EFFECTS OF TOMATO POWDER OR SOY FIBER ADDITION AND FAT CONTENT ON PHYSICOCHEMICAL PROPERTIES OF HOT DOGS

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EFFECTS OF TOMATO POWDER OR SOY FIBER ADDITION AND FAT CONTENT ON PHYSICOCHEMICAL PROPERTIES OF HOT DOGS

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ABSTRACT

Tomato powder and soy fiber may provide health benefits by supplying dietary fiber and antioxidant compounds. The main objective of this study was to investigate the effects of dietary fiber additions (tomato powder 3%, tomato powder 5%, soy fiber 3% and soy fiber 5%) and fat content (10, 15 and 20%) on physical and chemical properties of beef hot dog.

Tomato powder and soy fiber additions increased protein content and dietary fiber content in all cases ($P < 0.05$), and all dietary fiber additions provided a small degree of showed antioxidant activity in the order of ($P < 0.05$) 3% tomato powder >3% soy fiber> 5% tomato powder= 5% soy fiber.

Tomato powder content had no effect on cooking loss ($P > 0.05$) but decreased water holding capacity ($P < 0.05$), whereas soy fiber decreased cooking loss and increased water holding capacity ($P > 0.05$). Increasing fat content generally resulted in increased cooking loss and water holding capacity ($P < 0.05$). However, interaction effects on cooking loss due to fiber addition were found in 10 and 20% fat levels ($P < 0.05$).

For the color analysis, Tomato fiber decreased L* and a* values and increased b* value ($P < 0.05$), while soy fiber increased L* and b* value and decreased a* value in beef hot dogs ($P > 0.05$). Increasing fat content increased L* value and decreased a* ($P < 0.05$) value but did not affect b* value ($P > 0.05$).

In regard to the texture profile, increasing fat content decreased hardness, gumminess and chewiness ($P < 0.05$) but did not affect springiness and cohesiveness ($P > 0.05$). All dietary fiber additions increased hardness in hot dogs with 10% and 15% fat content ($P < 0.05$) but decreased hardness in hot dogs with 20% fat content. Springiness and cohesiveness decreased ($P < 0.05$) due to dietary fiber additions for all fat levels. Chewiness and gumminess also decreased ($P < 0.05$) when dietary fiber was added, and higher percentages of dietary fiber addition decreased springiness, cohesiveness, gumminess and chewiness to a greater extent ($P < 0.05$) but did not show additional effects on hardness ($P > 0.05$).

CHAPTER 1

INTRODUCTION

1.1Background

There is a large and growing hot dog market in the United States (Daniel and others 2011). According to data of the National Hot Dog & Sausage Council, more than $1.7 billion in hot dogs was sold in 2011 and low fat and fat free hot dogs continue to sell well since 2004. At the same time, 60% of all hot dog consumers prefer all beef hot dogs. However, some studies found the risk of chronic diseases is positively associated with dietary meat intake, including red meat (Pan and others 2012) and processed meat (Jedrychowski and others 2012: Jiang and others 2008). On the other hand, American's consumption of dietary fiber is inadequate. Dietary fiber intake has remained statistically stable at 15 g/day from 1999 to 2008, which is much lower than the recommended 25 to 38 g/day (King and others 2012), despite the health benefits associated with eating more dietary fiber, such as reduced risks of breast cancer (Li and others 2013), obesity (Kantor and others 2013) and other chronic diseases (Varraso and others 2010). Moreover, a number of dietary fibers have been considered as appropriate additives to improve the texture of meat products (Weiss and others 2010; Dhingra and others 2012). Thus, developing nutritious hot dogs by adding fiber would be beneficial for the meat industry and meat consumers at the same time.

Tomatoes and soy beans are important foods and sources of food ingredients for the food industry. They are also considered healthy foods. Tomato is a good source of carotenoids, vitamin C, vitamin A and lycopene. Tomato powder can be easily made by collecting the waste of tomato processing, which are skins and seeds. Numerous studies have shown that there is an association between tomatos or tomato related product intake and lower risk of several types of cancers, which might be due to the high antioxidants content of tomato (Zuniga and others 2013; Liu and others 2009; Boileau and others 2003). Soy fiber is an ingredient, which is used in many current products in the market, and it provides many health benefits, such as reducing serum cholesterol, as well as lowering insulin and glucose responses (Dakhara and others 2012). Thus, the addition of these two fibers into an emulsified meat system could be expected to result in nutritious and tasty hot dogs.

Dietary fiber has long been recognized as an excellent ingredient in meat systems. The suitability of fiber incorporation into meat products is increasing because of the numerous functional properties, such as water retention, ability to decrease cooking loss and texture modification (Jimenez, 1996). Tomato powder received wide attention in recent years due to containing antioxidants, including lycopene. The antioxidant activity from lycopene in tomato powder might improve the antioxidant capacity of the hot dogs and extend their shelf life (Duthie and others 2013). Additionally, the color associated with lycopene might be preferred over that of nitrite by consumers, who are interested in natural pigments (Kim and others 2011; Eyiler and Oztan 2011). In addition to the direct effects of different fiber contents and fiber varieties on the functionalities mentioned above, the fat content and the interaction between fat and dietary fiber are also important factors that determine hot dog quality but little information regarding the effects of these variables on the physical and chemical properties of hot dogs containing tomato powder or soy fiber is available.

1.2 Objectives

1) To produce all beef hot dogs of different fat contents containing tomato powder or soy fiber
2) To study the effects of fiber type, fiber content, fat content and their interactions on chemical and physical properties, including moisture content, fat content, protein content, fiber content, lycopene content, lipid oxidation, cooking loss, water holding capacity, texture and color properties.

CHAPTER 2

LITERATURE REVIEW

2.1 Red Meat and Processed Meat

The United States is a country of meat eaters. In 2007, the red meat consumption in the United States attached 85 g/ cap/ day (Carrie and others 2010). Red meat is a concentrated dietary source of macro- and micronutrients and has been hypothesized to have complex effects on human health (Murphy and Allen 2003). Processed meats are mostly made from pork or beef that are preserved by methods, such as curing, smoking and so on, that also improve the quality of various cuts of meat by developing specific flavors (Raphaelle and others 2008). Processed meat intake makes up about 50% of total red meat intake, which in North Americas about72 g/d per person (Raphaelle and others 2008).

2.1.1 Health Concerns for Red and Processed Meat

Numerous studies have shown the association between red and processed meat intake and diseases, such as cancer and cardiovascular disease. A few studies looked specifically at the effect of red meat on cardiovascular diseases. David and others (1984) followed 25,153 respondents and found people who consumed beef more than three times per week had 10% increase in risk in coronary heart disease compared with people who did not consume beef at all. In another study, 34,000 respondents were followed for 12 years and investigators observed a 130% increase in fatal myocardial infarction in men consuming beef consumptionaftercontrolling for potential confounding factors (Sinha and others 2009). Gramenzi and others (1990) separated processed from unprocessed red meat in their observation. They found an increase in red and processed meat consumption was both associated with a higher risk of cardiovascular mortality and with a greater increase in risk for women than for men. Researchers also analyzed constituents of red meat that may account for the higher risk of heart diseases, like heme iron, saturated fat, cholesterol and even the compounds created by cooking red meat (Knize and others 1999; Kono 2004).

Red and processed meat consumption has been identified as a risk factor for colon cancer in a large number of cohort studies. Long-time consumption increases the risk for colon cancer by 20% to30% and is linked to an increased mortality rate from colorectal cancer (Corpet 2011; Chan and others 2011). Several hypotheses may explain why processed meat intake is linked to higher risk of cancer than fresh meat consumption, including higher fat content, specific additives, and the formation of cholesterol oxidation products due to long-time storage (Raphaelle and others 2008). Red and processed meat is rich in fat, protein and heme iron which can promote carcinogenesis in vivo. Processing and cooking of meat can generate heterocyclic amines (HCAs), polycyclic aromatic hydrocarbon (PAHs) and N-nitroso compounds (NOCs). Specific HCAs, PAHs and NOCs are animal carcinogens (Sinha and others 1998). Several studies gave direct evidence that a high-fat diet can increase carcinogen-induced tumorigenesis in the colon of rats (Reddy and others 1976; Pence and others 1995). According to the International Agency for Research on Cancer, nitrite ingestion under conditions that result in endogenous nitrosation is potentially carcinogenic to humans.

NOCs are present in some processed meat and are formed endogenously after red and processed meat consumption. Due to the health concerns with red and processed meat consumption, Adam and Walter (2010) recommended that patients with cardiovascular disease decrease or eliminate red and processed meats from their diet and replace them with healthier protein sources, such as nuts and fish.

2.2 Dietary Fibers

In 1953, Hipsley (1953) described dietary fiber as a nondigestable constituent making up the plant cell wall but definitions have been revised several times. In 2000, the American Association of Cereal Chemists (AACC) defined dietary fiber as the edible parts of plants or analogous carbohydrate that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber has been recognized for its health benefits and the recommended intake ranges from 25 to 38 g. Currently, dietary fiber is divided into two basic categories, which are soluble and insoluble dietary fiber based on the solubility of the different types of dietary fiber.

2.2.1 Health benefits of dietary fibers

A variety of fibers have been shown to reduce blood cholesterol levels. These fibers come from foods, such as cereal, fruit and vegetables, and purified sources such as beet fiber, guar gum, karaya gum, konjacmannan, locust bean gum, pectin, psyllium seed husk, soy polysaccharide and xanthan gum (Marlett 2001). Beta glucan in oats and psyllium husk have been sufficiently studied by the FDA to authorize a health claim that foods meeting specific requirements and containing 0.75g or 1.7 g of soluble fiber per serving can reduce the risk of heart disease (CFR 2001). The mechanism of lowering blood cholesterol levels has been studied in recent years. One commonly accepted one is related to the viscosity of these soluble fibers (Marlett 1997). Due to their viscosity, the fibers interact with bile acid absorption which stimulates the LDL cholesterol absorption and converts it into bile acids in the liver to replace the bile acids lost in the stool (Marlett and others 1994). Thus, increasing soluble fiber intake has been recommended to lower blood cholesterol and prevent heart disease (Jenkins and others 1993).

A strong inverse relationship between dietary fiber intake and weight has been established in animal tests (Ushida and others 2011; Jimenez-Escrig and others 2008; Artiss and others 2006; Choi and others 2010; Bartley and others 2010) and human clinical studies (Du and others 2010; Tucker and Thomas 2009; Liu and others 2003; Campagnolo and others 2008). The protective effect of dietary fiber against excessive weight gain has been associated with greater satiety due to increased mastication, calorie displacement and decreased absorption of macronutrients (Kaczmarczyk and others 2012). Soluble dietary fibers form viscous solutions that prolong gastric emptying which inhibits glucose, triglycerides and cholesterol transportation (Lairon and others 2007). Furthermore, dietary fiber modifies lipid and carbohydrate metabolism in vivo by influencing the expression of key genes and function of hormones (Kaczmarczyk and others 2012).

The hypothesis that dietary fiber may prevent the formation of several types of cancer, including gastric cancer, esophageal cancer and colon cancer, is still a controversial topic in nutrition (Anderson and others 2009). Park and others (2005s) found dietary fiber intake could decrease fecal carcinogen and pro-carcinogen concentration and resident time of these compounds in the colon, and the fermentation of dietary fiber in colon leads to short-chain fatty acids producing and promotes bile acids to bind with carcinogenic. However, in an analysis of 13 prospective cohort studies with follow-up periods of 6-20 years, which followed about725,000 patients, persons with high fiber intake had only an insignificant 6% reduction in the development of colorectal cancer (Anderson and others 2009). Anderson and his co-workers (2009) speculated that there were too many factors that could have affected these cohort research results, such as type of fiber, living habits, experimental design and so on. Although there is no doubt that dietary fiber consumption is good for health, more evidences needed to support the anticancer ability of dietary fiber.

2.3 Tomato

Sales of fresh and processed tomatoes exceed more than $2 billion per year in the United States. Consumption of tomatoes and tomato products ranked in second place of vegetable consumption in United States. Tomato is a good source of several required nutrients, especially carotenoids and lycopene which contribute to the antioxidant activity of tomato and make tomatoes beneficial to health (Beecher 1998). In the United States, an average of 70 lbs of processed tomatoes is consumed per person (ERS 2012).

2.3.1 Health Benefits of Tomato and Tomato Fiber

There is increasing evidence showing that tomatoes and tomato products may decrease the risks of cardiovascular disease and many kinds of cancers, such as breast, gastric, prostate and ovarian cancer (Etminan and others 2004; Helzlsouer and others 1996; Baghurst and others 1991; Dorgan and others 1998; Liu and Russell 2008). Oxidative stress induced by reactive oxygen species has been considered as one of the main factors for the etiology of cancer and cardiovascular disease, and antioxidants are protective agents which can inactivate reactive oxygen species and then prevent oxidative damage of healthy cells (Agarwal and Rao 2000).Lycopene, a highly unsaturated hydrocarbon, is the red tomato natural pigment which has been thought to be important in preventing oxidation (Clinton1998; Rao and Agarwal 2000). Researchers also found several mechanisms, including gene function regulation (Nagasawa and others 1995; Kobayashi and others 1996), gap-junction communication (Zhang and others 1991; Zhang and others 1992), hormone and immune modulation (Levy and others 1995), carcinogen metabolism, metabolic pathways (Fuhrman and others 1997) and reducing reactive oxygen species (Rao and Agarwal 1998), which may explain why lycopene can reduce the risk of cancer.

Although lycopene has been shown to be beneficial for human health, its value in reducing cancer risk has become suspect due to recent studies. Kavanaugh and others (2007) reviewed and analyzed hundreds of research papers which correlated cancer and lycopene, and they did not find credible evidence to support an association between lycopene intake and reducing risk of several types of cancers. However, consumption of processed tomato products rather than fresh tomato was associated with reducing risk of prostate cancer (Giovannucci 2002).Moreover, Mossine and others (2008) found interactions between lycopene and carbohydrates, which may contribute to decreased cancer risks in animal studies. Tan and others (2010) suggested the necessity of developing a highly consistent tomato-based food product rich in antioxidants, and they also recommended consuming tomato products rather thanlycopene only.

Tomato powder can be produced from tomato waste of the tomato processingindustry. It is a cheap and a good source (>50% total weight) of dietary fiber (Borycka 2010).In rodent models of prostate cancer, tomato powder was found to be much more effective than lycopene alone in preventing prostate cancer (Zuniga and others 2013). Consuming tomato powder has been associated with risk reduction of several types of cancers, include leiomyoma (Sahin and others 2007) and prostate cancer (Zuniga and others 2013).Possible explanations revolve around the bioactive abilities of lycopene and β-carotene (Moreira and others 2005) and interactions between lycopene and other chemicals in tomato powder (Mossine and others 2008).

2.4 Soy Bean

Soy beans and soy products are rich in protein, fatty acids, phytoestrogens and fiber. Soybeans are a relatively recent agricultural crop in United States and have been produced commercially only since the 1920s. Soy fiber is a food product made from soybeans. Soybeans are first dehulled.Then, the oil is extracted and used for food and industrial applications. Soy flour, soy protein and soy fiber are made from soy bean flakes (Hasler and Finn 1998).

2.4.1 Health Benefits of soy bean and soy fiber

There is abundant evidence on the benefits of consuming soybeans. Consuming soybeans or soy products is associated with a lowered risk of heart disease and reduced risk of cancer (Hasler and Finn 1998).Anderson and others (1995) reported that soybeans decrease low-density lipoprotein cholesterol (LDL) and increase high density lipoprotein cholesterol (HDL). The soy isoflavones may increase the flexibility of blood vessels which decreases the risk of heart disease (Nestel and others 1997). An observation study also found that Asian women, whose diet is rich in soy, have a significantly lower rate of breast cancer than western women (Messina and Bames 1991).Due to its economical and nutritional properties, Chen (1994) described the soybean as an important tool in satisfying world hunger and improving world health.

Soybean polysaccharides derived from soybean hull or cotyledon has also received researchers' interest. Soy fiber is a soy product from cotyledon with 75%~80% total dietary fiber content, which is a mix of soluble and insoluble fiber (Nelson 2001). Soy fibers provide many of the health benefits of other soluble and insoluble fibers. It was claimed that soy fibers have been shown to reduce serum cholesterol, insulin and glucose responses, and reduce mineral absorption to a lesser extent than other fibers (Riaz 2001). There is considerable evidence to support this claim. Lo and colleagues (1986) found that a 25 g soy fiber daily intake provided a significant reduction in blood cholesterol. Moreover, the positive effect of soy fiber intake on glucose response has been shown in type IV hypertriglyceridemia patients and in diabetic animals (Lo and others1986; Madaz 1983).

2.5 Dietary Fiber Applications in Meat Products

Our modern lifestyle has forced many consumers to be dependent on fast and ready to eat foods. Many of these processed foods, including meat products, lack in dietary fiber but are rich in fat and salts. The increasing processed meat consumption also turns the good image of meat products, which are good sources of minerals, vitamins, and proteins, to a more negative one (Verbeke and others 2010). Thus, consumers demand changes and global competition is causing the meat product manufacturers to create new processing technologies and new ingredient systems (Jochen and others 2010). Epidemiological research has demonstrated a relationship between processed meat intake and high ricks of a range of chronic diseases include obesity, cardiovascular disease and cancers. However, processed meat products can be transformed into healthier versions by adding ingredients considered beneficial for health or by eliminating or reducing components that are considered harmful (Arun and Rituparna 2010). Dietary fiber is one of the components that can be incorporated in meat products not only from a health point of view but also to improve processing. Various types of fibers have been studied alone or in combination for the formulation of low fat meat products and meat emulsions. The effect of dietary fiber on the quality attributes of meat has been reviewed as follow.

The suitability of dietary fiber incorporation into meat products is increasing because of the numerous functional attributes of fibers, such as water and oil retention, color modification, decreasing cooking loss, texture modification and neutral flavor. In 2010, Viuda-Martos and others (2010) concluded that dietary fibers isolated from various plant sources, dehydrated fruits, vegetables and cereal fibers are being used in the food industry and have shown promising results. Rodriguez and others (2006) found that fruit and vegetable fibers have excellent oil binding capacity, which is of importance in emulsified products. Fleury and Lahaye (1991) stated that chemical structure, pH, ionic strength and particle size can affect water and oil binding ability of fibers. In turn, all of these properties will affect the use of different fibers as ingredients in meat products. Dietary fiber with high oil retention ability allows the use as stabilizers in emulsified meat products, while dietary fiber with high water holding capacity can be used to modify viscosity and texture of some kinds of foods. Various fibers like oat, sugar beet, soy, pea, psyllium and so on have been tried in some meat products, such as patties and sausages. Also, fiber is being used as an extender, binder and fat replacer in manufacturing various meat products. A list of different fibers utilized in meat products is presented in Table 1.

Table 1 Various fiber sources utilized in meat products

Type of meat products	Source of fiber	References
Sausages	Inulin	Garcia and others 2006
	Carboxyl methyl cellulose	Morin and others 2004
	Oat bran	Huges and others 1997; Hung-Chia and Carpenter 1997;
	Soy fiber	Confrades and others 2000; Paulo and others 2013
	Sugar beet fiber	Vural and others 2004; Javidipour and others 2005
	Tomato powder	Il-Suk and others 2010;
Patties	Wheat bran	Talukder and Sharma 2010; Besbes and others 2008; Saricoban and others 2009
	Oat bran	Talukder and Sharma 2010; Dawkins and others 1999; Serdaroglu 2006
	Pea fiber	Besbes and others 2008; Anderson and Berry 2000 Alakali and others 2010
	Peanut flour	
	Barley flour	Prinyawiwatkul and others 1997
	Hazel nut pellicle fiber	Manish and Sharma 2004
	Flax seed flour	Turhan and others 2005
	Common bean flour	Bilek and Turhan 2009 Dzudie and others 2002
Meat batters	Rice bran	Yun-Sang and others 2007
Chicken nuggets	Ragi millet flour	Naveena and others 2006
Meatball	Black eye bean flour	Serdaroglu and others 2005
	Chickpea flour	Serdaroglu and others 2005
	Lentil flour	Serdaroglu and others 2005
	Rusk	Serdaroglu and others 2005
	Oat flour	Modi and others 2009
	Carrageenan	Modi and others 2009
	Rye bran	Yilmaz 2004
	Orange fiber	Viuda-Martos and others 2010
Fish sausage	Inner pea fiber	Cardoso and others 2008
	Chicory root fiber	Cardoso and others 2008
Heat induced gel	Rice bran	Yun-Sang and others 2007
Broiler meat	Tomato fiber	Adeyemi and Ao (2012)
Comminuted meat	Tomato fiber	Modzelewska- Kapitula 2012

2.5.1 Effect of fiber addition on physical-chemical properties of meat products

One of the important proprieties of meat products is Water Holding Capacity (WHC). WHC is the ability of meat to hold inherent or added water during processing. A good WHC will provide a desirable characteristic to the end product. Dietary fiber is a suitable additive for meat products to increase WHC (Confrades and others 2000). Talukder and Sharma (2010) used wheat bran (high total fiber content but low soluble fiber content) and oat bran (low total fiber content but high soluble fiber content) in chicken meat patties. They found both brans were very effective in increasing WHC at the 5%, 10% and 15% levels and meat patties with 15% oat bran showed the highest WHC. Presence of high amount of soluble dietary fiber might be the reason for higher WHC (Dawkins and others 1999). Hung-Chia and Carpenter (1997) used oat bran to reduce fat in frankfurters. With an increased oat bran level, more water was retained in frankfurters. Hughes and others (1997) investigated the effects of fat level (5, 12 and 30%), carrageenan and oat fiber on the hydration/binding properties of frankfurters. They found decreasing the fat content from 30% to 5% significantly increased cooking losses and decreased water holding capacity and emulsion stability. However, the addition of 2% oat fiber reduced the total expressible fluid in the 5 and 12% targeted fat products. They concluded that addition of carrageenan or oat fiber reduced cooking loss and increased both water holding capacity and emulsion stability.

Utilizing sugar beet fiber was reported to significantly increase WHC and total dietary fiber content of frankfurters and Turkish-type salami (Vural and others 2004;

Javidipour and others 2005). Yun-Sang and others (2007) found the incorporation of rice bran at different levels in meat batters could increase emulsion pH, emulsion stability and cooking yield. The addition of dietary fibers from pea and wheat improved the WHC, including cooking yield, and decreased shrinkage in beef burgers (Besbes and others 2008). Pinero and others evaluated the effect of adding oat fiber, a source of beta-glucan, in 10% fat beef patties as compared to 20% fat patties and they observed significant improvement in cooking yield, fat retention and moisture content in fiber added patties as compared to the control.

Raw and dehydrated lemon albedo at 5 different concentrations (0, 2.5, 5, 7.5 and 10%) was used by Saricoban and others (2008) to evaluate their effect on functional properties of emulsions. They found emulsion viscosity values were positively correlated with an increase in albedo concentration. In addition, the emulsion capacity was increased the most in 5% albedo added emulsions.

The use of Bambara Groundnut Seed Flour(BGSF) significantly increased the pH of cooked patties, and it significantly reduced the shrinkage of cooked patties from 9.13% to 6.76%, while percentage cooking yield, moisture retention and fat retention increased significantly with increasing BGSF levels (Alakali and others 2010). An increase in cooking yield in chicken patties and chicken nuggets was reported with addition of peanut flour and ragi millet flour (Prinyawiwatkul and others 1997; Naveena and others 2006).

Low fat ground beef patties containing pea fiber had improved cooking yield and greater tenderness (Anderson and Berry 2000). Prabhakara and Srinivasa (2000) used

20% bengal gram flour and 20% black gram flour in chicken loaves and found that addition of these two fiber sources resulted in significant reduction of cooking losses and extract release volume. Manish and Sharma (2004) observed that cooking yield, moisture retention and dimensional parameters of low fat ground pork patties increased with increasing levels (4, 7 and 10%) of barley flour as the fiber source. Turhan and others (2005) concluded that addition of hazel nut pellicle fiber increased the cooking yield and thickness of beef burgers. Similar results had been observed by Serdaroglu and others (2005) who used black eye bean flour, chickpea flour, lentil flour and rusk in meatballs. However, some opposing results have also been found. Morin and others (2004) found an increase in cooking loss after addition of carboxymethyl cellulose in breakfast sausages and Modi and others (2009) reported that inclusion of oat flour and carrageenan resulted in a significant increase in cooking loss of fried meat kofta.

2.5.2 Effect of fiber addition on composition of meat products

Overall meat product composition can be changed by addition of dietary fiber. However, different observations were made based on the composition of the dietary fibers and meat products.

Hung-Chia and Carpenter (1997) and Dawkins and others (1999) found moisture, fat and protein content were decreased and carbohydrate content was increased with increasing levels of oat bran in frankfurters and chevon patties. However, Mansour and Khalil (1997) reported an increase in moisture, protein, ash and carbohydrate content in cooked and uncooked beef burgers with hydrated wheat fiber. Huang and others (2005) found that use of rice bran in emulsified pork meatball decreased protein and fat contents and increased carbohydrate content significantly, while Yilmaz (2004) reported a decrease in moisture and fat content but an increase in protein and ash content with an increasing amount of rye bran addition in low fat meatballs.

Serdaroglu (2006) observed that addition of oat flour resulted in a decrease in moisture content in raw patties but an increase in cooked patties. However, the addition of oat flour did not change the protein, fat and ash content of raw or cooked patties. Bilek and Turhan (2009) added flax seed flour to beef patties and observed that fat and ash content increased with an increasing level of flax seed flour, while moisture and protein content decreased. Low fat soy flour or mung bean powder at a level of 10% reduced the moisture and fat content, whereas the fiber and protein content increased.

Oat flour and carrageenan significantly lowered fat content and increased moisture, protein, ash and carbohydrate percentage in mutton kofta (Modi and others 2009). However, Dzudie and others (2002) and Naveena and others (2006) reported lower protein content in beef patties and chicken patties which were formulated with different levels of common bean flour and ragi millet flour.

2.5.3 Effects of fiber addition on textural properties of meat products

Texture is one of the major aspects for food acceptability. It can be determined by a Texture-Analyzer and described as hardness, cohesiveness, springiness, chewiness and shear force. There are considerable data to show the effects of dietary fiber on the texture of meat gel systems.

Garcia and others (2006) reported an increase in hardness value of meatballs made with inulin. Similarly, Viuda-Martos and others (2010) found the addition of orange dietary fiber to meatballs also led to an increase in hardness and a decrease in springiness and chewiness as compared to control products. Kaack and others (2006) observed that addition of dry potato pulp, which had high contents of cellulose and lignin, resulted in an increase of hardness and gumminess with an overall negative effect on texture, while potato pulp with soluble non starch polysaccharides resulted in better textural properties.

Han-Sul and others (2007) observed a gradual decrease of hardness, gumminess and chewiness with the increased addition of hydrated oatmeal. However, springiness did not differ significantly between samples. A low fat fish sausage containing dietary fiber from inner pea and chicory root was developed by Cardoso and others (2008). The addition of inner pea fiber increased gel strength and hardness, and high chicory root fiber sausages were less cohesive and chewable than control group sausages but also had higher hardness. Frankfurters and bologna had higher hardness, gumminess and chewiness as compared to controls due to addition of soy fiber and other types of fiber (Confrades and others 2000; Colmenero and others 2005).

In a three-factor Box-Behnken test, Saricoban and others (2009) found that addition of wheat bran increased hardness and gumminess but decreased springiness, resilience and cohesiveness of the cooked beef patties. Yun-Sang and others (2011) studied the effects of rice bran fiber on the textural properties of heat induced gels and found that hardness, springiness, cohesiveness, gumminess and chewiness were lower in all samples with added rice bran fiber when compared to controls.

2.5.4 Effects tomato fiber and soy fiber on meat products

The primary quality parameters of meat and meat products for consumers are color, appearance and texture. The color is the first major impression on consumers during the selection of food products (Eyiler and Oztan 2011). Meat and meat products tend to discolor during storage. Moreover, low fat meat products suffer reduced meat gel strength, low WHC, low moisture content and so on.

In recent years, the possibility of using tomato-derived products (such as tomato powder and tomato fiber) in meat has been tested by a few researchers because of their high dietary fiber content and lycopene content. Il-Suk and others (2010) used different levels of tomato powder in low fat pork sausages. They found a significant increase in WHC, lightness and hardness values and a significant decrease in redness, yellowness, TBA values, cohesiveness and springiness values. The score of overall acceptability for the tomato powder groups were significantly higher than the acceptability of the control. Similarly, Adeyemi and Ao (2012) compared the antioxidant potency of tomato powder with that of Butylated Hydroxyl Anisole (BHA) in broiler meat and found 0.5% and 1.5% tomato powder exhibited higher antioxidant potency than BHA. However, Modzelewska-Kapitula (2012) observed a contradictory result in her study. She found the addition of tomato powder had no effect on lightness and did not retard lipid oxidation in meatloaves but actually promoted it in the products containing 1.0% tomato powder.

Soy fiber is a fairly new kind of fiber which was tested for use in meat products. Confrades and others (2000) used soy fiber in Bologna sausage and found it was beneficial in reducing the effects of fat reduction on texture and cooking yield. Paulo and others (2013) used soy fiber in meat to produce a healthy low fat fermented sausage. They found no effects on the manufacturing process, and volatile compounds from lipid oxidation were reduced in the modified fermented sausage.

Although some studies on tomato powder and soy fiber have been done as mentioned above, only a few results have been reported on the effects of fat content and tomato powder or soy fiber on meat product properties.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials and Methods

3.1.1 Sample preparation

Hot dog samples were prepared using a MU beef hot dog recipe (Mizzou Meat Market, Columbia). Fresh ground beef was purchased from a Hy-Vee grocery store in Columbia, MO and frozen at -18 °C until use. Two kinds of ground beef were used in this research, namely a Cargill brand 9% fat ground beef and a Cargill 27% fat ground beef. All ground beef was held at 4 °C for 48 hours until completely thawed. Seasoning was obtained from Mizzou Meat Market, including salt, dextrose, white pepper, curing salt, nutmeg, and coriander. Tomato fiber (Marshall Ingredient CO., New York City) and soy fiber (Solae LLC, Saint Louis) were added to hot dogs with various fat contents and were compared with all-beef hot dogs without added fiber according to the following table. Proximate compositions of tomato powder and soy fiber can be found in Table 3.1.1.

Table 3.1.1. Proximate composition of tomato powder and soy fiber

	Tomato powder	Soy fiber
Protein %	21.20	16.00
Fat %	11.66	< 1.00
Moisture %	< 10.00	< 9.00
Dietary fiber %	52.10	75.00
Ash %	4.32	4.00
Vitamin C	0.440 mg/ 100 g	1 mg/ 100 g
Lycopene	6.9 µg/ g	Non

Table 3.1.2 Composition of Hot Dogs

	Fat content	Lean meat content	Fiber Source	Seasoning	Ice
Tomato fiber 20-3	20%	62.5%	3%	2.5%	12%
Tomato fiber 20-5	20%	62.5%	5%	2.5%	10%
Tomato fiber 15-3	15%	62.5%	3%	2.5%	17%
Tomato fiber 15-5	15%	62.5%	5%	2.5%	15%
Tomato fiber 10-3	10%	62.5%	3%	2.5%	22%
Tomato fiber 10-5	10%	62.5%	5%	2.5%	20%
Soy fiber 20-3	20%	62.5%	3%	2.5%	12%
Soy fiber 20-5	20%	62.5%	5%	2.5%	10%
Soy fiber 15-3	15%	62.5%	3%	2.5%	17%
Soy fiber 15-5	15%	62.5%	5%	2.5%	15%
Soy fiber 10-3	10%	62.5%	3%	2.5%	22%
Soy fiber 10-5	10%	62.5%	5%	2.5%	20%
Control 10	10%	62.5%	0%	2.5%	25%
Control 15	15%	62.5%	0%	2.5%	20%
Control 20	20%	62.5%	0%	2.5%	15%

Ground beef (250 g) was chopped with ice, salt, dextrose, curing salt and fiber source until well-blended (about 3 min) by a meat blender (Prep 9, Cuisinart CO., East Windsor, NJ). Then, the remaining seasonings were added and the blender resumed chopping until a smooth texture was obtained. After that, the meat batter was stuffed into cellulose casings (15 mm) using a jerky cannon (Lem Product Direct, West Chester, OH). At the end, the stuffed hot dogs were linked by hand, loaded into a convection oven (Model 27-2DOX, Keating of Chicago, Inc., Chicago, IL) and heated at 200 °F until an internal temperature of 161 °F was obtained.

Cooked hot dogs were allowed to cool down to room temperature. Preliminary research showed that vacuum packaging inhibited lipid oxidation and no significant changes were found during storage. Thus, around 100 g samples of each treatment were cut into 5 ± 1 g small pieces and packaged by treatments with zip lock bags and stored at 4 ℃ in a refrigerator to improve lipid oxidation velocity. Remaining samples were vacuum packaged (GameSaver, SunBeam Products, Inc., Columbia, MO) and stored at 4 ℃ in a refrigerator until use. All treatments (Table 3.1.2), about 300 g each, were prepared in triplicate from separate meat purchased at three different time periods.

3.2 Analysis Methods

3.2.1 Protein Content (PC)

Protein Content determination was based on Microchemical Determination of Nitrogen-Micro Kjeldahl Method (AOAC 1997).

Hot dog samples (1 g) were weighed and transferred to a 100 mL digestion flask containing 5 mL of 0.01 M HCl solution. Then, 1.9 ± 0.1 g K_2SO_4, 40 ± 10 mg $CuSO_4$-$5H_2O$, and 5 mL 98% H_2SO_4 were added to the same digestion flask. Several boiling chips, which passed a No. 10 sieve, were added. The mixture was kept boiling in the digestion flask on a digestion rack heater until it became clear without any color (3 ~ 4 Hours). The mixture was cooled down to room temperature.

A minimum volume of distilled water was added to dissolve solids. The digested mixture was transferred to a 25 mL volume flask and the flask and boiling chips were rinsed 5 or 6 times with distilled water and the mixture was diluted to 25 mL with distilled water. Then 10 mL of the diluted digest was transferred into a distillation apparatus (Labcon North America, Petaluma, CA). An Erlenmeyer flask (125 mL) containing 5 mL H_3BO_3-Methyl Red-Methylene Blue indicator solution was placed under the condenser with the tip extending below the surface of the solution. Then 10 mL 50% NaOH solution was added to the still and ca 20 mL distillate was collected (indicator color changed from red to blue). The distillate was titrated with 0.05 M HCI to end point (color change from blue to light pink). The volume of used HCI solution was recorded during titration. Blank determination was made every time. The test was duplicated for each treatment.

$$\text{Percent N} = \frac{(\text{mL HCI} - \text{ mL Blank}) \,*\, 0.05 \,*\, 14.007 \,*\, 100 \,*\, (\frac{25}{10})}{\text{mg sample}}$$

Percent Protein= Percent N * 6.25

3.2.2 Fat content and Moisture Content

Fat content and moisture content were determined by nuclear magnetic resonance (NMR) analysis and microwave drying method. Both of them were performed using a SMART system (microwave drying system, CEM Corp.) and SMART Trac system (NMR system, CEM Corp.).

Hot dog samples (3.5 ~ 4.5 g) were smashed and spread evenly on the center of a square pad and covered by another square pad on it. The SMART system was switched to the “Hot Dog working model” and started when the spread sample was placed in it. The moisture content was recorded after microwave drying (around 3 min). Then, the dried sample and the 2 square pads were rolled in a Trac Film into a cylinder. The cylinder was placed into a plastic column. The column with the sample was plugged into the SMART Trac system and was run by the system until the analysis was complete (around 1 min). Every treatment was measured 2 times for each of the three replicates.

3.2.3 Dietary Fiber Content (DFC)

Vacuum packaged hot dogs were used for the dietary fiber content analysis, which was based on AOAC method 985.29 (AOAC 1997).

Hot dog samples were dehydrated using a vacuum oven (Model 3640, National Appliance Company, Novato, CA) at 70 ℃ overnight. The weights before and after dehydration were recorded. Dehydrated samples were defatted with petroleum ether using a Soxhlet extraction glassware system. The weight after defatting was recorded. Duplicate analyses were done for each replicate and treatment.

Hot dog samples (1 ± 0.0001 g) were mixed with 50 mL of phosphate buffer pH 6.0 in a 400 mL high form beaker. 100 μl heat stable alpha-amylase solution was pipette into the high form beaker and mixed with a magnetic stirrer. The stirred beaker was covered with aluminum foil and placed in a 100 ℃ water bath (National Appliance Company, Portland). A sample temperature of 95 ℃-100 ℃ was attained in about 15 minutes and was maintained for 15 minutes.

The beaker was removed from the boiling water bath and cooled down to room temperature. The pH of the solution in the beaker was adjusted to 7.5 ± 0.2 by adding 10 mL 0.275 N NaOH solution. After that, the beaker was put into a 60 ℃ shaking bath (Labline, San Diego, CA) and 100 μL of protease solution (50 mg in 1 mL phosphate buffer) was added into the beaker. After 30 minutes, the beaker was taken out of the shaking bath and cooled down to room temperature. The pH was adjusted to 4.0-4.6 by 10 mL 0.325 N HCl.

The third enzyme, 300 μL of amylo-glucosidase solution, was added into the beaker and incubated for 30 minutes at 60 ℃ in the shaking bath and covered with aluminum foil. After 30 minutes, 280 mL of 60 ℃ 95% ethanol was added into the beaker and allowed to precipitate for 60 minutes at room temperature.

About 0.5 g of acid-washed Celite was added to a clean glass crucible and the crucible was heated to 130 ℃ in an oven to constant weight (about 1 hour) to nearest 0.1 mg. The filtration equipment was assembled with the weighed crucible with Celite. The enzymatic digest was transferred to the crucible through a funnel. The liquid filtrate was collected through the outlet tube into the collecting vessel.

The residue in the crucible was washed with three 20 mL volumes of 78% ethanol, two 10 mL volumes of 95% ethanol and two 10 mL volumes of acetone. The filtration and washing procedure was finished within half an hour.

The crucible with the residue and the Celite was dried in a 70 ℃ vacuum oven overnight. After allowing it to cool down to room temperature, it was weighed to the nearest 0.1 mg. The weight of residue was obtained by subtracting the weight of the crucible and the Celite from final weight.

One of the duplicate residues was analyzed by the micro Kjeldahl method as shown in 3.2.1 for indigestible protein content. The second duplicate residue was incinerated in a muffle oven at 525 ℃ for 5 hours. The crucible was allowed to cool down in a dessicator and weighed to the nearest 0.1 mg. The ash content was obtained by subtracting the weight of the crucible and diatomaceous Celite.

Blanks were run through entire procedure to control possible contributions from reagents to final results.

$$\% \text{ Total Dietary Fiber} = \frac{(\text{mg Residue } \times (100 - \text{ Protein Content} - \text{ Ash Content}) - \text{ mg Blank})}{\text{mg Sample}}$$

3.2.4 Cooking Loss (CL)

Hot dog samples were weighed before and after heat processing. The cooking loss was determined from their weights and expressed as a percentage of the weight loss to the initial weight.

3.2.5 Water Holding Capacity (WHC)

Water Holding Capacity (WHC) was determined as described by Hughes and others (1997). Two core (5 ± 1 g) representatives of each treatment were cut and placed in glass jars, closed and heated for 10 min in a 90 °C water bath. After heating, samples were cooled to room temperature, wrapped in cotton cheesecloth and centrifuged in 50 mL centrifuge tubes for 10 min at 9000 *x* g (Model 5840R, Eppendorf, Hauppauge, NY) at 4 °C. The cheesecloth was removed and sample weights were recorded. WHC was calculated as the percentage of retained water in relation to total water content.

3.2.6 TBARs Value Test

The Thiobarbituric Acid (TBA) value was determined according to Malonaldehyde (MDA) concentration. The first sample was taken the day after the hot dog samples were prepared and then in 2-day intervals. Thus, in total six tests were done for every treatment and each replicate.

Hot dog samples (5 ± 0.5 g) were added into a glass jar with 2.5 mL antioxidant solution and 50 mL ice-cold trichloroacetic acid (TCA) agent and mixed for 2 minutes in a homogenizer (manufacturer and city). Then 50 mL ice-cold distilled water was added to the same glass jar and mixed for another minute. A glass funnel was placed over the top of a 100 mL volumetric flask and lined with a 1:1 TCA reagent:water pre-wetted Whatman No.1 filter paper. The content in the glass jar was poured into the glass funnel and filtered. A 1:1 TCA reagent:water solution was used to fill the 100 mL volumetric flask to the mark.

An aliquot (5 mL) was pipette from the 100 mL volumetric flask into a 50 mL centrifuge tube and 5 mL of 0.02 M TBA was added into the centrifuge tube. The tubes were capped and vortexed before being put into a boiling water bath. The vortexed tubes were heated for 35 min in the boiling water bath to allow for the TBA reaction to occur and then cooled down in ice water for 5 min. A blank of only 5 mL 1:1 TCA reagent:water and 5 ml 0.02 M TBA was prepared. A spectrophotometer (Genesys 20, Thermo Scientific, Brookfield, WI) was warmed up and set to a wavelength of 532 nm. The spectrophotometer was zeroed using the blank and then the absorbance of the test sample was measured.

The TBA value was calculated using a standard cure and the malonaldehyde recovery rate. For determining the standard curve, a series of aliquots (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5 mL) of 0.2 mM 1,1,3,3,-tetramethoxypropane (TMP) were transferred to separate 100 mL volumetric flasks. Volumetric flasks were filled to the mark with 1:1 TCA reagent:water. An aliquot (5 mL) from each 100 mL volumetric flask and 5.0 mL 0.02 M TBA were pipette into separate 50 mL centrifuge tubes. The tubes were capped and vortexed before being placed into a boiling water bath. The vortexed tubes were heated for 35 min in the boiling water bath and then cooled down in ice water for 5 min. Absorbance of each standard was measured at 532 nm and plotted against moles of TMP in the reaction. The slope of this curve was determined.

Malonaldehyde recovery was determined by adding 0, 1.5, 3.0 and 4.5 mL of 0.02 mM TMP into four separate glass jars with hot dog samples replacing the same volume of ice-cold distilled water. Then 1.5, 3.0 and 4.5 mL of 0.2 mM TMP were added into three 100 mL volumetric flasks, and the flasks were filled to the mark with 1:1 TCA reagent:water. Four TMP spiked samples and the three TMP dilutions were used to perform the TBA reaction and measure the absorbance as explained above. The 0 mL 0.02mM TMP added sample was used to correct for endogenous malonaldehyde content and then compared to the spiked values in the TMP dilutions.

$$\%\ \mathrm{Recovery} = 100 \times \frac{\mathrm{A_{sp}}}{\mathrm{A_{tmp}}}$$

A_{sp} is the absorbance of the spiked food sample (corrected for endogenous malonaldehyde)

A_{tmp} is the absorbance of the corresponding TMP dilution.

$$\mathrm{K} = \frac{\mathrm{S \times MA\ mol.Wt \times DF \times 10^{6}} \times \left(\frac{100}{\%\mathrm{Recovery}}\right)}{\mathrm{Slope\ of\ Standard\ Curve \times m}}$$

S= 1 X 10^{-9} mol/ 5 ml

MA mol. Wt= 72.03 g/ mol

DF=20

m= sample mass

Slope of Standard Curve= 0.163

$$TBA\ value = K \times A_{532}$$

3.2.7 Color Analysis (CA)

Color was determined using a colorimeter (CR-410, Konica Minolta, Mahwah, NJ) with an 8 mm diameter for the measuring area and a 50 mm diameter illumination area, which was calibrated with a white standard plate (CIE L*= 97.83, a*= -0.43, b*=1.98). Color values (CIE L*, a* and b*) were measured on the sample surface. Every treatment was measured 2 times for each of the three replicates.

3.2.8 Texture Analysis (TA)

Texture measurement in the form of texture profile analysis (TPA) was performed at room temperature with a Texture Analyzer (TA-HDi Texture Profile Analyzer, Texture Tech Corp., NY). Cylindrical slices (10 mm length) of hot dogs were taken and subjected to a two-cycle compression test using the 50 Kg load cell. The samples were compressed to 40% of their original height with a cylindrical probe of 35mm in diameter and a cross-head speed of 1.5 mm/s. Texture profile parameters were determined following descriptions by Bourne (1978). It included hardness, springiness, adhesiveness, cohesiveness and chewiness. Every treatment was measured 4 times for each replicate.

3.2.9 Data Analysis

Analysis of variance (ANOVA) was conducted to determine the significance of each independent variable using SPSS (SPSS, version 19, IBM Company, USA). The factorial consisted of 3 levels of fat (10, 15 and 20%) and 5 levels of dietary fiber addition (no fiber control, 3% soy fiber, 5% soy fiber, 3% tomato powder and 5% tomato powder) and days (only for TBARs). A general univariate linear model was used for all data to determine the significance of each independent factor, except for TBARs value, for which a mixed linear model was used. All significantly different means ($P<0.05$) were separated using least square means.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Proximate chemical composition

The proximate chemical composition of uncooked hot dogs is presented in Table 4.1.1 and for cooked hot dogs in Table 4.1.2. These tables clearly illustrate the effect of cooking on the composition of hot dogs. Total content of fat and moisture was decreased by cooking which in turn increased the percentage of protein and dietary fiber in the cooked samples. Samples which were initially higher in fat also displayed the higher level of fat after cooking. All treatments had the same lean meat contents. However, Table 4.1.1 shows that samples which contained 5% tomato powder had the highest percentage of protein content at each fat level. The reason is that the tomato powder has a high protein content (20%), and the tomato powder addition increased the protein content of final products. Control groups had highest moisture content at each fat level before cooking due to the higher amount of ice addition. However, after cooking, moisture content of 3% soy fiber addition treatments became the highest, which might be explained by the low cooking loss when soy fiber is added. Thus, soy fiber addition groups have lower protein content values and higher moisture content than other treatments.

Table 4.1. 1 Average values of percentage of fat, protein, dietary fiber and moisture in each uncooked treatments

Fat [%]	Sources of dietary fiber	Level of addition [%]	Fat [%]	Protein [%]	Dietary Fiber [%]	Moisture [%]
10	C	0	10.01 ±0.77 a	12.34 ±0.43 c	Not Detected	69.96 ±1.70 a
	TP	3	10.44 ±0.44 a	12.97 ±0.87 b	1.81 ±0.29 d	67.67 ±1.56 b
		5	10.76 ±1.01 a	13.25 ±1.04 a	2.85 ±0.46 b	66.81 ±2.20 b
	SF	3	9.66 ±0.62 b	12.61 ±0.35 bc	2.30 ±0.44 c	66.92 ±1.81 b
		5	9.87 ±0.81 ab	12.75 ±0.62 b	3.63 ±0.30 a	68.29 ±1.07 b
15	C	0	14.88 ±1.26 a	12.25 ±0.21 c	Not Detected	67.28 ±2.15 a
	TP	3	14.57 ±1.04 a	12.65 ±0.58 b	1.90 ±0.37 c	65.83 ±0.87 b
		5	14.83 ±1.57 a	13.45 ±0.52 a	2.69 ±0.57 b	64.47 ±1.22 b
	SF	3	14.50 ±1.44 a	12.58 ±0.31 bc	2.45 ±0.38 b	65.39 ±1.78 b
		5	14.45 ±1.59 a	12.83 ±0.47 b	3.66 ±0.33 a	63.64 ±2.11 c
20	C	0	20.79 ±1.23 a	12.19 ±0.40 c	Not Detected	62.99 ± 1.68 a
	TP	3	21.04 ±0.93 a	12.78 ±0.53 b	1.77 ±0.40 d	60.85 ±1.15 b
		5	20.73 ±1.56 a	13.51 ±1.23 a	2.93 ±0.55 b	59.63 ±1,39 c
	SF	3	20.11 ±0.80 a	12.74 ±0.37 b	2.47 ±0.23 c	61.01 ±1.88 b
		5	20.25 ±1.77 a	12.87 ±0.61 b	3.71 ±0.45 a	59.30 ±1.79 c

C= Control; TP= Tomato Powder; SF= Soy Fiber; Values in the same block (% Fat and properties) that do not share same letter in the same column are significantly different ($P < 0.05$).

Table 4.1. 2 Average values of percentage of fat, protein, dietary fiber and moisture in each cooked treatments

Fat [%]	Sources of dietary fiber	Level of addition [%]	Fat [%]	Protein [%]	Dietary Fiber [%]	Moisture [%]
10	C	0	13.07 ±0.56 a	17.34 ±0.63 c	NA	60.46 ±0.89 a
	TP	3	13.83 ±1.52 a	18.01 ±1.07 b	2.48 ±0.69 b	58.62 ±1.33 b
		5	13.84 ±1.40 a	19.92 ±1.24 a	4.07 ±0.56 a	57.05 ±1.32 b
	SF	3	11.82 ±1.89 b	16.37 ±0.55 d	2.99 ±0.44 b	60.33 ±1.45 a
		5	12.13 ±1.50 b	15.55 ±0.82 d	4.43 ±0.60 a	59.79 ±1.08 a
15	C	0	16.49 ±0.88 a	20.08 ±0.61 a	NA	57.35 ±1.95 b
	TP	3	16.27 ±0.30 a	19.17 ±0.88 b	2.88 ±0.37 d	56.69 ±0.96 c
		5	15.02 ±1.08 bc	20.69 ±0.82 a	4.14 ±0.57 b	55.91 ±1.13 c
	SF	3	15.63 ±1.42 b	16.77 ±1.11 c	3.27 ±0.38 c	61.57 ±1.54 a
		5	14.73 ±0.91 c	16.66 ±0.97 c	4.75 ±0.93 a	57.42 ±1.01 b
20	C	0	21.04 ±1.85 a	17.93 ±1.40 b	NA	54.40 ±2.05 b
	TP	3	18.37 ±1.55 b	18.52 ±0.93 b	2.90 ±0.60 c	53.36 ±1.33 c
		5	16.42 ±1.58 c	20.47 ±1.23 a	4.44 ±0.75 a	54.63 ±1.56 b
	SF	3	17.41 ±1.99 c	16.76 ±1.37 c	3.25±0.33 b	55.66 ±1.35 a
		5	18.67 ±1.93 b	16.93 ±0.81 c	4.88 ±0.55 a	54.57 ±1.89 b

C= Control; TP= Tomato Powder; SF= Soy Fiber; Values in the same block (% Fat and properties) that do not share same letter in the same column are significantly different ($P < 0.05$)

4.2 Cooking Loss

Cooking loss is one of the quality parameters of meat products that affects consumers' acceptance. After cooking by convection oven and cooling down to room temperature, percent cooking loss of three replications of cooked beef hot dogs were determined by using weight differences between raw and cooked beef hot dogs. This type of cooking mimics the combination of the cooking during hot dog manufacture and the home preparation on a grill. The effects of factors on cooking loss and average values of percent cooking loss are presented in Table 4.1.1 and Table 4.2.2, respectively.

Analysis of Variance showed that cooking loss was greatly affected by fat content and dietary fiber addition ($P<0.05$), but because cooking loss was also influenced by the interaction between fat content and dietary fiber addition ($P<0.05$), no generalized statement can be made for the two main effects.

Table 4.2. 1 Effects of fat content, dietary fiber addition and interaction between fat content and dietary fiber addition on Cooking Loss

	Factors		
	Fat	Dietary Fiber	Interaction
Sig	0.001	0.001	0.001

Table 4.2. 2 Average values of cooking loss for each beef hot dog treatment with different combination of fat content and dietary fiber addition.

Fat%	Fiber	Fiber Content		
		0%	3%	5%
10%	Tomato Powder	$27.60 \pm 1.60^{B}_{a}$	$28.50 \pm 3.40^{C}_{a}$	$29.37 \pm 2.12^{B}_{a}$
	Soy Fiber	$27.60 \pm 1.60^{B}_{a}$	$23.52 \pm 2.51^{D}_{b}$	$18.16 \pm 1.74^{D}_{c}$
15%	Tomato Powder	$31.34 \pm 2.84^{A}_{a}$	$34.30 \pm 1.84^{B}_{a}$	$34.99 \pm 1.32^{A}_{a}$
	Soy Fiber	$31.34 \pm 2.84^{A}_{a}$	$25.22 \pm 1.10^{D}_{b}$	$23.50 \pm 0.46^{C}_{b}$
20%	Tomato Powder	$31.89 \pm 2.02^{A}_{b}$	$38.54 \pm 2.33^{A}_{a}$	$33.94 \pm 2.47^{A}_{b}$
	Soy Fiber	$31.89 \pm 2.02^{A}_{a}$	$23.66 \pm 0.60^{D}_{b}$	$23.71 \pm 1.06^{C}_{b}$

Value in the same table that do not share same superscript (in the same column) or same subscript (in the same row) are significantly different ($P<0.05$)

From Table 4.2.2, cooking loss of hot dogs in this research (around 30%) was much higher than that (around 8%) seen during industrial hot dog manufacture where a smokehouse is used for cooking. The cooking environment of convection oven is much drier than that of a smokehouse.

It can be seen that increasing the fat content from 10 to 15% resulted in an increase in cooking loss for all treatments ($P < 0.05$), except for the 3% soy fiber ($P > 0.05$), but even in that case a tendency for an increased cooking loss can be discerned (23.52% for 10% fat and 25.22% for 15% fat). This result is the same as reported by Jeong and others (2004), which was that increasing fat content could increase cooking loss. However, when the fat content was increased from 15 to 20%, no additional increase in cooking loss can be seen, except for the 3% tomato fiber. These results clearly indicate an interaction between fiber and fat content. The interaction of fat content and dietary fiber addition was mainly due to the increase of fat from 15% to 20%. In the 20% fat treatments, 3% tomato powder significantly increased cooking loss ($P < 0.05$), while 3% soy fiber significantly decreased cooking loss ($P < 0.05$).

It can be seen that tomato powder addition did not affect cooking loss ($P < 0.05$), whereas soy fiber decreased cooking loss at all fat levels ($P > 0.05$). However, while for the 10% fat level, an increase of soy fiber from 3 to 5% further decreased cooking loss ($P < 0.05$), no such additional effect was seen for the 15% or 20% fat content. General results for soy fiber and tomato powder stayed in line with those by other researchers, who found a decrease in cooking loss when soy fiber was added (Garcia and others; Confrades and others 1997) and no significant difference was found when tomato powder was added in comminuted meat products (Modzelewska- Kapitula 2012).

4.3 Water Holding Capacity (WHC)

WHC is highly correlated with fat content and dietary fiber addition in hot dogs. The effects of these factors on WHC and average values of WHC are presented in Table 4.3.1 and Table 4.3.2, respectively. Analysis of variance (ANOVA) showed that dietary fiber addition and fat content ($P < 0.05$) both affected WHC.

Table 4.3. 1 Effects of fat content, dietary fiber addition and interaction between fat and dietary fiber on

	Factors		
	Fat	Dietary Fiber	Interaction
Sig	0.001	0.001	0.482

Table 4.3. 2 Water Holding Capacity (WHC)

Fat%	Fiber	Fiber Content		
		0%	3%	5%
10%	Tomato Powder	$70.68\pm 2.02^{B}_{a}$	$67.45\pm 1.26^{C}_{b}$	$68.50\pm 1.88^{C}_{b}$
	Soy Fiber	$70.68\pm 2.02^{B}_{c}$	$72.39\pm 2.43^{B}_{b}$	$77.82\pm 1.01^{B}_{a}$
15%	Tomato Powder	$80.63\pm 3.88^{A}_{a}$	$75.97\pm 1.54^{B}_{b}$	$74.24\pm 1.50^{B}_{b}$
	Soy Fiber	$80.63\pm 3.88^{A}_{c}$	$83.16\pm 1.78^{A}_{b}$	$84.21\pm 1.80^{A}_{a}$
20%	Tomato Powder	$80.70\pm 1.55^{A}_{a}$	$74.33\pm 1.77^{B}_{b}$	$74.58\pm 1.57^{B}_{b}$
	Soy Fiber	$80.70\pm 1.55^{A}_{b}$	$82.49\pm 1.75^{A}_{a}$	$82.81\pm 1.10^{A}_{a}$

Values in the same table that do not share same superscript (in the same column) or same subscript (in the same row) are significantly different ($P<0.05$)

Increasing the fat content from 10 to 15% resulted in an increase in WHC for all treatments ($P < 0.05$). This has been reported for various types of meat emulsions, such as frankfurters (Hughes and others 1997), bologna (Claus and others 1990) and breakfast sausages (Mittal and Barbut 1993). However, when the fat content was increased from 15 to 20%, no additional increase in WHC can be seen for any of the treatments ($P > 0.05$).

However, tomato powder addition decreased the WHC ($P < 0.05$) but the percentage of tomato powder did not affect the WHC at any of the fat levels ($P > 0.05$). In this study, tomato powder, which had been added as a source of fiber showed results opposite to those of other studies, which reported a positive relationship between dietary fiber addition and WHC (Talukder and Sharma 2010; Hung-Chia and Carpenter 1997; Hughes and others 1997). However, not all cases exhibited such relationship. Modzelewska-Kapitula (2012) reported that WHC value of comminuted meat with tomato powder was lower than that of the control group. There are two possible reasons that can explain these results. One possible reason is the particle size of tomato powder. The tomato powder (< 1 mm) used in that study was similar to the one used in our study, which is much larger than the sizes (0.025-0.05 mm) used in other studies (Calvo and others 2007; II-Suk and others 2010). The results suggest that different particle size of tomato powder possess different hydration properties. A second reason might be the source of tomato powder. Calvo and others (2007) used tomato skins rather than a mixture of tomato pulp, skins and seeds. The tomato powder from the mixture had a much higher fat (11.66%) and protein (21.20%) content than the tomato skin powder.

Looking at the effect of soy fiber addition, it can be seen that increasing soy fiber addition from 3 to 5% resulted in an increase in WHC, except for the 20% fat content, but even in that case a slight but not significant increase in WHC can be seen.

4.4 TBARs

The TBARs value is commonly used as an indicator of lipid oxidation in meats and meat products. TBARs values in this study depended on dietary fiber addition (P<0.001), storage time (P<0.001) and an interaction between fat content and dietary fiber addition (P=0.0198) (Table 4.4.1). The average TBARs values for all treatments and the trends of TBARs values over the 15 days of storage and effects of factors on TBARs value are shown in Table 4.4.2.

Table 4.4. 1 Effects of fat content, dietary fiber addition and interaction of fat and dietary fiber on TBARs value

	Factors		
	Fat	Dietary Fiber	Interaction
Sig	0.138	0.001	0.019

In regard to storage time, TBARs value reached the highest point either on the 3rd day, 6th day or 9th day (only for 5% soy fiber in 15% fat) but then declined in the following days and increased again on the 12th or 15th day (except for 5% soy fiber at 20% fat content which decreased from the 12th day to the 15th day).

For the dietary fiber addition, TBA values decreased for all treatments when compared with the control group. For the 10% fat treatments, TBARs value of the fat control group was the second lowest (0.14) on day 0. From day 0 to day 3, TBARs value of the 10% control group increased sharply from 0.14 to 0.34, which was the highest value for all treatments on day 3. After that, the TBARs value remained the highest in the 10% fat control group for the remainder of the study. Similarly, for the 15% fat treatments, the TBARs value of the control group was the second lowest (0.18) on day 0 and increased sharply to 0.26 which was the highest one on day 3. After the 3rd day, the 15% fat control group continued to have the highest TBARs value for the remaining days until the 15th day when the TBARs value of the 5% soy fiber addition group (0.30) surpassed that of the 15% fat control group (0.28). The trend was similar for the 20% fat treatments. The TBARs value of the 20% fat control group increased sharply to 0.39 on day 3. After that, the 20% fat control group continued to have the highest TBARs value for the following test days.

The interaction of fat content and dietary fiber addition was mainly shown by the changing trends of the TBARs values. An obvious antioxidant activity of the different dietary fiber additions, in the order of 3% tomato powder > 3% soy fiber addition > 5% tomato powder = 5% soy fiber addition, was observed. However, the same percentages and types of dietary fiber additions had different effects on TBARs value for the different fat levels, which are shown in Figure 4.4.1, Figure 4.4.2, Figure 4.4.3, and Figure 4.4.4.

Table 4.4. 2 Average TBARs value of all treatments during 15 days refrigerator storage

Fat [%]	Sources of dietary fiber [%]	Level of addition [%]	Days in storage					
			0	3	6	9	12	15
20	C	0	0.19 ± 0.01a	0.39 ± 0.01a	0.33 ± 0.02a	0.29 ± 0.02a	0.30 ± 0.01a	0.35 ± 0.03a
	SF	3	0.11 ± 0.01c	0.24 ± 0.01c	0.21 ± 0.02b	0.18 ± 0.01c	0.23 ± 0.02c	0.25 ± 0.01b
		5	0.14 ± 0.01b	0.29 ± 0.01b	0.23 ± 0.01b	0.23 ± 0.03b	0.27 ± 0.01b	0.25 ± 0.01b
	TP	3	0.14 ± 0.01b	0.23 ± 0.02c	0.19 ± 0.01c	0.15 ± 0.03c	0.14 ± 0.02d	0.19 ± 0.02c
		5	0.17 ± 0.01a	0.26 ± 0.01bc	0.23 ± 0.01b	0.22 ± 0.02b	0.25 ± 0.01b	0.27 ± 0.01b
15	C	0	0.18 ± 0.02b	0.26 ± 0.02a	0.31 ± 0.02a	0.28 ± 0.01a	0.26 ± 0.01a	0.28 ± 0.01b
	SF	3	0.16 ± 0.01c	0.17 ± 0.01d	0.26 ± 0.01b	0.23 ± 0.02c	0.20 ± 0.01c	0.26 ± 0.01c
		5	0.22 ± 0.01a	0.24 ± 0.01b	0.25 ± 0.01b	0.26 ± 0.02b	0.21 ± 0.02d	0.30 ± 0.02a
	TP	3	0.18 ± 0.02b	0.20 ± 0.01c	0.18 ± 0.01c	0.19 ± 0.01d	0.20 ± 0.02c	0.25 ± 0.01c
		5	0.19 ± 0.01b	0.21 ± 0.01c	0.24 ±0.02b	0.22 ± 0.01c	0.24 ± 0.01b	0.26 ± 0.01c
10	C	0	0.14 ± 0.01c	0.34 ± 0.02a	0.29 ± 0.02a	0.24 ± 0.01a	0.23 ± 0.01a	0.35 ± 0.01a
	SF	3	0.18 ± 0.01b	0.29 ± 0.02b	0.28 ± 0.01a	0.19 ± 0.01bc	0.17 ± 0.01c	0.22 ± 0.01c
		5	0.23 ± 0.01a	0.25 ± 0.02c	0.27 ± 0.01b	0.21 ± 0.03b	0.19 ± 0.01c	0.27 ± 0.02b
	TP	3	0.19 ± 0.01b	0.23 ± 0.01d	0.26 ± 0.02b	0.17 ± 0.02c	0.18 ± 0.03c	0.20 ± 0.01c
		5	0.07 ± 0.01d	0.26 ± 0.02c	0.28 ± 0.01a	0.18 ± 0.01c	0.21 ± 0.02b	0.24 ± 0.01c

C= Control; SF= Soy Fiber; TP= Tomato Powder; Values in the same block (% Fat and Day) that do not share same letter in the same column are significantly different (P < 0.05)

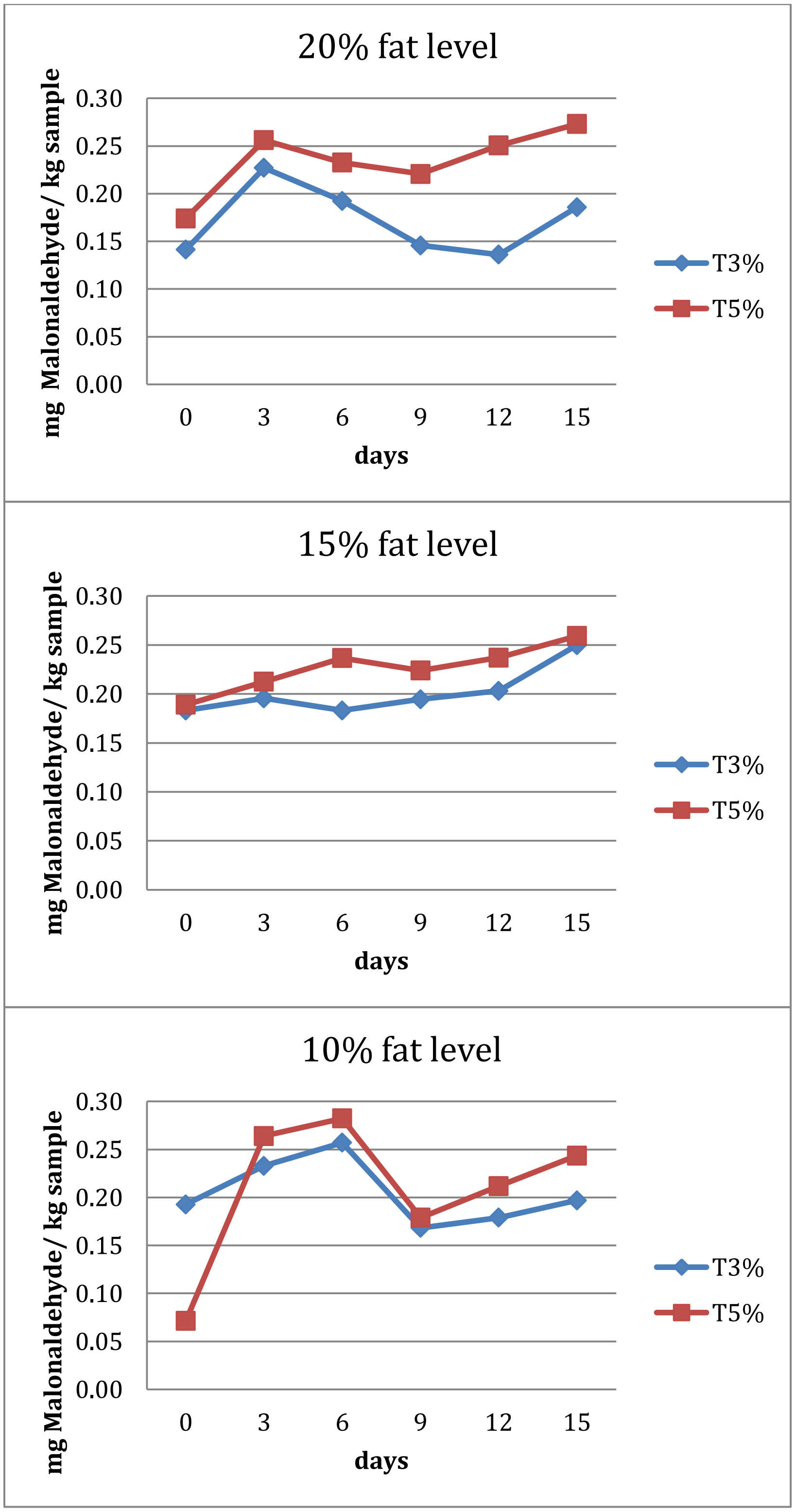


Figure 4.4. 1 Effect of tomato powder addition on TBARs value in 10, 15 and 20% fat content. T3%=Tomato powder 3%; T5%=Tomato powder 5%

Effect of tomato powder addition can be seen in Figure 4.4.1. T3% always had lower TBARs values than T5%, except for day 0 of the 10% fat level group, which simply means that for some reason the initial TBARs value for that fat and tomato fiber level was very low. However, even in that case a sharp increase was found from day 0 to day 3 and the TBARs value of the T5% (0.26) was then higher than that of T3% (0.23). It can be concluded that tomato powder is more effective in reducing lipid oxidation at the 3% level than at the 5% level. A higher TBARs values, as a result of high amounts of tomato-derived product addition was reported by Modzelewska-Kapitula (2012), Deda and others (2007) and Eyiler and Oztan (2011). In oil-in-water emulsions, carotenoids can have antioxidative or pro-oxidative activity, depending on storage conditions, concentration, the type of carotenoid, and the presence of other antioxidants and pro-oxidants in the system (Mercadante and others 2010). In this study, both the 3% and 5% tomato powder addition reduced TBARs value when compared with the control group. However, the higher amount of tomato powder addition (5%) may have reduced the antioxidant ability due to upsetting the balance between antioxidant and pro-oxidant activity.

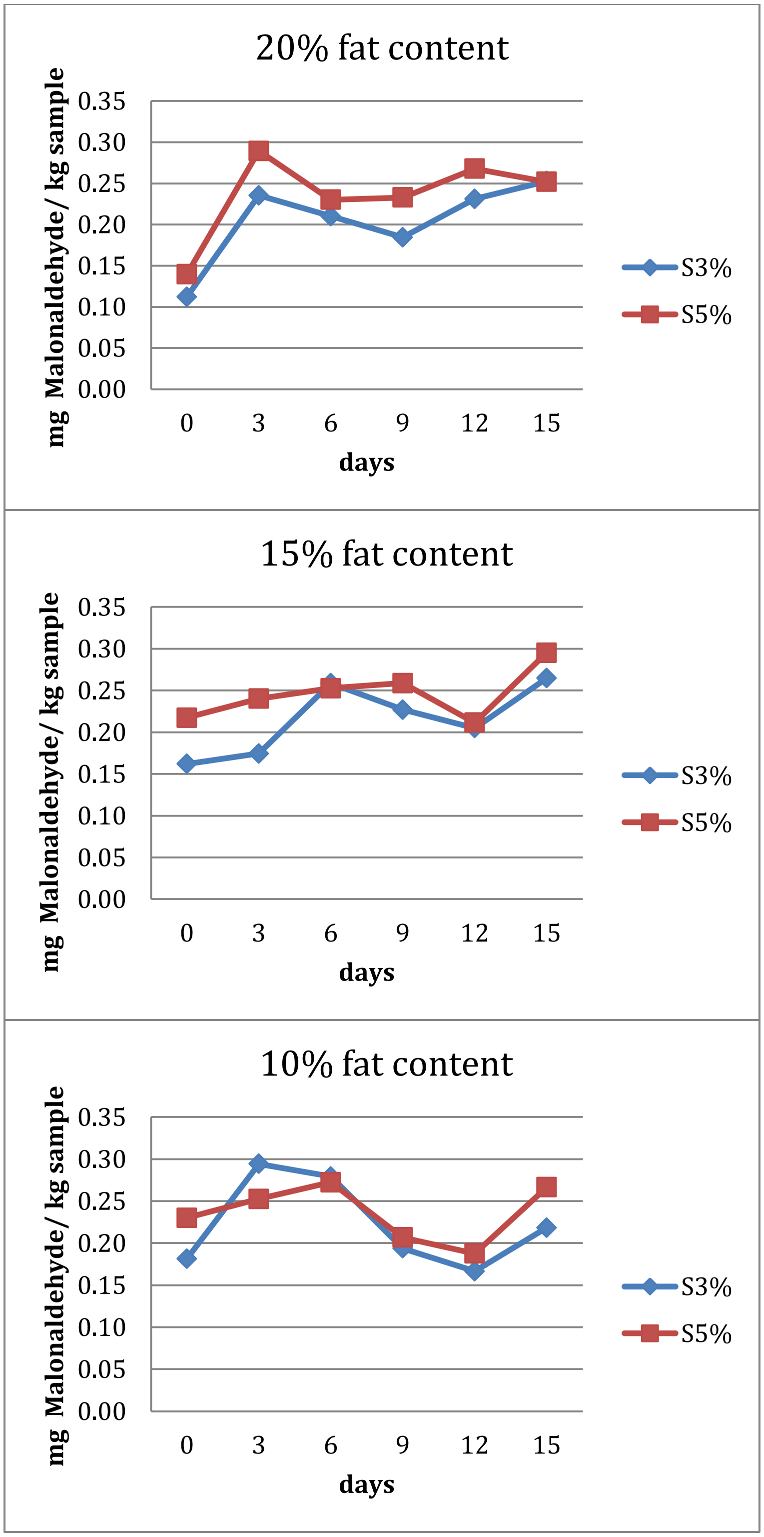


Figure 4.4. 2 Effect of soy fiber addition on TBARs value in 10, 15 and 20% fat content. S3%=Soy fiber 3%; S5%=Soy fiber 5%

Figure 4.4.2 shows the effect of soy fiber percentage on TBARs value. In the 20% fat group, S5% had higher TBARs values throughout the test period except for day 15, when S3% and S5% had the same TBARs values. In the 15% fat group, S5% had higher TBARs values for most of the days, except for day 6, even though there were no significant differences. In the 10% fat group, TBARs value of S3% showed a sharp increase from day 0 to day 3 and then continuously declined from 0.29 on day 3 to 0.17 on day 12. TBARs values of S5% increased slowly from day 0 to day 6 and then decreased from 0.28 on day 6 to 0.24 on day 12, when the TBARs value of 5% soy fiber became higher than that of the 3% soy fiber group. In general, the 3% soy fiber showed better antioxidant activity than the 5% soy fiber addition. Similar results were found by Paulo and others (2012) who added soy fiber to fermented sausages and found reductions of volatile compounds from lipid oxidation. The reason of soy fiber addition reducing TBARs value may be related to the presence of soy isoflavones in soy fiber. Similar to carotenoids isoflavones can exhibit pro-oxidant activity at high concentrations. So, when the amount of soy fiber addition was increased to 5%, it might be that isoflavones' concentration increased to a level at which the antioxidant activity started to decrease.

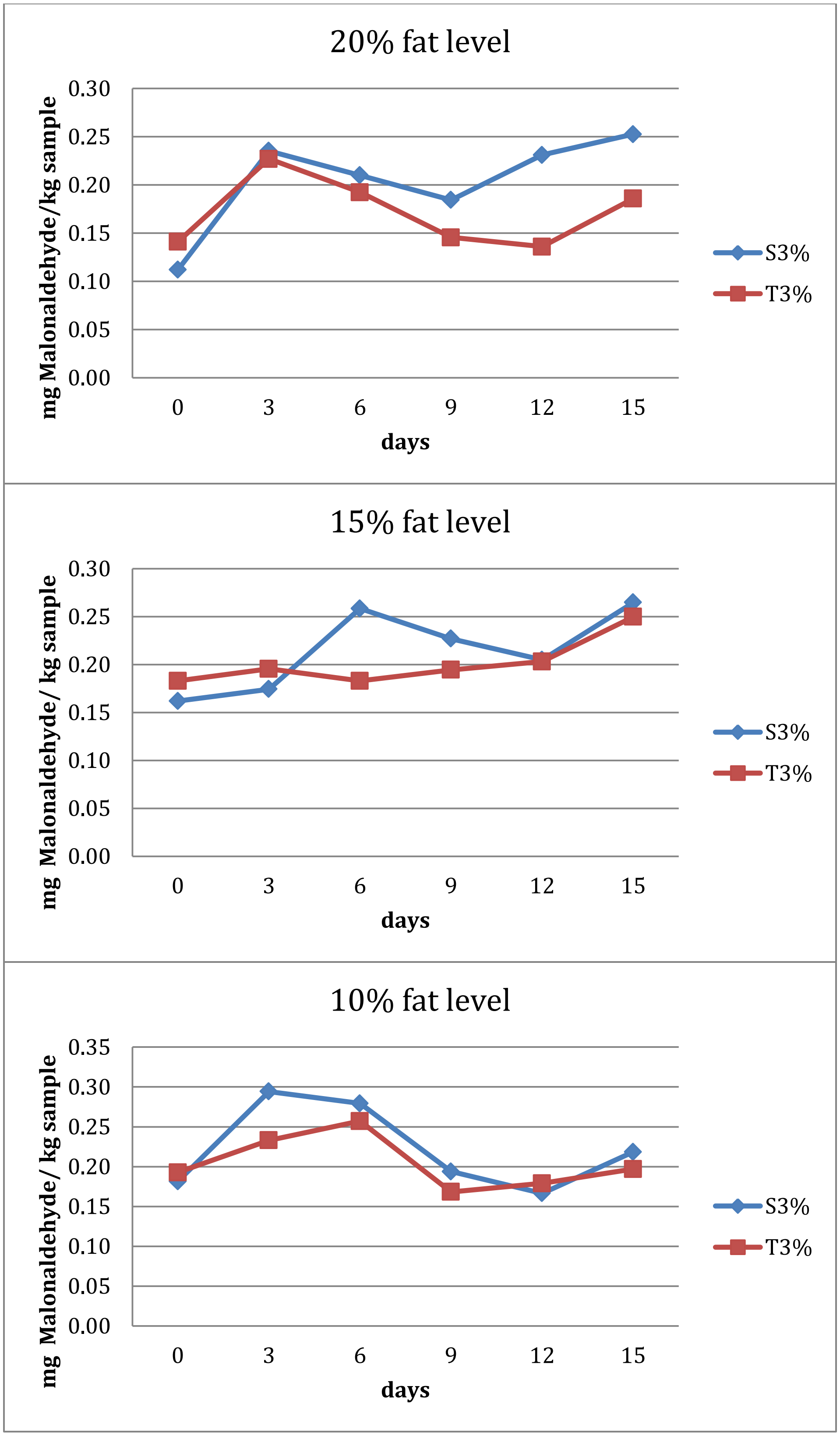


Figure 4.4. 3 Effect of 3% dietary fiber addition on TBARs value in 10, 15 and 20% fat content. S3%=Soy fiber 3%; T3%=Tomato powder 5%

In the direct comparison of soy fiber to tomato powder at the 3% level (Figure 4.4.3), the 3% soy fiber added treatments showed lower TBARs value for some time. However, for all fat levels, for the most part the T3% curve was below the curve of S3% and T3% had a lower TBARs end point after 15 days for all fat levels. Thus, when the same amount of 3% of tomato powder or soy fiber was added to hot dogs, the tomato powder was more effective in reducing TBARs value.

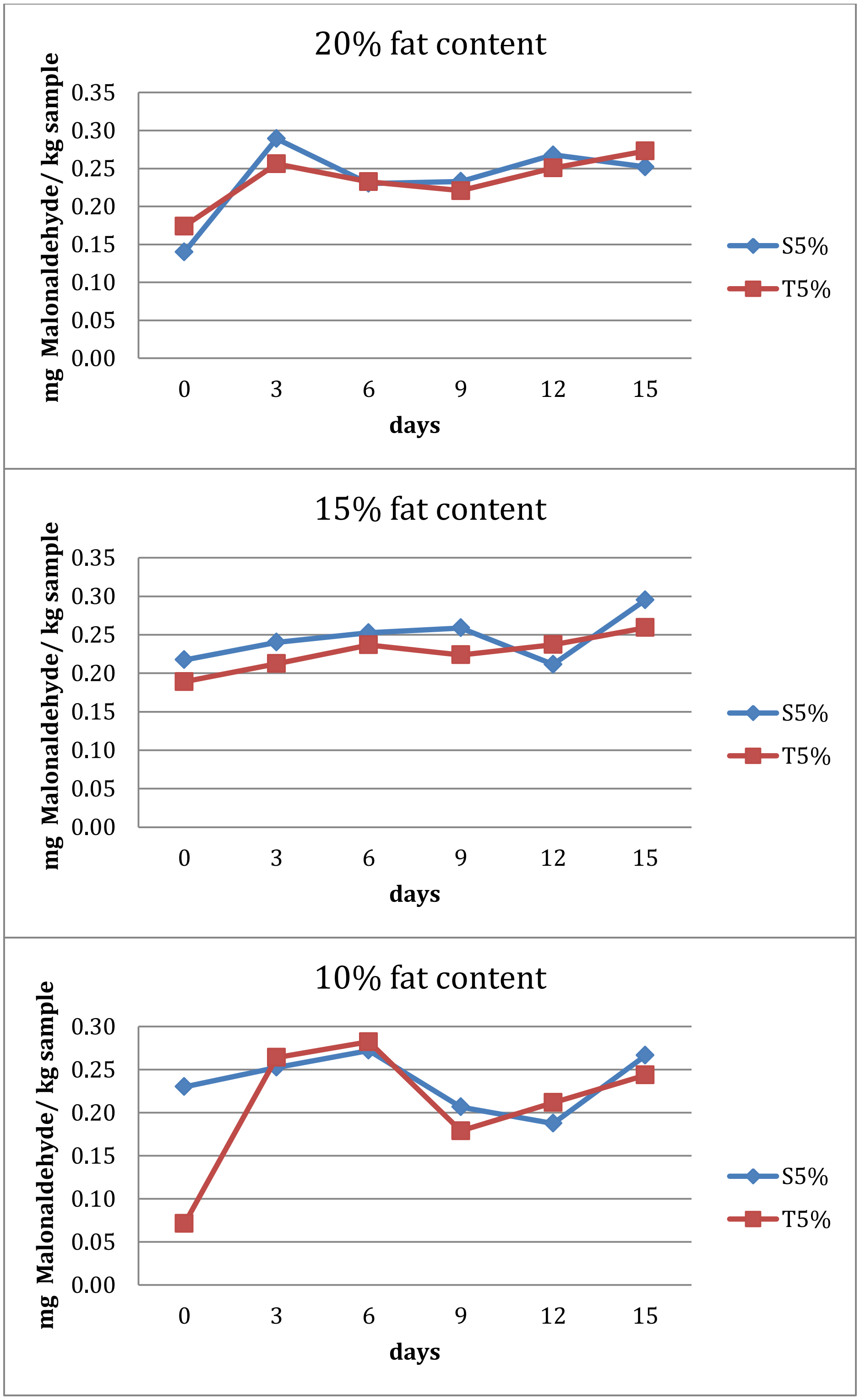


Figure 4.4. 4 Effect of 5% soy fiber and tomato powder addition on TBARs value in 10, 15 and 20% fat content. S5%=Soy fiber 5%; T5%=Tomato powder 5%

Figure 4.4.4 shows the effects of 5% soy fiber and tomato powder on TBARs values. For the 20 and 10% fat levels, there were no significant differences between soy fiber and tomato powder addition except for the initial value on day 0. For the 15% fat level, S5% had a significantly higher TBARs value during the 15 testing days, except for day 12. In general, tomato powder addition showed higher antioxidant activity than soy fiber at the 15% fat level whereas no significant differences were found for the 10% and 20% fat levels.

4.5 Color Profile Analysis

Color is a very important factor that often determines whether the consumer will purchase the product or not. It has been reported that 74% of consumers indicated that color was important in product purchase decisions (Lynch and others 1986). Color of hot dogs was measured by the spectrophotometric method in the CIE L*a*b* color system. The effects of factors on color profile and average values of L*, a* and b* are presented in Table 4.5.1, Table 4.5.2, Table 4.5.3 and Table 4.5.4.

Table 4.5. 1Effects of fat content, dietary fiber addition and interaction of fat and dietary fiber on L*a*b*

	Factors		
	Fat	Dietary Fiber	Interaction
L*	0.001	0.001	0.056
a*	0.006	0.001	0.069
b*	0.005	0.001	0.110

Table 4.5. 2 Average values of L* of hot dog samples for each combination of fat% and dietary fiber additions.

Fat%	Fiber	Fiber Content		
		0%	3%	5%
10%	Tomato Powder	42.34±1.42$^{B}_{a}$	41.26± 0.88$^{B}_{ab}$	40.40± 0.52$^{C}_{b}$
	Soy Fiber	42.34± 1.42$^{B}_{b}$	45.36± 0.40$^{A}_{a}$	45.76± 0.80$^{B}_{a}$
15%	Tomato Powder	42.60± 0.93$^{B}_{a}$	41.60± 0.79$^{B}_{a}$	41.2± 0.70$^{C}_{a}$
	Soy Fiber	42.60± 0.93$^{B}_{c}$	46.55± 0.91$^{A}_{b}$	48.47± 1.09$^{A}_{a}$
20%	Tomato Powder	44.17± 0.87$^{A}_{a}$	41.59± 2.32$^{B}_{b}$	40.74± 1.22$^{C}_{b}$
	Soy Fiber	44.17± 0.87$^{A}_{c}$	46.87± 1.76$^{A}_{b}$	48.70 ± 1.00$^{A}_{a}$

Values in the same table that do not share same superscript (in the same column) or same subscript (in the same row) are significantly different (P<0.05)

Table 4.5. 3 3 Average values of a* of hot dog samples for each combination of fat% and dietary fiber additions

Fat%	Fiber	Fiber Content		
		0%	3%	5%
10%	Tomato Powder	16.03± 0.67$^{A}_{a}$	12.77± 1.67$^{C}_{b}$	12.98± 0.41$^{BC}_{b}$
	Soy Fiber	16.03± 0.67$^{A}_{a}$	14.52± 1.95$^{A}_{b}$	14.87± 0.95$^{A}_{b}$
15%	Tomato Powder	15.03± 0.59$^{B}_{a}$	12.18± 1.26$^{CD}_{b}$	12.15± 0.67$^{C}_{b}$
	Soy Fiber	15.03± 0.59$^{B}_{a}$	13.55± 1.99$^{B}_{b}$	13.71±1.46$^{B}_{b}$
20%	Tomato Powder	14.26± 1.40$^{C}_{a}$	11.85± 0.97$^{D}_{b}$	11.85± 0.97$^{C}_{b}$
	Soy Fiber	14.26± 1.40$^{C}_{a}$	13.38±0.63$^{B}_{b}$	12.96±1.79$^{BC}_{b}$

Values in the same table that do not share same superscript (in the same column) or same subscript (in the same row) are significantly different (P<0.05)

Table 4.5. 4 Average values of b* of hot dog samples for each combination of fat% and dietary fiber additions.

Fat%	Fiber	Fiber Content		
		0%	3%	5%
10%	Tomato Powder	7.28± 0.74$^{A}_{c}$	9.53± 0.77$^{A}_{b}$	10.52± 0.49$^{B}_{a}$
	Soy Fiber	7.28± 0.74$^{A}_{b}$	8.15± 0.51$^{B}_{a}$	7.99± 0.62$^{C}_{a}$
15%	Tomato Powder	7.20± 0.26$^{A}_{b}$	10.15± 0.22$^{A}_{a}$	11.43± 0.40$^{A}_{a}$
	Soy Fiber	7.20± 0.26$^{A}_{b}$	8.27± 0.29$^{B}_{a}$	8.62± 0.21$^{C}_{a}$
20%	Tomato Powder	7.57± 0.77$^{A}_{c}$	9.99± 0.79$^{A}_{b}$	11.27± 0.67$^{A}_{a}$
	Soy Fiber	7.57± 0.77$^{A}_{b}$	8.33± 0.29$^{B}_{a}$	8.55± 0.11$^{C}_{a}$

Values in the same table that do not share same superscript (in the same column) or same subscript (in the same row) are significantly different (P<0.05)

The characteristic cured meat color of hot dog is created by nitrates/nitrites which react with myoglobin to form nitrosylmyoglobin before cooking and nitrosylhaemochromogen post cooking (Varnam and Sutherland 1995). Table 4.5.1,

Table 4.5.2 and Table 4.5.3 show the effect of dietary fiber addition and fat content on L*, a* and b* values.

Looking at the main effect of fat content, it can be seen that increasing the fat content from 10 to 20% had no significant effects on L* for all treatments, except for the control group and soy fiber 5%. Specifically, when fat content was increased from 15 to 20% in control groups, L* value increased from 42.60 to 44.17 ($P<0.05$), and when fat content increased from 10 to 15% for the 5% added soy fiber treatment, L* value increased from 45.76 to 48.47 ($P<0.05$). For the effect of dietary fiber, it can be seen that tomato powder addition decreased L values, whereas soy fiber increased L* at all fat levels. However, whereas the percentages of tomato powder (3 and 5%) did not appear to affect L* values at either fat level, increasing soy fiber addition seemed to increase L* values, except for 10% fat content, which showed only a slight increase from 45.36 in 3% soy fiber to 45.76 in 5% soy fiber, which was not significant.

The changes in a* values can be seen in Table 4.5.2. For the main effect fat content, a* values tended to decrease with an increase in fat content (10 to 20%), although not all of these decreases were statistically significant Specifically, for treatments with added soy fiber, no significant changes were found by increasing fat content from 15 to 20%. For treatments with 5% tomato powder, slight but non-significant decreases were found when fat content increased from 10 to 20%., whereas for the 3% tomato powder, the 10% fat treatments and 20% fat treatments were significantly different. For the dietary fiber additions, both tomato powder and soy fiber addition decreased a* values, but the percentage of dietary fiber addition did not matter ($P<0.05$). Soy fiber treatments had higher a* values than tomato powder at the same fat levels.

Average b* values are shown in Table 4.5.3. Dietary fiber addition was the only factor that affected b* values. Both, soy fiber and tomato powder additions increased b* values. However, while tomato powder addition appeared to have a concentration dependent effect, the percentage of soy fiber addition (3 vs 5%) did not have a significant effect on b* values. In addition, at the same percentage of dietary fiber addition within a certain fat level, soy fiber addition resulted in lower b* values than tomato powder.

In general, increasing fat content increased L* values, decreased a* values and did not affect b* values in hot dogs. While soy fiber addition increased L* values, decreased a* values and increased b* values, tomato fiber addition decreased L* and a* values and increased b* values. The increase in lean beef content can explain both, fat content related findings of L* values and a* values, because lean beef is redder and darker than fat (Brian and others 2012). The color of soy fiber can be used to explain soy fiber related findings. Soy fiber is a pale yellow powder, which transfer this color into meat emulsified systems. However, the effect of tomato fiber was different than that reported previously by Calvos and others (2007). In their research, freeze-dried tomato peel fiber, which has higher lycopene content (55.7mg/ 100g), was used. Compared with drum drying, freeze-drying can protect the heat-sensitive components, such as lycopene, in products (Mehdi and Sayed 2013) and contributed to a higher redness value for tomato fiber.

4.6 Texture Profile

Texture Profile Analysis has been found to provide good correlations to sensory analysis for meat products such as frankfurter-type sausages (Yang and others 2001; Ritzoulis and others 2010). The effects of fat levels and dietary addition are shown in Table 4.6.1., and the average values for hardness, gumminess, chewiness, springiness and cohesiveness are shown in Table 4.6.2.

Table 4.6. 1 Effects of fat content, dietary fiber addition and interaction of fat content and dietary fiber addition on texture properties ($P<0.05$)

Factors	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
Fat	0.001	0.319^{ns}	0.077^{ns}	0.001	0.001
Dietary Fiber	0.020	0.001	0.001	0.004	0.001
Interaction	0.153^{ns}	0.880^{ns}	0.253^{ns}	0.931^{ns}	0.742^{ns}

ns= no significant

As shown in Table 4.6.1, dietary fiber had significant effects on all attributes, while fat affected hardness, gumminess and chewiness, but not springiness and cohesiveness.

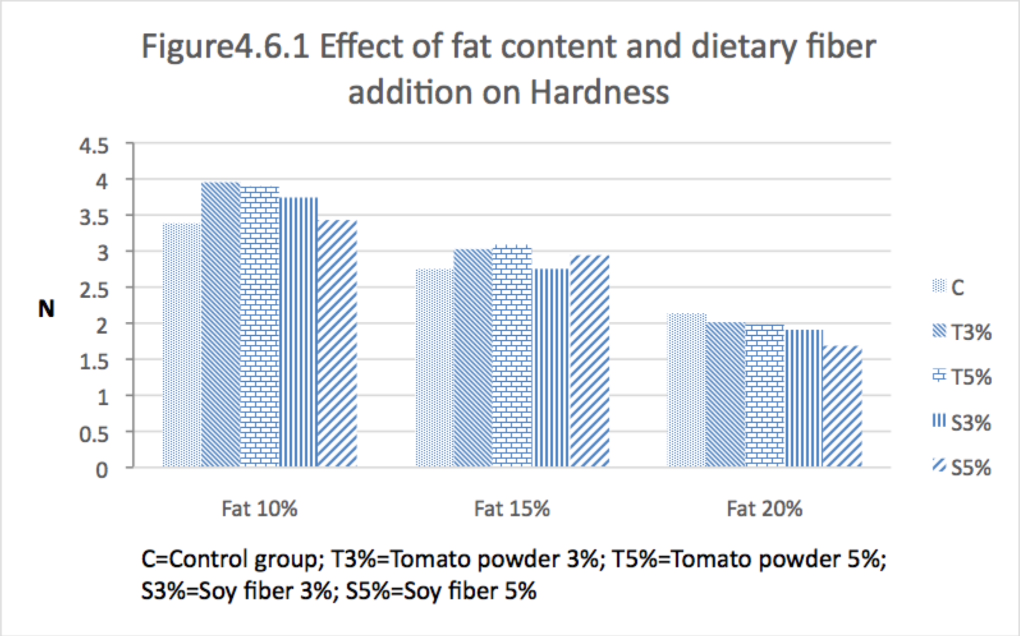


Figure 4.6. 1 Effect of fat content and dietary fiber addition on hardness

The effects of fat content and dietary fiber addition are presented in Table 4.6.2 and Figure 4.6.1. Hardness decreased with increasing fat content, which is in agreement with other studies (Matulis and others 1995; Garcia and others 2002; Olivares and others 2010). Dietary fiber addition increased hardness for all 10 or 15% fat content treatments. However, when fat content was increased to 20%, dietary fiber addition did not affect hardness, except for the 5% soy fiber addition which decreased hardness significantly. Tomato powder addition had a greater effect on hardness than soy fiber addition. While the percentage of tomato powder addition did not affect hardness, the higher percentage of soy fiber addition decreased the hardness in 10 and 20% fat levels whereas it increased hardness in 15% fat content.

Table 4.6. 2 Average Values of Texture Profile Analysis for Hardness, Springiness, Cohesiveness, Gumminess and Chewiness

Fat [%]	Sources of dietary fiber [%]	Level of addition [%]	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
10	C	0	3.38± 0.21 c	1.79± 0.14 a	0.75± 0.02 a	2.92± 0.17 a	4.44± 0.46 a
	TP	3	3.95± 0.31 a	1.38± 0.04 b	0.72 ± 0.02 a	2.84± 0.22 b	3.98± 0.28 b
		5	3.90 ± 0.36 a	0.97 ± 0.14 c	0.66 ± 0.01 b	2.58 ± 0.29 c	3.23 ± 0.55 c
	SF	3	3.74 ± 0.17 b	1.03 ± 0.17 c	0.69 ± 0.02 b	2.58 ± 0.14 c	3.32 ± 0.47 c
		5	3.42 ± 0.18 c	0.92 ± 0.07 c	0.65 ± 0.02 b	2.22 ± 0.10 d	2.23 ± 0.19 d
15	C	0	2.75 ± 0.22c	1.84 ± 0.16 a	0.77 ± 0.01 a	2.45 ± 0.17 a	3.92 ± 0.33 a
	TP	3	3.02 ± 0.23a	1.55 ± 0.03b	0.71 ± 0.02b	2.24 ± 0.18 b	3.24 ± 0.80 b
		5	3.08 ± 0.48a	0.97 ± 0.06 d	0.63 ± 0.02 c	2.14 ± 0.38 bc	2.49 ± 0.48 c
	SF	3	2.75 ± 0.37c	1.23 ± 0.03 c	0.68 ± 0.02 b	2.08 ± 0.22 c	2.56 ± 0.22 c
		5	2.94 ± 0.12b	0.93 ± 0.05 d	0.64 ± 0.01 c	2.02 ± 0.08 c	1.88 ± 0.17 d
20	C	0	2.13 ± 0.29 a	1.84 ± 0.10 a	0.78 ± 0.03a	2.16 ± 0.27 a	3.23 ± 0.40a
	TP	3	2.01 ± 0.22 a	0.99 ± 0.03 b	0.74 ± 0.01 b	1.75 ± 0.14 b	1.67 ± 0.12 b
		5	1.98 ± 0.15 a	0.91 ± 0.05 b	0.69 ± 0.03 c	1.71 ± 0.09 b	1.46 ± 0.11 c
	SF	3	1.9 ± 0.32 a	1.01 ± 0.16 b	0.76 ± 0.02 b	1.65 ± 0.20 bc	1.75 ± 0.38 b
		5	1.68 ± 0.47 b	0.99 ± 0.10b	0.69 ± 0.02 c	1.52 ± 0.29 c	1.38 ± 0.34 c

C= Control; TP= Tomato Powder; SF= Soy Fiber; Values in the same block (% Fat and Day) that do not share same letter in the same column are significantly different (P < 0.05)

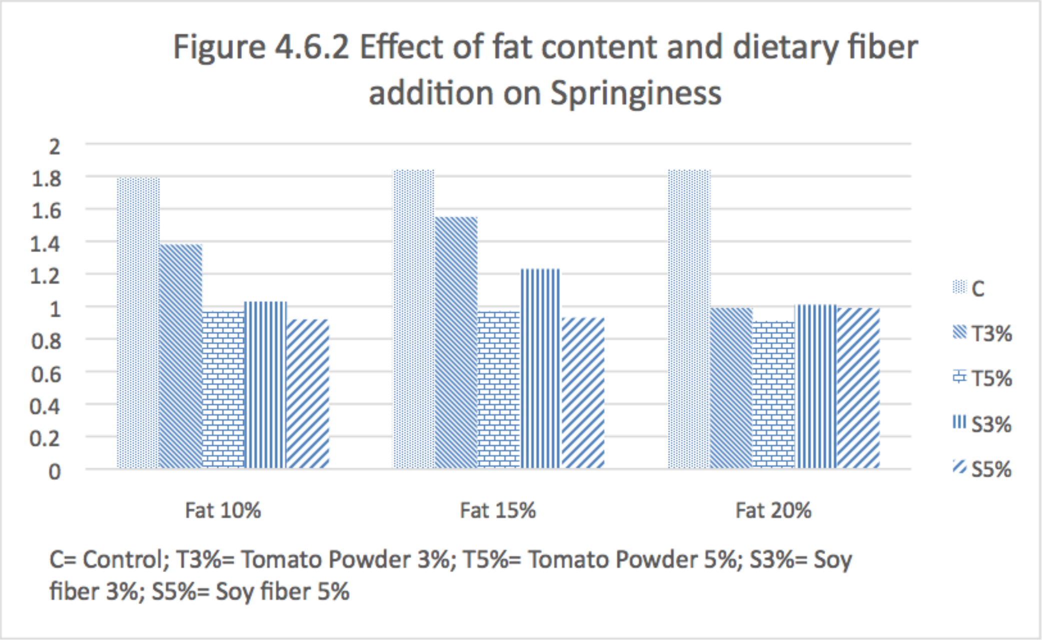


Figure 4.6. 2Effect of fat content and dietary fiber addition on springiness

Figure 4.6.2 shows the effect of fat content and dietary fiber addition on springiness. Fat levels did not affect springiness, whereas dietary fiber addition had a significant effect on it. The springiness decreased upon dietary fiber addition. Tomato powder at the 3% addition decreased springiness the least, and there appears to be a concentration dependency.

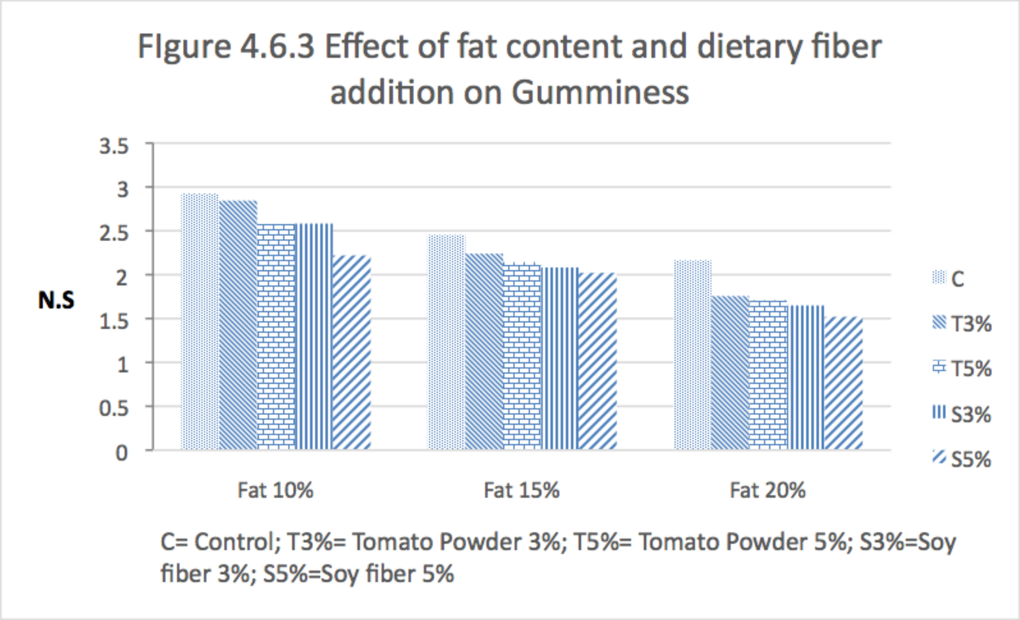


Figure 4.6. 3 Effect of fat content and dietary fiber addition on gumminess

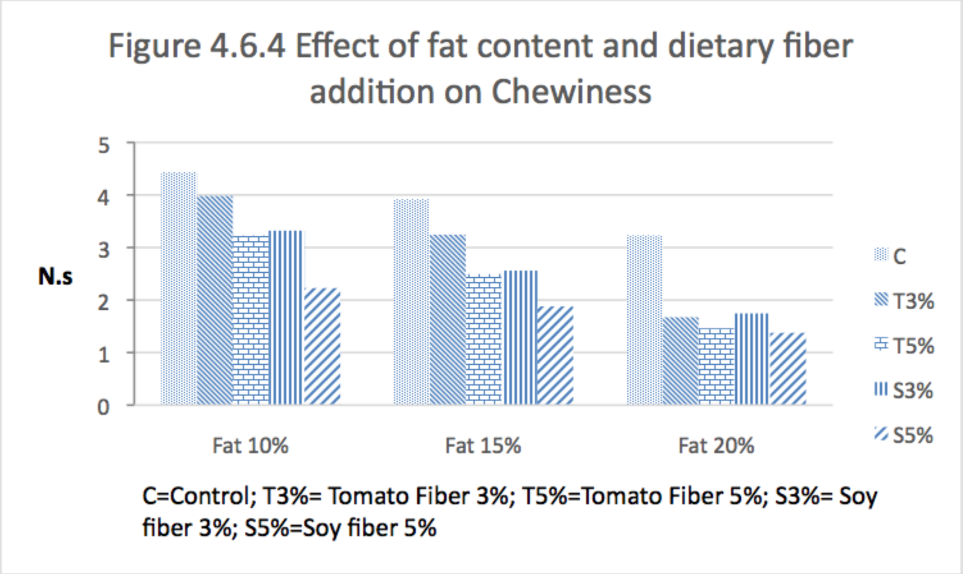


Figure 4.6. 4 Effect of fat content and dietary fiebr addition on chewiness

Effects on gumminess and chewiness are shown in Figure 4.6.3 and Figure 4.6.4, respectively. Gumminess and chewiness were found to decrease with an increase in fat content. For the main effect dietary fiber addition, gumminess and chewiness decreased for all fat levels. Both gumminess and chewiness were sensitive to the percentage of dietary fiber addition where more fiber decreases gumminess and chewiness to a greater extent. Moreover, tomato powder addition contributed to higher gumminess and chewiness than soy fiber when the same percentage of addition was used, except for chewiness at the 20% fat content, which had a slight but non-significantly higher chewiness value for soy fiber at the 3% addition than tomato fiber did.

Petridis and others (2010) found similar effects of starch addition on meat texture, where starch reduced gumminess and chewiness. They believed that starch addition decreased the capability of the meat protein gel to store energy upon mechanical deformation. The most plausible cause for the findings in this research is dietary fiber affected the meat gel network. Dietary fiber and meat protein appeared to have no interactions with each other upon cooking (Li and Yeh 2002), and it is reasonable to assume that no direct interaction between dietary fiber and protein takes place. The dietary fiber phase separates and interferes with the continuous meat protein gel, which reduces elasticity and its related parameters such as chewiness (Vu dang and others 2009; Aguilera and Rojas 1996).

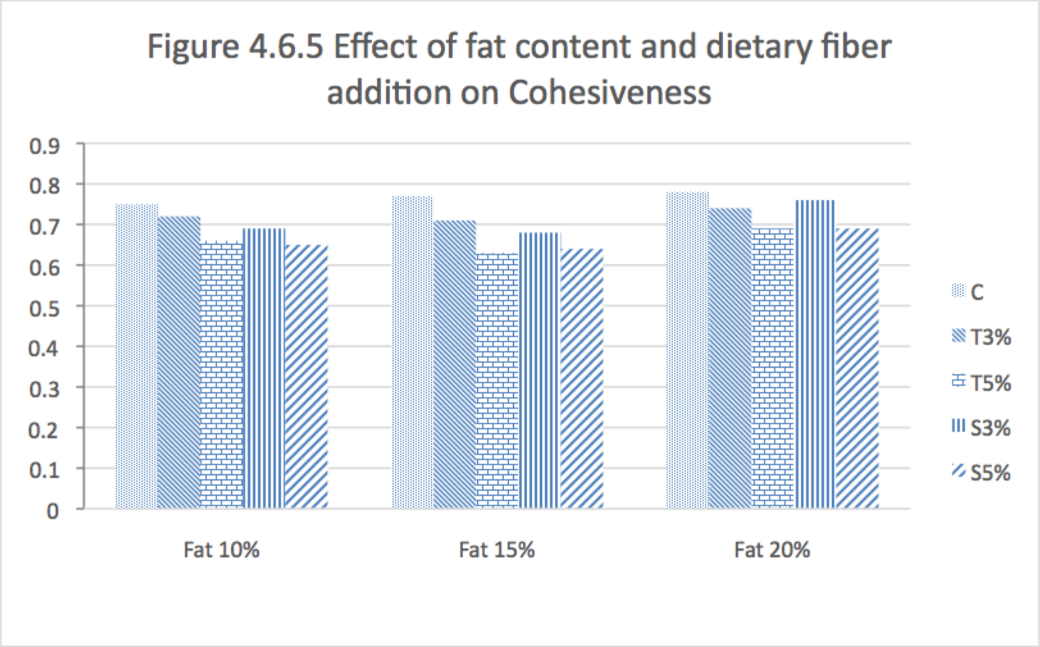


Figure 4.6. 5 Effect of fat content and dietary fiber addition on cohesiveness

Dietary fiber addition is the only factor, which significantly affected cohesiveness (Figure 4.6.5). Cohesiveness decreased when dietary fiber was added. Increasing the percentage of soy fiber or tomato powder addition from 3 to 5% decreased the cohesiveness for all fat levels. When 3% dietary fiber was added to the hot dogs, tomato fiber resulted in greater cohesiveness than soy fiber for the 10 and 15% fat levels, whereas an opposite result was found for the 20% fat level. Similar results were obtained by Calov and others (2008), who reported a significant decrease in cohesiveness when tomato peel fibers were added to fermented sausage. Insoluble fiber may cause this decrease because the components of this type of fiber have a complex crystalline structure, making it easier to break foods into small pieces in the mouth.

CHAPTER 5

SUMMARY AND CONCLUSION

Beef hot dogs with different fat contents (10, 15 and 20%) and dietary fibers addition (tomato powder 3%, tomato powder 5%, soy fiber 3% and soy fiber 5%) were manufactured. The effects of dietary fiber addition, fat content and the interaction between fat and dietary fiber on chemical properties (protein content, fat content, moisture content, dietary fiber content and TBARs value) and physical properties (cooking loss, water holding capacity, texture and color) were investigated.

Both tomato powder and soy fiber addition increased the protein content in the final product due to the protein content in the powders. Soy fiber added treatments had higher dietary fiber content than the same percentage of tomato powder added treatments for raw samples, due to the higher percentage of dietary fiber in soy fiber. Control groups had highest moisture contents before cooking due to higher ice addition, whereas 3% soy fiber added treatments had the highest moisture content after cooking due to lower cooking loss.

All dietary fiber additions showed antioxidant ability and significantly reduced TBARs value in the order of 3% tomato powder >3% soy fiber> 5% tomato powder= 5% soy fiber. The interaction of fat and dietary affects the trend of changes in TBARs values but did not affect the order of antioxidant ability of different dietary fiber additions at each fat level.

Tomato powder content generally had no effect on cooking loss and decreased water holding capacity whereas soy fiber decreased cooking loss and increased water holding capacity, probably due to the particle size and complex structure of tomato powder. The percentage of dietary fiber addition did not affect cooking loss in general. Higher fat content generally resulted in increased cooking loss and water holding capacity. However, 3% tomato powder increased cooking loss significantly at the 20% fat content and 5% soy fiber decreased cooking loss significantly at the 10% fat content and these phenomena were not found for other fat levels. It indicated the effects of interactions between fat and dietary fiber addition.

Due to the colors of fat, lean meat, soy fiber and tomato powder, dietary fiber addition and fat content had significant effects on the color of hot dogs. Soy fiber addition increased L* and b* value and decreased a* value in hot dogs. Tomato fiber decreased L* and a* values and increased b* value. Increasing fat content increased L* value and decreased a* value and did not affect b* value. No effects of interaction were found during color profile analysis. Higher soy fiber content increased L* value and did not affect a* and b* values in general. Higher tomato powder increased b* value and did not affect L* and a* values in general.

In texture profile analysis, dietary fiber additions and fat content showed significant effect on texture properties. Increasing fat content decreased hardness, gumminess and chewiness but no effects were found on springiness and cohesiveness. All dietary fiber additions increased hardness in 10 and 15% fat content and decreased hardness in 20% fat content. Tomato power contributed to higher hardness values than soy fiber at all fat contents. All dietary fiber additions decreased springiness and cohesiveness for all treatments. Increasing the percentage of dietary fiber addition decreased springiness and cohesiveness and chewiness and gumminess decreased when dietary fiber was added for all treatments. Higher percentage of dietary fiber addition decreased gumminess and chewiness, and tomato powder contributed higher gumminess and chewiness values than the same percentage of soy fiber addition in all fat levels.

Adding dietary fiber to hot dogs might be a good way to improve dietary fiber consumption because hot dogs is one of the major meat products consumed in the US and meat products generally do contribute dietary fiber. Soy fiber and 3 % tomato powder addition might be an efficient way to change the texture profile and extend shelf life in low fat beef hot dogs. Soy fiber might be used as an ingredient to reduce cooking loss and increase water holding capacity.

However, sensory evaluation needs to be conducted to determine the effects of dietary fiber addition on mouth feel, flavor and aroma before recommendations can be made.

APPENDICES

APPENDIX 1. Chemicals

For Protein Analysis:

Sulfuric acid, specific gravity 1.84, N-free: 086363, Fisher Scientific, Fair Lawn, NJ

Copper sulfate, N-free: 42287100, Fisher Scientific, Fair Lawn, NJ

Potassium sulfate, N-free: 714911, Fisher Scientific, Fair Lawn, NJ

Sodium hydroxide solution: Dissolve 60 g NaOH (905378, Fisher Scientific, Fair Lawn, NJ) to 100 mL distilled water.

Boric acid solution with indicator: 106432, Ricca Chemical Company, Arlington, TX.

Hydrochloric acid-0.05 N: Dilute 10 mL 1 N HCL solution (SHBB4705V, Sigma-Aldrich, Saint Louis, MO) to 200 mL

For Dietary fiber content analysis:

98% ethanol: Mizzou Chemical Store, Columbia, MO.

78% ethanol: Place 207 mL distill water into 1 L volumetric flask. Dilute to volume with 95% ethyl alcohol (Mizzou Chemical Store, Columbia, MO). Mix and dilute to volume again with 95% ethyl alcohol.

Acetone: 111133, Fisher Scientific, Fair Lawn, NJ

Petroleum Ether: 127892, Fisher Scientific, Fair Lawn, NJ.

Phosphate buffer: 0.08M, pH 6.0. Dissolve 1.400 g sodium phosphate dibasic, anhydrous (Na_2HPO_4) and 9.68g sodium phosphate monobasic monohydrate ($Na_2H_2PO_4$) in ca 700 mL. Dilute to 1 L with H_2O. Check pH with pH meter (Model 230A, Fisher Accumet, Fair Lawn, NJ).

Heat stable alpha-amylase solution: 081M872V, Sigma-Aldrich, Saint Louis, MO)

Protease: SLBB7238V, Sigma-Aldrich, Saint Louis, MO.

Amyloglucosidase: 091M8701V, Sigma-Aldrich, Saint Louis, MO.

Sodium hydroxide solution- 0.275 N: Dissolve 11.00 g NaOH ACS (905378, Fisher Scientific, Fair Lawn, NJ) in ca 700mL distilled water in 1 L volumetric flask. Dilute to volume with diluted water.

Hydrochloric acid solution-0.325 N: Dilute 325 mL 1N HCl (SHBB4705V, Sigma-Aldrich, Saint Louis, MO) to 1 L with distilled water.

Celite C-211, Acid washed: SLBB6122V, Sigma-Aldrich, Saint Louis, MO.

For TBARs test:

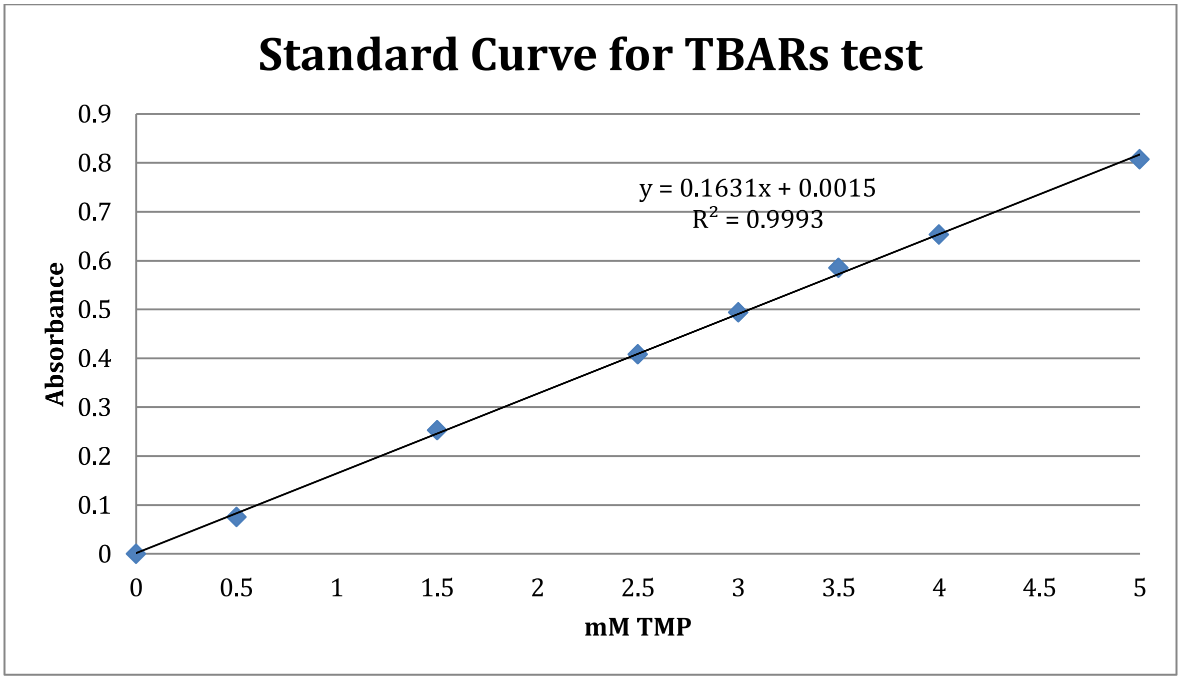
Antioxidant solution: Weigh 0.5 g propyl gallate (SLBD6728, Sigma-Aldrich, Saint Louis) and 0.5 g EDTA (SLBC3665V, Sigma-Aldrich, Saint Louis) into a 100 mL volumetric flask, dissolve in a small volume of 1:1 ethanol/water and dilute to mark with ethanol/water solution. Prepare Fresh Daily.

TMP solution-Malonaldehydebis: Prepare 20mM TMP stock solution by diluting 0.335 mL TMP (MKBJ6231V, Sigma-Aldrich, Saint Louis, MO) into 100 mL water or 300 mL water with 1 mL TMP (store up to 3 months at 4 ℃)

TCA reagent: Weigh 200g TCA (A0321729, Sigma-Aldrich, Saint Louis, MO) in a beaker and dissolve crystals in a small volume of water. To a volumetric flask, add some water and then add 16 mL of 85% phosphoric acid (704476, Fisher Scientific, Fair Lawn, NJ). Swirl solution and then quantitatively transfer TCA mixture from beaker with water. Fill to mark with water and mix contents thoroughly, can be stored 4-6 weeks at 4 ℃.

TBA solution: Weigh 2.883 g TBA (BCBH3605V, Sigma-Aldrich, Saint Louis, MO) in a beaker and dissolve crystals in a small volume of water. Transfer solution into 1 L volumetric flask and fill to mark with water.

APPENDIX 2. Standard curve of TBARs test



$$y = 0.163x + 0.001$$

Explanation for the equation

$$K = \frac{S \times \text{MA mol. Wt} \times DF \times 10^{6} \times \left(\frac{100}{\%\text{Recovery}}\right)}{\text{Slope of Standard Curve} \times m}$$

I. 1 ml 0.2 mM TMP dilutes to 100 mL

Weight of TMP in it is $0.2 \times 10^{-3} \times 10^{-3} \times 72.03$

II. Pipet 5 mL aliquot and get the dilute factor (DF) 100/20=5

Weight of TMP in it is I. $\times 5 \times 10^{-3}$

III. Covert g to kg for sample mass and covert g to mg for TMP and get the index 10^6

IV. All $K = \frac{0.2 \text{ X } 10^{-6} \text{X } 72.03 \text{ X } 5 \text{ X } 10^{-3} \text{X } 20 \text{ X } 100}{0.164 \text{ X R X m}}$

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