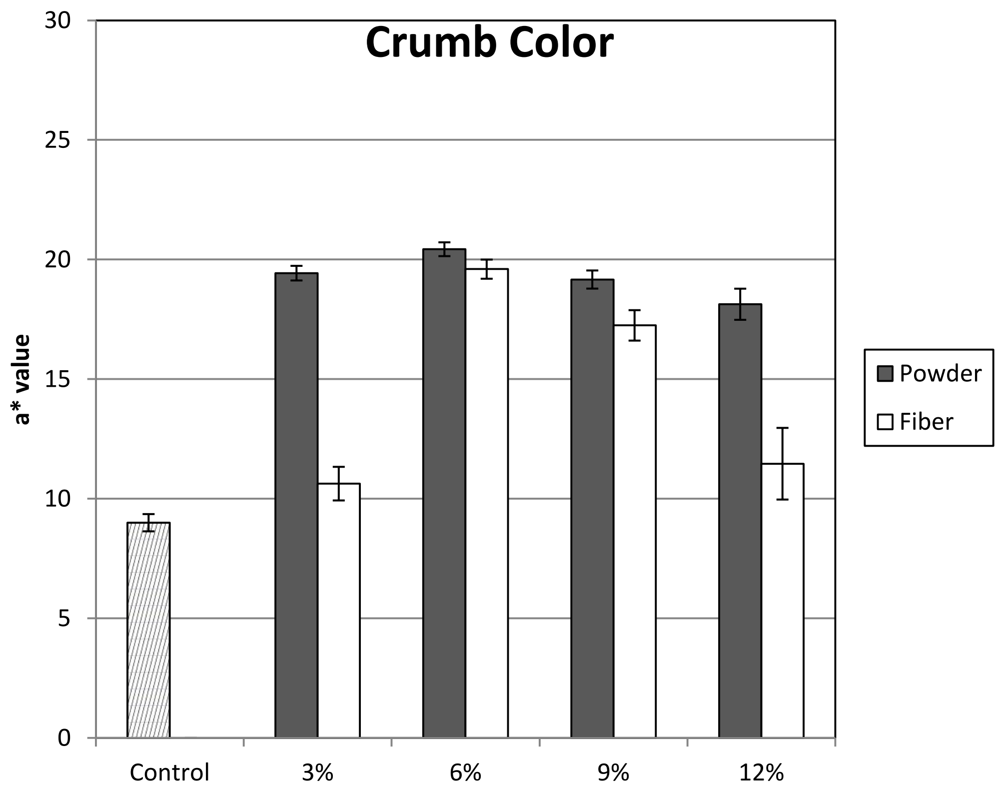

Figure 3.46 The effects of cacao powder and fiber concentrations on the a* values of crumb color

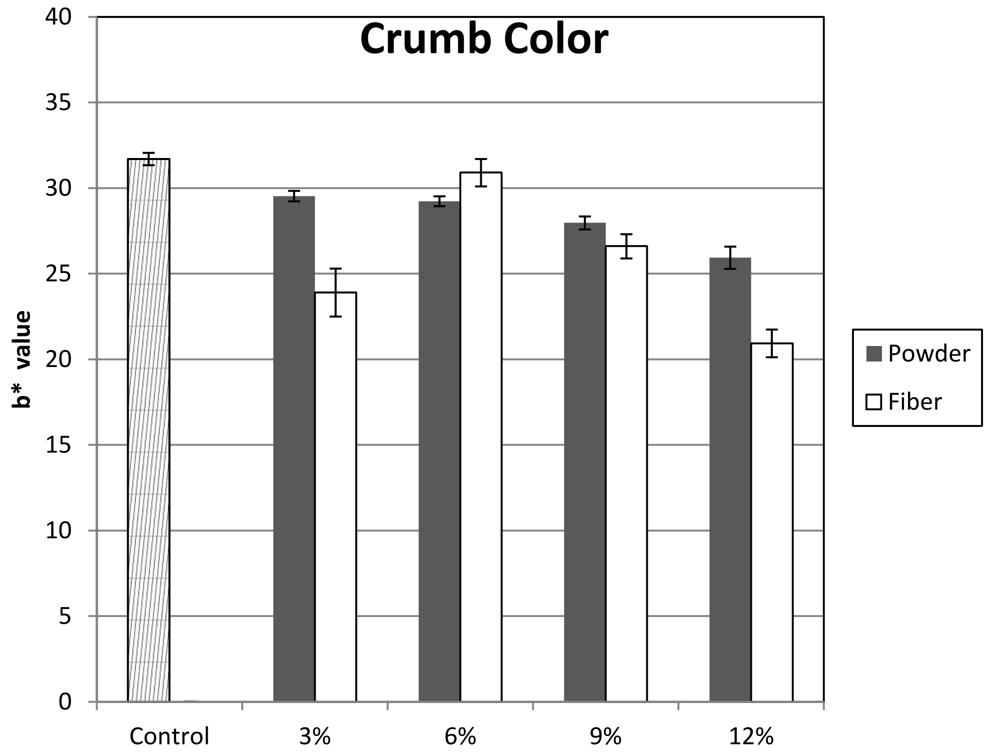

Figure 3.47 The effects of cacao powder and fiber concentration on the b* values of crumb color

Fermentation process give dark color to cacao beans.Polyphenols difuse with cell liquids from their storage cells and oxidate to condensed high molecular mostly insoluble tannins during fermentation of cacao beans(Wollgast et al. 2000). These tannins are responsible of dark color in cacao powder. These storage cells might brake down during microfludizaiton process.These free polyphenols might be oxidized to tannins leading darker color in cacao fiber and in the samples with cacao fiber.

3.7. Sensory Evaluation

Sensory results of different concentration of cacao powder and cacao fiber can be seen in Table 3.2.The highest scores for both texture and taste were obtained for the cakes containing 9 % cacao fiber. The highest score for odor were obtained for 12 % containing cacao fiber and for color highest score belong to both 9 % and 12 % cacao fiber samples.Control sample had the highest score for texture only.Texture score decreased with increasing cacao fiber ratio but it was higher than samples with cacao powder except for 12 % cacao fiber sample .

With the increase in the level of cacao fiber in formulation, the sensory scores for overall acceptability of cakes increased until 9 % fiber. The samples of 9 % added fiber had maximum overall acceptability. At 12 % levels of substitution, the overall acceptability was rated as poor compared to 12 % powder used samples.

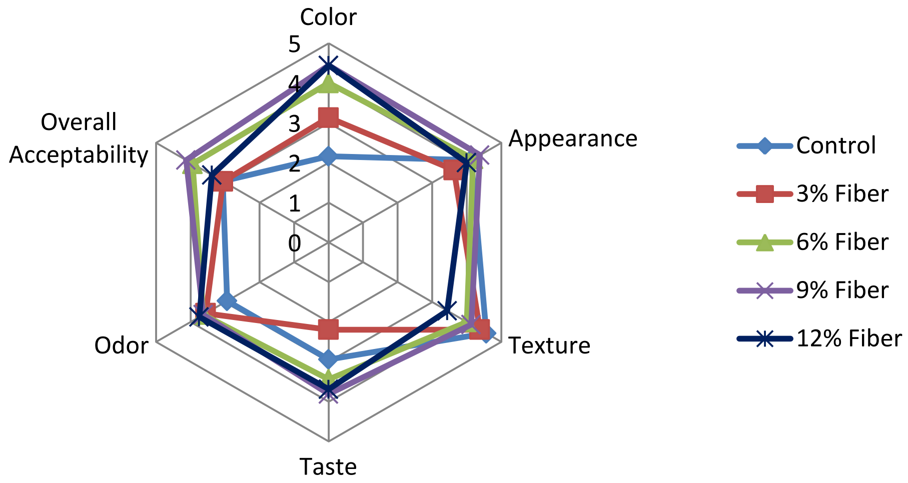

Figure3.48 The effects of cacao powder concentrations on sensory properties of cake samples

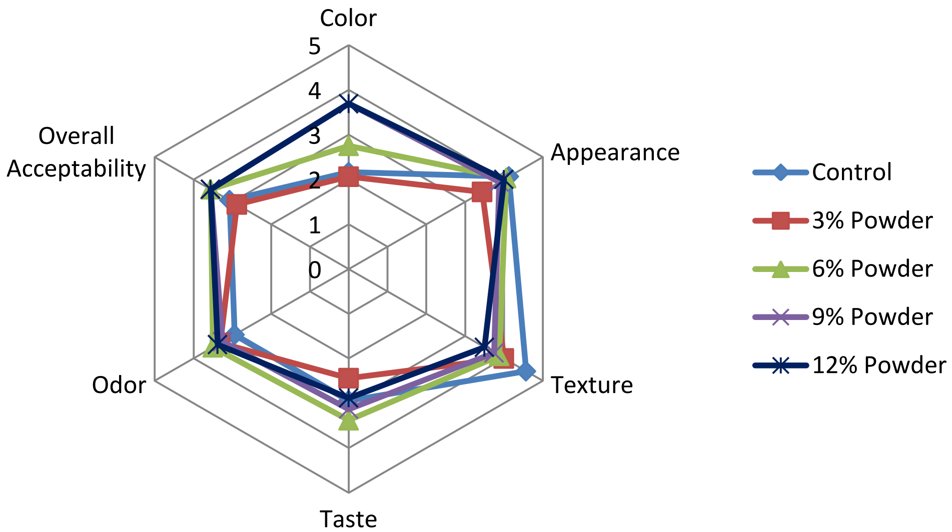

Figure3.49 The effects of cacao fiber concentrations on sensory properties of cake samples

Table 3.5. Sensory results of different concentration of cacao powder and cacao fiber

	Samples	Color	Appearance	Texture	Taste	Odor	Overall Acceptability
	Control	2.16±0.2	4.13±0.4	4.57±0.4	2.94±0.3	2.94±0.3	3.07±0.3
Cacao Powder (%)	3	2.06±0.2	3.44±0.4	4.00±0.2	2.44±0.2	3.31±0.4	2.88±0.1
	6	2.75±0.3	4.06±0.3	3.88±0.3	3.38±0.4	3.50±0.3	3.56±0.4
	9	3.69±0.3	3.88±0.4	3.75±0.4	3.13±0.2	3.25±0.4	3.56±0.4
	12	3.69±0.2	4.00±0.2	3.50±0.3	2.88±0.4	3.38±0.3	3.56±0.3
Cacao Fiber (%)	3	3.13±0.5	3.63±0.3	4.38±0.2	2.19±0.3	3.56±0.4	3.06±0.3
	6	4.00±0.6	4.19±0.4	4.00±0.3	3.44±0.4	3.63±0.3	3.94±0.4
	9	4.44±0.2	4.38±0.2	4.13±0.2	3.81±0.2	3.63±0.3	4.13±0.2
	12	4.44±0.3	4.00±0.3	3.44±0.4	3.69±0.3	3.75±0.2	3.38±0.3

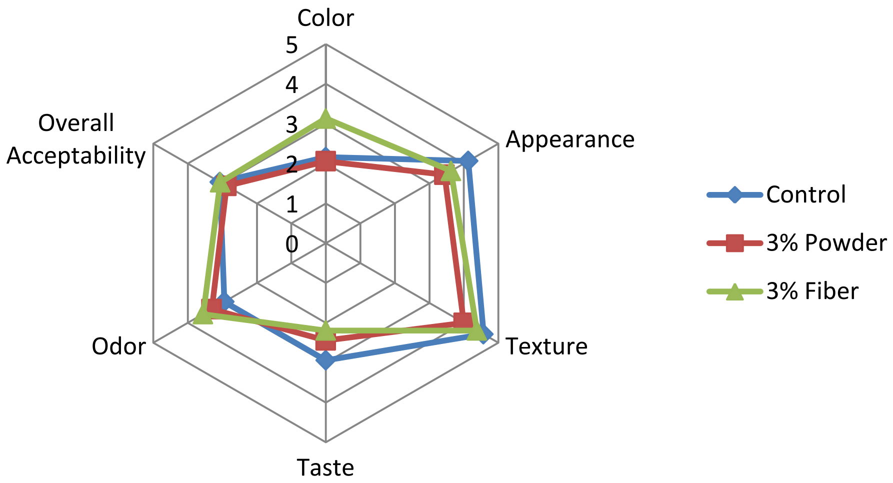

Figure3.50 Sensory properties of 3 % cacao powder and fiber containing cake samples

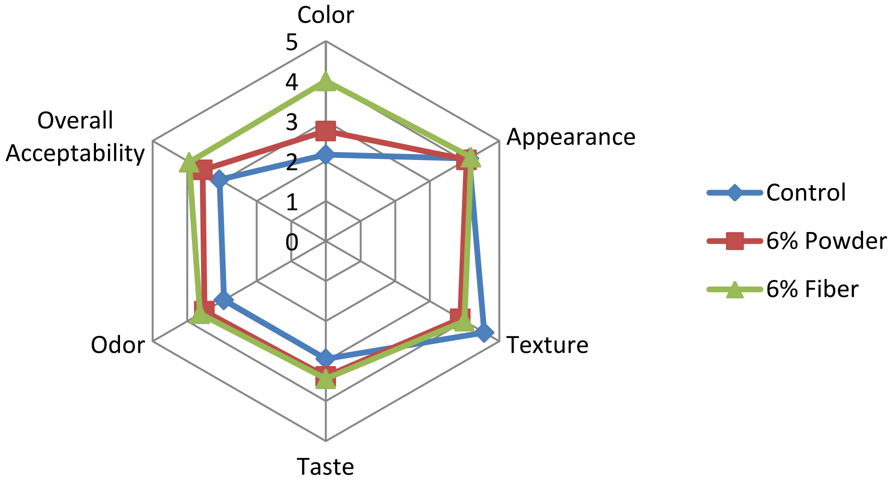

Figure3.51 Sensory properties of 6 % cacao powder and fiber containing cake samples

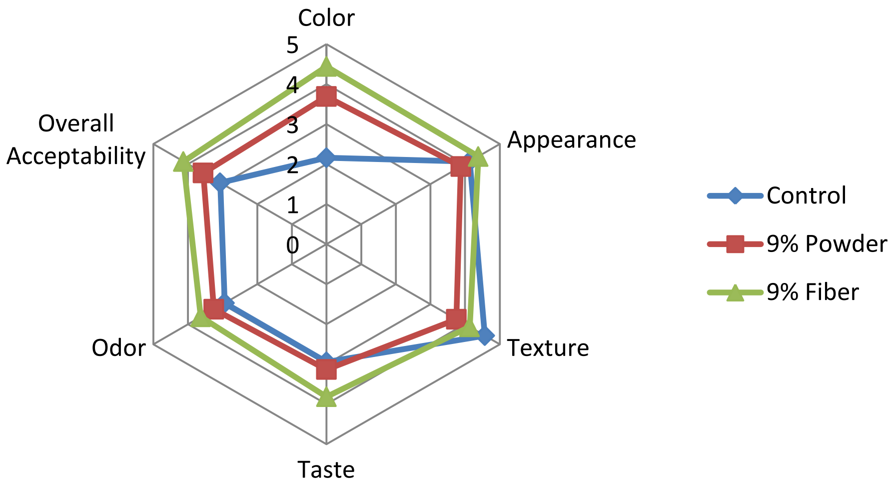

Figure3.52 Sensory properties of 9 % cacao powder and fiber containing cake samples

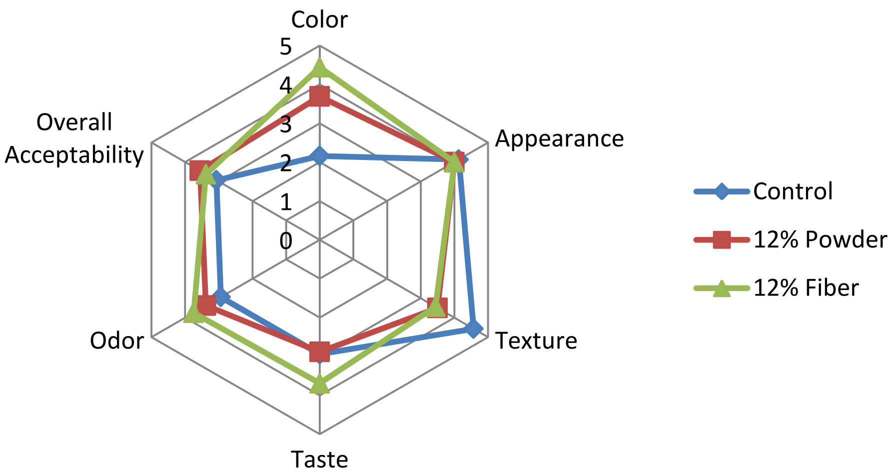

Figure3.53 Sensory properties of 12 % cacao powder and fiber containing cake samples

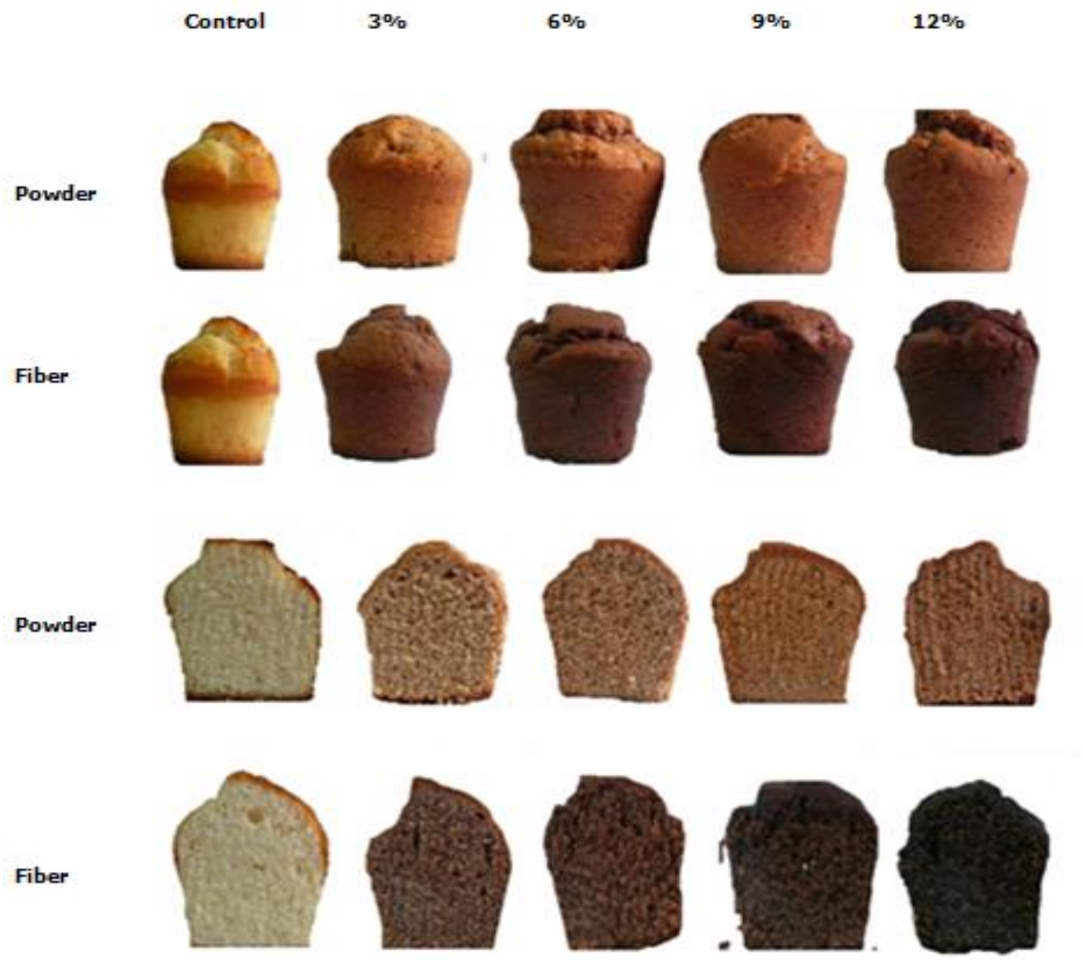

Figure 3.54 Photographs of Cake Samples

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

All the cake batter samples exhibited shear thinning and time-independent behavior. Experimental data provided a good fit for the Power Law model. It was shown that viscosity values increased with the increase in percentage of both cacao powder and cacao fiber. However for all cake formulations, the addition of cacao fiber resulted in higher viscosity values as compared to the cacao powder addition. We may conclude that the rheology strongly depends on the concentration of fiber. Oscillatory test showed that the magnitudes of G′ were higher than those of G″, and both increased with oscillatory frequency.

When cakes were investigated, as the concentration of fiber increased, specific volume started to decrease after 6 %. Addition cacao fiber decreased baking weight loss and weight loss during storage. Crumb and crust color became more brownish. The TPA results showed an increase in hardness, springiness, chewiness and resilience with an increased level of cacao fiber. The fiber also minimized the changes in hardness, springiness and recovery values during storage. It could be concluded that fiber slower the rate of staling. With the increase in the level of cacao fiber in formulation, the sensory scores for overall acceptability of cakes increased until 9 % fiber ratio. Fiber also increases acceptability in terms of odor, taste and color.

As a result of this study, more acceptable and slow staling chocolate cake can be produce by adding cacao fiber instead of cacao powder. However, fiber ratio and initial hardness must be optimized.

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