EVALUATION OF DRIED PLUM POWDER IN MEAT PRODUCTS DESTINED FOR CONVENIENCE AND FOODSERVICE OUTLETS

A Thesis

by

ROBERT MATTHEW MERRILL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2010

Major Subject: Food Science and Technology

EVALUATION OF DRIED PLUM POWDER IN MEAT PRODUCTS DESTINED FOR CONVENIENCE AND FOODSERVICE OUTLETS

A Thesis

by

ROBERT MATTHEW MERRILL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Co-Chairs of Committee,	Jimmy T. Keeton
	Wesley N. Osburn
Committee Member,	Rhonda K. Miller
Intercollegiate Faculty Chair,	Jimmy T. Keeton

May 2010

Major Subject: Food Science and Technology

ABSTRACT

Evaluation of Dried Plum Powder in Meat Products Destined for Convenience and Foodservice Outlets. (May 2010)

Robert Matthew Merrill, B.S., Johnson & Wales University

Co-Chairs of Advisory Committee: Dr. Wesley N. Osburn, Dr. Jimmy T. Keeton

Antioxidant activity of dried plum powder (DPP) at 3% was compared to rosemary extract (RE) at 0.05% in turkey breakfast sausages which were stored under three aerobic conditions: raw refrigerated (RR; 6°C), raw and precooked frozen (RF and PF, respectively; -23°C). Sausage links were tested on specific days over a 56 day shelf-life. Analyses included pH, proximate composition, objective color (CIE L*, a*,b*), lipid oxidation (TBARS), aerobic plate count and enumeration of lactic acid bacteria, sensory, reheat yields and shear force.

All RR treatments surpassed the threshold of 3 for TBARS by day 6. Spoilage occurred by day 3 for all RR treatments (> 6.0 $\log_{10}$). Treatments containing DPP had lower TBARS values for RF ($P < 0.05$) and PF ($P < 0.01$). DPP containing treatments had lower external and internal L* values and a* values while internal b* values were higher. Sensory scores for plum and sweet were higher, while cardboard and rancidity were lower in treatments containing DPP. Sensory scores for cardboard and rancidity were lower for RF and higher for PF treatments. Reheated cooked yields and shear force values for PF treatments held either 15 or 30 min showed an increasing trend with

subsequent storage. Proximate composition data showed no significant differences for fat, moisture, and protein. DPP containing treatments were different from other treatments having a lower pH except for the PF RE treatment.

The addition of DPP at 3% into a turkey breakfast sausage had an inhibitory effect on lipid oxidation in a RF and PF treatments. Inclusion of DPP darkened the external and internal appearance and increased yellowness as well as increasing the sweetness and plum flavor.

ACKNOWLEDGEMENTS

This project was funded by the California Dried Plum Board and special thanks are also given to J. M. Degen, James M. Degen & Company, Inc.

I would like to thank my major advisor, Dr. Osburn, and my committee members, Dr. Keeton and Dr. Miller, for their guidance, support, and expertise throughout the course of my research, as well as Dr. Hardin for substituting in place of Dr. Osburn during his absence for my defense.

I would like to thank my fellow graduate students for their assistance during production, data collection, and coordination: Austin Lowder, Gabriel Chmielewski, Lyda Garcia, Peter Andreasen, Marcel Pinnerup, Sonia Garza, Amanda King, and Dawna Winkler. I would also like to thank our lab technicians, Dr. Sharen Nowak, Dr. Betsy Booren, Liz Hirschler and our student workers, Colton Atkins and Amy Frenchmeyer who provided support throughout the course of the project.

Finally, I would like to thank my parents, Will and Kathy Merrill, and my wife, Sarah, for their help and encouragement which brought me to this point in my life and career.

TABLE OF CONTENTS

CHAPTER Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Introduction

Consumers have less free time to prepare their meals at home, due to increased work load, city congestion such as traffic, and other everyday factors. This increases the demand for quick and convenient alternatives to a home cooked meal. However, consumers are not only looking for food that they can prepare in minutes, they are also concerned about their health and cost. They are paying more attention to ingredients in foods, as well as looking for more organic or natural products with fewer or no synthetic additives. Consumers are also interested in "functional foods", foods that contain ingredients that have an ability to prevent, treat, or mitigate the effects of diseases (Jimenez-Colmenero, Carballo, & Cofrades, 2001). Increased demand for convenient, healthy and low cost meat products has resulted in the development of low-fat sausage products containing alternative protein sources, such as mechanically separated turkey meat (MSTM). Although use of these alternative protein sources reduces the cost of the product, MSTM is highly prone to lipid oxidation due to its method of manufacture and level of unsaturated fatty acids. By-products formed during oxidation can have a negative impact on sensory properties like color, flavor, odor and texture; which are important for overall consumer acceptance. To ensure quality and acceptability of products with MSTM, it has become necessary to use antioxidants that are naturally occurring and appealing to the consumer (Mielnik, Abay, Rolfsen, Ellekjaer & Nilsson, 2002).

This thesis follows the style of *Meat Science*

Lipid Oxidation

Lipid oxidation is the primary cause of sensory quality degradation of attributes such as color, flavor, texture, and odor in meats; especially those that are further processed such as breakfast sausage links (Britt, Gomaa, Gray & Booren, 1998; Yanishlieva & Marinova, 2001; Erickson, 2002; Sebranek, Sewalt, Robins & Houser, 2005). Processed meat products are more susceptible to lipid oxidation due to processing procedures such as mixing, grinding, and chopping which can increase the product temperature and/or exposure to oxygen (Ladikos & Lougovois, 1990; Sebranek et al., 2005). This is a major concern for processors due to the negative impact that lipid oxidation can have on consumer acceptance (Karpinska, Borowski & Oziewicz, 2001). Lipid oxidation is a consequence of a series of complex chemical changes that result from oxygen reacting with lipids (Fennema, Damadaran & Parkin, 2008). The rate of lipid oxidation is affected by the fatty acid composition of a product with unsaturated fatty acids being more susceptible to lipid oxidation (Gray, 1978; Ladikos et al., 1990; Fernandez, Perez-Alvarez & Fernandez-Lopez, 1997; Mercier, Gatellier, Vincent & Renerre, 2001; Yanishlieva et al., 2001; Sebranek et al., 2005). It is well known that pork (51% of the total fat content in pork loin steaks) and poultry (59% of the total fat content of turkey breast) contain a high amount of unsaturated fatty acids, causing them to be more prone to lipid oxidation than beef (36% of the total fat content in beef loin steaks; McCarthy, Kerry, Lynch, Kerry & Buckley, 2001; Mercier et al., 2001; Baggio, Vicente & Bragagnolo, 2002; Wood, Richardson, Nute, Fisher, Campo, Kasapidou, Sheard & Enser, 2003; Sebranek et al., 2005; Jayathilakan, Sharma, Radhakrishna & Bawa, 2007; Capitani, Carvalho, Rivelli, Barros & Castro, 2009). Deterioration in quality due to lipid oxidation has been reported to occur under refrigerated and frozen storage in

both raw and precooked meat products (Ladikos et al., 1990; Mercier et al., 2001; Jayathilakan et al., 2007). Cooking has also been reported to accelerate the onset of lipid oxidation and in precooked pork; it can become noticeable within 48 hours of refrigerated storage at 4°C (Tims & Watts, 1958; Ladikos et al., 1990; McCarthy et al., 2001; Sebranek et al., 2005; Jayathilakan et al., 2007). The addition of synthetic and natural antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and rosemary extract, to meat products is an effective way to control the onset of lipid oxidation and increase product shelf-life (McCarthy et al., 2001; Sebranek et al., 2005; Capitani et al., 2009).

*Mechanism of Lipid Oxidation***:** Lipid oxidation is typically initiated by atmospheric oxygen which has been activated through the formation of singlet oxygen, partially reduced oxygen (hydrogen peroxide, superoxide anion, or hydroxyl radical), or an oxygen-iron complex (Erickson, 2002). However, many other prooxidants, like singlet oxygen, can be present in food products that may accelerate lipid oxidation (Fennema et al., 2008). The mechanism of lipid oxidation is a three phase system; these phases are (Grey, 1978; Fernandez et al., 1997; Yanishlieva et al., 2001):

Initiation:	$In\bullet + RH \rightarrow InH + R\bullet$
Propagation:	$R\bullet + O_2 \rightarrow ROO\bullet$
	$ROO\bullet + RH \rightarrow R\bullet + ROOH$
	$ROOH \rightarrow RO\bullet + \bullet OH$
Termination:	$R\bullet + R\bullet \rightarrow RR$
	$R\bullet + ROO\bullet \rightarrow ROOR$
	$ROO\bullet + ROO\bullet \rightarrow ROOR + O_2$

During initiation a single free alkyl radical (R•; atom with an unpaired electron) is formed by the removal of the hydrogen ion (H) from an unsaturated fatty acid by the

active oxygen species (In•), which forms a hydroxyl radical (•OH). The alkyl radical formed during initiation reacts with one of the two electrons of triplet oxygen that are present in the same orbital, forming a covalent bond thus creating a peroxyl radical (ROO•) in the first step of propagation (Ladikos et al., 1990; Erickson, 2002; Fennema et al., 2008). The peroxyl radical formed in the initiation phase is able to remove another hydrogen ion from a nearby unsaturated fatty acid. This produces a fatty acid hydroperoxide (ROOH) and a free alkyl radical thus propagating the reaction to another fatty acid. The fatty acid hydroperoxide undergoes a branching reaction or "secondary initiation" catalyzed by ferrous iron (Fe^{2+}) producing an alkoxyl radical (RO•) and a hydroxyl radical (Erickson, 2002; Fennema et al., 2008). Propagation interactions can continue 10 to 100 times before two free radicals bond, terminating their ability to remove hydrogen from fatty acid molecules (Erickson, 2002). Termination is the final phase where the free alkyl and peroxyl radicals bond together forming a non radical (RR, ROOR), stopping further lipid oxidation (Erickson, 2002; Fennema et al., 2008).

Secondary Compounds Affecting Sensory Attributes: Secondary compounds produced from the by-products of the propagation phase of lipid oxidation are indirectly responsible for the off-flavors and/or aromas, thus making products unacceptable to consumers. Lipid hydroperoxide is one of those compounds which, through their decomposition, produce a fatty acid alkoxyl radical which may be separated through β-scission, resulting in volatile compounds causing rancidity (Grey, 1978; Ladikos et al., 1990; Erickson, 2002; Jayathilakan et al., 2007; Fennema et al., 2008). Singlet oxygen is a prooxidant that aids in the production of lipid hydroperoxides. It can react with either carbon position in a double bond, resulting in the production of hydroperoxides with

various chemical structures. These hydroperoxides will produce different alkoxyl radicals which will decompose into volatile compounds contributing unique off-flavor and aromas. Prooxidants such as transitional metals, ultraviolet and visible light and elevated temperatures all promote the decomposition of hydroperoxides (Fennema et al., 2008). Transitional metals (iron and copper being the most common) are considered one of the major decomposers of hydroperoxides through the branching reaction of propagation as explained previously (Erickson, 2002; Fennema et al., 2008). The β-scission reaction cleaves the aliphatic chain of the fatty acid at the carbon-carbon bond adjacent to the bond site of the alkoxyl radical (Ladikos et al., 1990; Erickson, 2002; Fennema et al., 2008). This occurs due to the alkoxyl radicals' ability to extract an electron from the covalent bond, producing an alkyl radical and an aldehyde (Fennema et al., 2008). Aldehydes that are produced can undergo further oxidation if they are unsaturated and greatly impact off-flavor and aroma development (Ladikos et al., 1990; Erickson, 2002; Fennema et al., 2008). They also can react with other components such as sulfhydryls and amine groups in proteins altering their functionality (Hettiararchchy, 1996; Fennema et al., 2008).

Health Effects of Lipid Oxidation: Lipid oxidation has many negative effects on food products specifically producing rancid flavors and aromas through the production of secondary compounds. Along with that, the consumption of products which have undergone lipid oxidation is thought to negatively affect health in humans (Ladikos et al., 1990). Lipid hydroperoxides and by-products of decomposition may cause damage to proteins and membranes affecting cell functions and to the mucous membranes of the digestive tract (Ladikos et al., 1990; Karpinska et al., 2001; Jayathilakan et al., 2007).

Malonaldehyde specifically has been implicated as catalysis for the formation of N-nitrosamines and may cause mutagenesis (Ladikos et al., 1990). Other secondary products of lipid oxidation may serve as chemical toxicants and are believed to cause deteriorative processes in humans such as aging, and interfere with protein and folic acid absorption (Ladikos et al., 1990; Britt et al., 1998; Karpinska et al., 2001; Jayathilakan et al., 2007). Peroxides and oxidized cholesterol are thought to increase the onset of tumors and atherosclerosis (Ladikos et al., 1990; Britt et al., 1998; Karpinska et al., 2001; Yanishlieva et al., 2001). Thus, to prevent the possible ill health effects due to lipid oxidation, maintaining the oxidative stability of meat products becomes especially important (Karpinska et al., 2001; Yanishlieva et al., 2001).

Lipid Oxidation Assays: Acceptable chemical (peroxide value, kreis test, thiobarbituric acid test, total and volatile carbonyl compounds) and physical (conjugated diene, fluorescence, infrared spectroscopy, polarography, gas chromatography, and refractrometry) methods are available for determining the degree of lipid oxidation in meat products, by measuring either primary or secondary products of lipid oxidation (Grey, 1978; Ladikos et al., 1990; Fernandez et al., 1997). However, their acceptability is dependent on the type of product and the processing and storage conditions for that product (Ladikos et al., 1990). According to Grey (1978) there are four questions that must be answered to determine the usefulness of a test which measures the degree of lipid oxidation: (1) would the property being measured occur under conditions other than oxidation? (2) Is the property being measured found in all oxidizing systems? (3) Is the method specific for that property? (4) Does the property adequately represent the degree of oxidation? Currently, there are three techniques used frequently to determine

lipid oxidation in meat systems: determination of peroxide value, malonaldehyde, and hexanal content (Fernandez et al., 1997).

The most commonly used method for determining lipid oxidation in meats is the 2-thiobarbituric acid (TBA) or thiobarbituric acid reactive substances test (TBARS) test (Grey, 1978; Ladikos et al., 1990; Fernandez et al., 1997). This method determines the amount of malonaldehyde, a three-carbon dialdehyde containing carbonyl groups at the C_1 and C_3 positions, either in the whole food product, in extracted fat, or in a distillate (Grey, 1978; Ladikos et al., 1990; Fernandez et al., 1997; Capitani et al., 2009). The distillation method suggested by Tarladgis, Watts and Younathan (1960) is the most common modification of the TBA method performed on meats (Ladikos et al., 1990). This modification of the TBA test involves heating the sample with anti-oxidizing agents and acid to aid in the removal of malonaldehyde, the volatile compound thought to produce the rancid sensory attributes. Then 50 ml of distillate is collected in a graduated cylinder, of which 5 ml is combined with 5 ml of TBA reagent and then heated for 35 min to develop the pink pigment. After the 35 min the sample is cooled in a water bath for 10 min, prior to being place into a cuvette to have the absorbance read in a spectrophotometer at 530 nm (Tarladgis et al., 1960; Grey, 1978). A strong correlation between sensory attributes and TBA values has been reported, adding to the acceptability of this test (Ladikos et al., 1990). Oxidized flavors were detected at TBA values of 0.3 to 1.0 in beef or pork, 1.0 to 2.0 in chicken, and 3.0 in turkey (Melton, 1983; Fernandez et al., 1997). However, these should not be considered thresholds because TBA values are also influenced by animal age, diet, and whether the product is raw or cooked, not solely by animal species (Fernandez et al., 1997). It has been noted that during the distillation, the acid and heat treatments changed the structure of the TBA

reagent, thus making it necessary to run blank samples in conjunction with meat samples (Grey, 1978). Tarladgis et al., (1960) also noted that the greatest amount of malonaldehyde was extracted in the first 50 ml of distillate. The oxidation of unsaturated fatty acid samples is typically measured as a red pigment at 532-535 nm that results when two molecules of TBA condense with one molecule of malonaldehyde (Tarladgis et al., 1960; Grey, 1978; Fernandez et al., 1997). However, yellow pigments also have been observed by Johansson during a study of TBA reactions with various aldehydes (Grey, 1978). Patton (1974) found the reaction of TBA with aldehydes that are not true products of oxidation produced these yellow pigments at different heat sensitivities, leading him to conclude that yellow pigments are not a true monitor of oxidative rancidity (Grey, 1978). Tarladgis et al., (1960) stated that the distillation method posed several advantages; one being that malonaldehyde is obtained in a clear aqueous solution separate from the reaction product. Rhee (1978) took this method a step further with the addition of propyl gallate (a phenolic antioxidant) and ethylenediaminetetraacetic acid (EDTA) to minimize any further oxidation of samples during distillation and extraction. Also, there is less likelihood for the product to further oxidize during the test. Other methods used for determining malonaldehyde content include ultraviolet spectrophotometry, HPLC, and gas chromatography (Fernandez et al., 1997).

Determining lipid oxidation on primary compounds such as oxygen uptake, loss of polyunsaturated fatty acids, and the formation of hydroperoxides are typically performed on raw products stored at low temperatures and generally, these have low levels of oxidation (Ladikos et al., 1990). Peroxide value measures the extent of oxidation by quantifying hydroperoxides, although this method is limited due to the transitory nature of the peroxides that are intermediates of carbonyl formation (Grey,

1978; Fernandez et al., 1997). The vulnerable state of peroxides to further reactions during and after lipid oxidation limits these tests to the early stages of oxidation (Grey, 1978). Peroxide value is commonly used on products such as edible tallow, margarine, shortenings, and frying fats. However, peroxide values can be determined on fats from meat, meat products, and meat meal. These fats must first be extracted with a solvent such as chloroform. The degree of rancidity from fats which originate from meats are generally determined through the combination of methods such as peroxide value and thiobarbituric acid (TBA) or by TBA itself. This is mainly due to the high iron content of meat and its ability to catalyze lipid oxidation (Peroxide Value, 1997). Two ways of determining peroxide value are the iodometric method of Lea and Wheeler and colorimetric method of Swoboda and Lea (Grey, 1978; Fernandez et al., 1997). The iodometric method measures the amount of iodine produced by potassium iodide and the present peroxides of the product. The addition of starch solution causes a reaction with amylase giving the sample a blue color which can then be read on a spectrophotometer (Grey, 1978). Although different compounds are measured with TBARS and peroxide value, these two analyses have been reported to have a linear correlation (Grey, 1978; Fernandez et al., 1997). However, it was also reported that while TBARS values increased past the threshold for acceptability, peroxide values were still low (Tarladgis et al., 1960; Fernandez et al., 1997). Thus, TBARS would be a better indicator of lipid oxidation for research studies that include long shelf-life studies.

Antioxidants

Antioxidants are widely used to prevent degradation of food products by inhibiting or delaying oxidation (Moreno, Scheyer, Romano & Vojnov, 2006). Naturally occurring

antioxidants can already be present in foods, although some processing procedures can remove or overwhelm these compounds (Fennema et al., 2008). As a consequence, antioxidants are becoming important additives in foods, especially processed meats (Erickson, 2002; Fennema et al., 2008). The use of antioxidants in processed meat products is necessary to maintain quality for consumer acceptability and may be categorized as synthetic or natural (Mielnik et al., 2002).

Synthetic vs. Natural Antioxidants: Currently synthetic antioxidants, such as butylated hydroxyanisole (BHA) butylated hydroxytoluene (BHT), tertbutly hydroquinone (TBHQ), tocopherol, ethylenediamine tetraacetic acid (EDTA), citric acid, and phosphates, are commonly used to reduce the effects of lipid oxidation (Ladikos et al., 1990; Karpinska et al., 2001; McCarthy et al., 2001; Sallam, Ishioroshi & Samejima, 2004; Capitani et al., 2009). The United States Department of Agriculture regulates the inclusion of BHA, BHT, and other synthetic antioxidants at 0.01% alone or 0.02% combined, based on fat content of fresh products or total weight of dried products (Sebranek et al., 2005). Due to research findings that have shown, BHA at dietary levels of 2, 1, and 0.5% and BHT at dietary levels of 0.5% developing of lesions in the fore stomach and tumors on the livers of rats (Shahidi & Wanasundara, 1992; Iverson, 1995; McCarthy et al., 2001). Replacement of synthetic antioxidants with natural alternatives such as rosemary extract has increased because of these potential negative health effects and consumer perception (Palic & Lucan, 1995; Karpinska et al., 2001; Yanishlieva et al., 2001; Nassu, Aparecida, Goncalves, Silva & Beserra, 2003; Sebranek et al., 2005; Jayathilakan et al., 2007; Capitani et al., 2009). In some countries, synthetic antioxidants are prohibited; for

example Brazil is one of these countries and rosemary extract is the most commonly used antioxidant (Nassu et al., 2003).

Natural antioxidants are derived from many sources especially plants, fruits, vegetables, nuts, seeds, leaves, spices, and herbs (Yanishlieva et al., 2001; Jayathilakan et al., 2007). Plant phenolics are becoming of greater interest due to their multifunctional properties, acting as reducing agents, free radical terminators, chelators of metal ions, and inhibitors of singlet oxygen (Jayathilakan et al., 2007; Capitani et al., 2009). Vitamin E (α-tocopherol) is one of the best known phenolic antioxidants which can be added to an animal's diet to inhibit subsequent oxidation of a meat product (Faustman, Cassens, Schaefer, Buege, Williams & Scheller, 1989; McCarthy et al., 2001). One natural antioxidant that has been researched extensively and found to be effective in meat products is rosemary extract (Yanishlieva et al., 2001; Formanek, Lynch, Galvin, Farkas & Kerry, 2003; Sebranek et al., 2005). The effectiveness of rosemary as an antioxidant is related to its phenolic content, which acts similarly to the synthetic phenolic antioxidants (McCarthy et al., 2001). Phenols are an important group of natural antioxidants and are known to protect easily oxidative foods (Lindberg, Andersen, Christiansen, Brockhoff & Bertelsen, 1996; Karpinska et al., 2001). Studies of natural antioxidants in various systems and under different storage conditions have shown natural antioxidants to be either less superior or more superior to synthetic antioxidants (Jayathilakan et al., 2007). For example, in cooked beef rosemary extract was less effective than BHA or BHT (Ahn, Gruen & Fernando, 2002). However, Yu, Scanlin, Wilson & Schmidt, (2002) found that in cooked turkey rolls rosemary extract was effective for inhibiting lipid oxidation. Sebranek et al. (2005) stated that rosemary extract is a suitable alternative to synthetic antioxidants, specifically in raw frozen

sausage products. In cooked meats from sheep, beef, and pork refrigerated at 5°C for 6 days, it was shown that cloves had a greater antioxidant ability ($P<0.05$) than BHA or propyl gallate, and that clove addition decreased oxidation and warmed over flavor development. This suggests spices and herbs could have positive effects on controlling oxidation of lipids (Barbut, Josephson & Maurer, 1985; Jayathilakan et al, 2007). Natural antioxidants are gaining acceptance and their use for suppressing lipid oxidation is becoming more promising. Although they are more expensive than synthetic antioxidants, there is still a demand for their use by consumers (Yanishlieva et al., 2001).

Antioxidant Mechanisms: Antioxidants function to delay the rate of lipid oxidation or reduce total oxidation (Erickson, 2002). There is not a single definition of an antioxidant due to the various ways in which oxidation can be inhibited (Fennema et al., 2008). Various substances and conditions could be perceived as antioxidants, although there are three main classifications (Ladikos et al., 1990). Among these are free radical inhibitors, prooxidant controllers, and intermediate suppressors (Shelton, 1959; Ladikos et al., 1990; Cadenas, 1997; Huang, Ou & Prior, 2005; Fennema et al., 2008).

Free Radical Inhibitors: Free radical inhibitors or free radical scavengers (FRS) slow lipid oxidation by donating a hydrogen ion to an alkyl (R•), peroxyl (ROO•) or alkoxyl (RO•) free radical before they are able to remove a hydrogen ion from an unsaturated fatty acid (Shelton, 1959; Ladikos et al., 1990; Cadenas, 1997; Yanishlieva et al., 2001; Huang et al., 2005; Fennema et al., 2008). This reaction is presented as follows: (R•, ROO• or RO•) + FRS → (RH, ROOH or ROH) + FRS• (Huang et al., 2005; Fennema et al., 2008). The resulting free radical scavenger radical has a low molecular energy which makes it

less likely to participate in oxidation (Yanishlieva et al., 2001; Fennema et al., 2008). This is explained by the fact that any radical requires a higher reduction potential than an opposing molecule to remove a hydrogen ion. As a result, free radicals with high energy react faster than those with low energy (Fennema et al., 2008). Free radical scavenger radicals also undergo termination with other free radical scavenger radicals or free radicals (Shelton, 1959; Yanishlieva et al., 2001; Fennema et al., 2008). Overall, one free radical scavenger is capable of inactivating two free radicals, one by donating hydrogen and another through termination (Fennema et al., 2008).

Prooxidant Controllers: Prooxidant controllers inhibit the activity of transitional metals, singlet oxygen, and enzymes that can affect the rate of lipid oxidation (Fennema et al., 2008). The prooxidant activity of transitional metals is reduced by metal complexing agents known as chelators which prevent the redox cycle, occupy the reactive sites on the metal, form insoluble metal complexes, and/or interrupt reactions between metals and lipids or intermediate compounds (Shelton, 1959; Ladikos et al., 1990; Fennema et al., 2008). The effectiveness of metal chelators is dependent on the ratio of metal to chelator. Thus, if there is more metal present, the chelator may increase the oxidative reaction instead of decreasing it. The main chelators used contain carboxylic acid or phosphate groups. Examples of these are citric acid, EDTA, and polyphosphates (Fennema et al., 2008).

Singlet oxygen is a highly reactive state of oxygen that promotes the formation of lipid hydroperoxides. Carotenoids can control singlet oxygen through two pathways, one chemical and one physical. The chemical reaction takes place when singlet oxygen attaches to the carotenoid at its double bonds, creating an oxygenated form of the

carotenoid; which can then break down secondary compounds like aldehydes. The physical reaction is a donation of electrons to singlet oxygen creating triplet oxygen and a carotenoid in an excited state, which can revert back to a carotenoid (Fennema et al., 2008).

Enzyme systems that can increase lipid oxidation are lipoxygenases. They are common in plants and animals and are controlled through heat deactivation and selective breeding to reduce the concentration (Fennema et al., 2008).

Intermediate Suppressors: Intermediate compounds such as superoxide anions and peroxides can affect the rate of lipid oxidation by interacting with prooxidants. Superoxide anions can either reduce transitional metals into an active state or release one bound to proteins. This is reduced by superoxide dismutation (SOD) which converts the superoxide anion into hydrogen peroxide. Peroxides interact with transitional metals to form free radicals. Their inactivation is performed by the enzyme systems; catalase breaks down hydrogen peroxide and glutathione peroxidase can breakdown lipid hydroperoxides and hydrogen peroxide (Fennema et al., 2008).

Phenolics: Phenolic compounds occur naturally in fruits and vegetables and have been shown to act as antioxidants suppressing lipid oxidation. They are organic compounds consisting of one or more hydroxyl groups on their aromatic ring (Lule & Xia, 2005). Phenolics are effective free radical scavengers as they are able to donate hydrogen from their hydroxyl group leaving a phenolic radical which is delocalized. This effectiveness is increased with the addition of substitution groups on the phenolic ring increasing their hydrogen donation capacity and the stability of the phenolic radical (Lule et al., 2005;

Fennema et al., 2008). Synthetic phenols butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and others are substituted monophenolic compounds, making them stronger antioxidants than a single phenol. Also synthetic phenolics are not readily reactive to oxygen, but readily catalyze free radical termination (Fennema et al., 2008). Natural phenolics include simple phenolics, phenolic acids, anthocyanins, hydroxycinnamic acids, and flavonoids. These can be found throughout plants, fruits, spices, seeds and grains (Lule et al., 2005; Fennema et al., 2008). Several factors such as the position and degree of hydroxylation, polarity, solubility, reducing potential, and the stability during and after processing can affect the antioxidant ability of phenolic compounds. Rosemary extract is a good example of natural phenolics used in the food industry to inhibit lipid oxidation (Fennema et al., 2008).

Rosemary

Rosmarinus officinal, commonly known as rosemary, is of the *lamiaceae* or *labiatae* family and one of the better known herbs for its distinctive flavor and taste in foods (Palic et al., 1995; Ho, Wang, Wei, Huang & Huang, 2000; Riznar, Celan, Knez, Skerget, Bauman & Glaser, 2006). Rac & Ostric-Matijasevic (1955) presented the idea of using extracts from rosemary as antioxidants. Later vacuum distillation of these extracts was developed by Chang, Ostric-Matijasevic, Hsieh & Huang, (1977) (Wu, Lee, Ho & Chang, 1982). This extraction process is performed on rosemary that has been finely ground, with an organic solvent of high polarity typically methanol or ether. The rosemary is dissolved with the solvent and bleached with active carbon which is then filtered and results in a purified antioxidant (Chang et al., 1977). Rosemary extracts used in the food industry are also becoming more readily available in markets, most

likely because of their natural origin and GRAS (Generally Recognized as Safe) status. However, rosemary extracts can be rather costly (Coronado, Trout, Dunshea & Shah, 2002; Riznar et al., 2006). Whole rosemary and extracts thereof have been a main focus in many studies to examine their antioxidant ability (Riznar et al., 2006). The antioxidant activity has been demonstrated in both animal and vegetable fats (Chang et al., 1977; Wu et al., 1982). There has also been interest on isolating compounds responsible for rosemary's powerful antioxidant ability (Riznar et al., 2006). Rosemary has been reported to positively affect the color and sensory scores by reducing lipid oxidation (Chang et al., 1977; Sebranek et al., 2005; Riznar et al., 2006; Yanishlieva, Marinova & Pokorny, 2006). Along with antioxidant effects, there has been research suggesting that rosemary extract possesses antimicrobial properties (Riznar et al., 2006).

Antioxidant Capacity: The antioxidant capacity of rosemary is determined by the active oxygen method (AOM), rancimat method, or electrochemical methods (HFK, HPLC; Palic et al., 1995). The antioxidant capacity of rosemary extracts has been the focus of resent studies (Yanishlieva et al., 2006). Although there has been some variation between the reported antioxidant ability of rosemary extracts in many studies, researchers are lead to believe that rosemary extracts function has hydrogen donors (Sebranek et al., 2005; Yanishlieva et al., 2006). The radical scavenging activity of rosemary leaves and flowers contain the most antioxidant ability and have been found comparable to BHT (Nassu et al., 2003; Sebranek et al., 2005; Moreno et al., 2006). Palic et al. (1995) compared rosemary extract to BHA at 0.01, 0.02, and 0.03% ratios in sunflower oil, which showed rosemary to be less effective than BHA. However, at higher

levels of rosemary extract, it showed a linear increase of rosemary's ability to inhibit lipid oxidation. Also, the use of 0.02% rosemary extract in oils has been shown to be comparable to BHT and reduce photo oxidation while increasing flavor stability (Chang et al., 1977; Wu et al., 1982). In a study conducted on chicken frankfurters, it was noted that the use of rosemary extracts was able to inhibit the formation of primary and secondary products of lipid oxidation. This inhibition extended shelf-life twice as long as the control at storage temperatures of 4, 12, and 25°C, and was generally more effective than a commercial preservative (Riznar et al., 2006). Another study indicated that rosemary along with phosphates and salt were comparable to the antioxidant ability of BHA and BHT (Coronado et al., 2002). Other studies have reported that the addition of rosemary extract in products such as turkey sausage, restructured beef, and precooked roast beef suppressed the rate of lipid oxidation and extended the shelf-life (Coronado et al., 2002; Nassu et al., 2003). The combination of rosemary extract with other compounds, ascorbic acid for example, can have potential synergistic effects increasing antioxidant ability (Chang et al., 1977; Yanishlieva et al., 2006).

Phenolic Composition: The great antioxidative effect of rosemary is due to its high phenolic content of monoterpenes, diterpenes, phenolic acids, flavonols, and triterpene acids (Moreno et al., 2006; Riznar et al., 2006). As many as twelve diterpenes have been isolated from rosemary and all have shown antioxidant activity. Carnosic acid, one of the twelve diterpene phenolics, is one of the main antioxidant compounds found in rosemary extract accounting for greater than 90% of the antioxidant activity (Ho et al., 2000). This acts by stabilizing unsaturated fatty acids, thus reducing their decomposition (Wu et al., 1982; Riznar et al., 2006; Yanishlieva et al., 2006). It was originally thought

to be a bitter note of rosemary, but was later determined to be an odorless and tasteless component (Wu et al., 1982). In analysis of rosemary leaf extract, rosmarinic and carnosic acid were found in greater quantity than the flowers or branches of rosemary (Moreno et al., 2006). Carnosic acid has been shown to be as strong as or stronger than synthetic antioxidants like BHA and BHT (Ho et al., 2000; Riznar et al., 2006). Additionally, carnosic acid possesses antimicrobial, anticancer, and antimutagenic effects (Riznar et al., 2006). Caffeic and rosmarinic acid are two other powerful antioxidant phenolic compounds that are found in greater quantities in rosemary (Moreno et al., 2006).

Health Benefits: Rosemary extracts, specifically rosmarinic acid, were suggested to have potentially positive dietary and therapeutic effects against human diseases. However, there is little reported research that elaborates on the clinical use of rosemary extracts. On the other hand, studies on carnosic acid and carnosol have shown anti-inflammatory and anti-tumor effects (Moreno et al., 2006). Topical and dietary application of rosemary extract inhibited growth of skin and intestinal tumors in mice (Ho et al., 2000).

Plum

Dried plums, commonly known as prunes, are reported to have a good antioxidant capacity which is related to their high phenolic content (Gil, Barberan, Pierce & Kader, 2002; Kayano, Kikuzaki, Fukutsuka, Mitani & Nakatani, 2002; Piga, Caro & Corda, 2003; Cevallos-Casals, Byrne, Okie & Zevallos, 2006). Prunes (*prunus domestica*) produced in California are roughly 67% of the world's supply and are of the *rosaceae* family (Donovan, Meyer & Waterhouse, 1998; Fang, Yu & Prior, 2002). Plum

and prune derived food ingredients are known to function as fat replacers and flavorings (Nunez, Hafley, Boleman, Miller, Rhee & Keeton, 2008a). Chemical compounds in plums such as pectin, malic, and sorbitol acids can help retain moisture and enhance flavor. The USDA has approved the use of dried plum puree in ground beef for the school lunch program because of its ability to retain moisture (Nunez, Hafley, Boleman, Miller, Rhee & Keeton, 2009). Dried plum products have been shown to darken the color of products due to its brown pigment (Lee & Ahn, 2005; Nunez et al., 2008a, 2009). The processing of fresh plums to prunes is thought to degrade the phenolic compounds by half, as well as decrease ascorbic acid content and results in a loss of vitamin C (Donovan et al., 1998; Piga et al., 2003). Despite loss in phenolic content, dried plums still possess high antioxidant capacity (Piga et al., 2003).

Antioxidant Capacity: Plums are known to have a relatively high antioxidant capacity (Gil et al., 2002; Kayano et al., 2002). Oxygen radical absorbance capacity (ORAC) is a common method used to measure the antioxidant capacity of fruits, such as plums (Kayano et al., 2002; Leheska, Boyce, Brooks, Hoover, Thompson & Miller, 2006). Other methods include diphenyl-1-picrylhydrazyl (DPPH) concentration, which evaluates free radical scavenging capacity, and ferric ion reducing antioxidant power (FRAP) which evaluates iron reducing capacity (Gil et al., 2002). Researchers at Tufts University have shown that dried plums have an ORAC value of 5770, the highest of twenty two of the most common fruits and vegetables (Castaldi & Degen, 2003; Leheska et al., 2006; Nunez, Boleman, Miller, Keeton & Rhee, 2008b). Plums have shown to be good free radical scavengers of hydroxyl and peroxyl radicals (Kim, Jeong & Lee, 2003). Gil et al. (2002) noted that a 100g serving of plums contains 33-55% of the antioxidant capacity of

a 100 ml glass of red wine. Nunez et al. (2008b) reported that the use of a dried plum puree at 3 and 6% in pork sausage products was as effective at suppressing lipid oxidation as BHA and BHT (Leheska et al., 2006). Similar results have been seen in precooked pork patties containing 3% dried plum puree. The use of fresh or dried plums has been shown to decrease TBARS values and extend the shelf-life of precooked roasts (Nunez et al., 2008a). This has also been reported in irradiated turkey breast rolls containing 2% plum extract (Lee et al., 2005). Cavallos-Casals et al. (2006) reported that fresh plums had an antioxidant ability 91% higher than that of blueberries, while dried plums only showed 36% higher antioxidant activity. Plums have also been shown to have 4.4 time's higher antioxidant capacity than apples and a higher total phenolic content, which may influence the antioxidant capacity (Kim et al., 2003). Piga et al. (2003) reported that drying plums at 85°C tended to increase the antioxidant capacity as compared to plums dried at 60°C. This was most likely caused by maillard reaction products that can be present in plums.

Phenolic Composition: Phenolic compounds and flavonoids contribute to the antioxidant properties of fruits and vegetables (Ko, Choi, Ye, Cho, Kim & Chung, 2005; Nunez et al., 2008b). Plums are rich in phenolic compounds ranging between 42 – 109 mg per serving, although the phenolic content varies between plum species (Gil et al., 2002). Leheska et al. (2006) reported that dried plum puree had a higher level of total phenolics as compared to a blueberry puree, possibly enhancing its antioxidant capacity. Polyphenolic composition in fruits includes hydroxycinnamates, flavan-3-ols, gallic acid derivatives, flavonols, and anthocyanins, all of which are thought to contain antioxidant abilities (Fang et al., 2002; Gil et al., 2002). The peel or rind of fruits is thought to

contain concentrated amounts of phenolics, anthocyanins, and flavonols in comparison to the flesh (Gil et al., 2002; Cevallos-Casals et al., 2006). Hydrocinnamic acids have been found in plums at high concentrations in their esterified form consisting of 84-90% of the total phenols (Donovan et al., 1998; Piga et al., 2003; Olsson, Gustavsson, Andersson, Nilsson & Duan, 2004). Chlorogenic and neochlorogenic acids are the two main phenolic compounds which contribute to the antioxidant ability of dried plums (Fang et al., 2002; Kayano et al., 2002; Castaldi et al., 2003; Piga et al., 2003). Chlorogenic acid was reported to scavenge reactive oxygen and nitrogen species to inhibit oxidation (Fang et al., 2002; Kayano et al., 2002; Piga et al., 2003). It was shown that the antioxidant capacity of chlorogenic acid is higher than vitamin C and E based on the Trolox equivalent antioxidant capacity test (Kayano et al., 2002). Cevallos-Casals et al. (2006) reported that plum phenolics had some antimicrobial capacity and were more effective against *Salmonella* Enteritidis than *Escherichia* Coli O157:H7.

Health Benefits: Prunes are considered a healthy food and have been used in India with medications to aid in the treatment of leucorrhea, irregular menstruation, and following miscarriage (Fang et al., 2002; Kayano et al., 2002). The high fiber content of prunes has been shown to lower low density lipoprotein (LDL) cholesterol in human plasma (Donovan et al., 1998; Kayano et al., 2002). Snack foods containing dried plums have been shown to suppress appetites by producing less glucose or appetite-regulating hormones (Furchner-Evanson, Petrisko, Howarth, Nemoseck, & Kem, 2009). Consumption of prunes reduced hypercholesterolemia and bone density loss in rats (Kayano et al., 2002). Antioxidant extracts from plum have been shown to reduce the proliferation of breast and colon cancer cells *in vitro* (Olsson et al., 2004). The

chlorogenic acid polyphenols of dried plum have been shown to possess anti-inflammatory and anti-oxidative properties in macrophage cells (Kumar, Hooshmand, & Arjmandi, 2009). Prunes are also known to reduce the glycemic index, slow osteoporosis, control lipoidoproteinosis and help regulate the digestive system in humans (Piga et al., 2003; Howarth, Petrisko, Furchner-Evanson, Nemoseck, & Kem, 2009).

Mechanically Separated Poultry Meat

Consumption of poultry meat has increased recently due to consumers purchasing more products that are considered healthy and are lower cost (Pettersen, Mielnik, Eie, Skrede & Nilsson, 2004). Increased demand for poultry has increased the use of materials from hand deboning which can go through an automated process to further harvest any remaining meat. This product is known as mechanically separated or mechanically deboned poultry meat (MSPM) with meat yields ranging from 55 to 80% from the hand deboned carcass (Mielnik et al., 2002; Pettersen et al., 2004; Negrao, Mizubuti, Morita, Colli, Ida & Shimokomaki, 2005). Mechanically separated poultry meat or mechanically separated turkey meat (MSTM) is used in processed meat products such as frankfurters, fermented sausages, restructured products, and breakfast sausages (Williams, Lee, Sloan & Littell, 1997; Mielnik et al., 2002). MSPM has a smooth consistency and is relatively inexpensive (Pettersen et al., 2004; Pussa, Pallin, Raudsepp, Soidla & Rei, 2008). Generally, MSPM from turkey is darker in color due to the higher myoglobin content as compared to chicken (Mielnik et al., 2002). The main limitation of MSPM is its increased susceptibility to lipid oxidation, resulting in off-flavors and odors (Williams et al., 1997; Mielnik et al., 2002; Mielnik, Aaby & Skrede, 2003;

Pettersen et al., 2004). Lipid oxidation is due to exposure to air and mechanical action during processing, with subsequent exposure to unsaturated fatty acids inherent to poultry (Mielnik et al., 2002, 2003; Pettersen et al., 2004; Pussa et al., 2008).

Fatty Acid Composition: The inclusion of bone marrow in the processing of mechanically separated poultry increases the cholesterol and phospholipid content in the final product (Mielnik et al., 2002, 2003; Pussa et al., 2008). MSPM contains 10 times more polyunsaturated fatty acids and more hemoproteins than hand-deboned poultry meat (Pussa et al., 2008). Total fatty acid content of MSPM ranges from 13.8 to 17.2% (Mielnik et al., 2003; Pettersen et al., 2004). The primary unsaturated fatty acid categories present in MSPM are ~34.4% monounsaturated and ~25.8% polyunsaturated, that consisting mainly of ~29.3 to 38.3% oleic acid (C18:1) followed by ~17.8 to 20.9% linoleic acid (C18:2) and ~ 20.3 to 26% palmitic acid (C16:0; Mielnik et al., 2003; Pettersen et al., 2004). The susceptibility to lipid oxidation increases with increasing numbers of C-C double bonds (Pussa et al., 2008). Thus, MSPM having mainly unsaturated fatty acids has increased oxidation potential (Mercier et al., 2001; Pussa et al., 2008).

Lipid Oxidation: Lipid oxidation has been shown to increase during frozen storage of MSPM, thus decreasing its functionality. The prevention of lipid oxidation in products containing MSPM is performed by the addition of antioxidants or through packaging that reduces oxygen (Mielnik et al., 2002, 2003; Pettersen et al., 2004). Pussa et al. (2008) has demonstrated this with the addition of sea buckthorn berry residue at 1, 2, and 4% in cooked MSPM stored at 6°C for 6 days. Mielnik et al. (2003) investigated the use of

various levels of antioxidants added to raw MSPM and stored for up to 7 months, showing a significant decrease in oxidation for all antioxidants tested at all levels when compared to a control with no antioxidant. Several studies have looked at different packaging procedures to enhance the shelf-life of MSPM and showed that vacuum and modified atmosphere packaging had a positive influence on suppressing lipid oxidation over storage (Pettersen et al., 2004).

Summary of Literature

Consumers demand for inexpensive convenient, foods that are also considered healthy has resulted in the development of meat and poultry products containing alternative protein sources, such as mechanically separated poultry meat (MSPM). MSPM increases the unsaturated fatty acid content of a processed meat product and reduces costs. However, it increases the products susceptibility to lipid oxidation. This makes control of lipid oxidation by suppression of free radicals and their resulting by-products necessary to maintain quality. The use of antioxidants retards or inhibits lipid oxidation and natural antioxidants like rosemary extract and dried plums possess equal to if not greater antioxidant capacity when compared to the synthetic antioxidants.

CHAPTER II

MATERIALS AND METHODS

Non-Meat Ingredients

Dried plum powder (Low moisture prune powder (3.5 g moisture, 3.0 g protein, 0.5g fat, 45 g total sugar, per 100 g sample) , Sunsweet Growers Inc., Yuba City, CA), packaged in a sealed plastic lined cardboard box and stored at an ambient temperature, was the principle antioxidant used in the study. A liquid rosemary extract (Herbalox Type HT-25, Kalsec Inc., Kalamazoo, MI) was used at 0.05% in the treatment formulations for comparison to, and to test for possible synergistic effects with the dried plum powder. Fresh sausage seasoning (pork sausage seasoning (no salt), blend of spices and sugar, blend RF-08-058-000) and encapsulated salt were provided by AC Legg Inc. (Longview, TX). DeWied Inc. (San Antonio, TX) collagen casings (19mm clear) were purchased and used in this study.

Raw Material Preparation

Fresh lean turkey (boneless, skinless young turkey breast half without ribs, NAMP P2015, Cargill, Waco, TX) and partially frozen mechanically deboned turkey meat (MDTM, Cargill, Wichita, KS) were shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University (College Station, TX). Once received, random samples were taken from the turkey breast and MDTM, and ground (Biro Model 10-56, Biro Mfg. Co. Marblehead, OH) separately through a 1.3cm plate, placed in Whirl Pak® bags, then analyzed for fat, moisture, and protein content prior to sausage formulation. The remaining turkey breast was portioned into 12.3 kg lots, vacuumed

packaged, and stored frozen (-23°C) until used. The MDTM was cut into 5.1 x 10.2 cm blocks (Biro Meat Saw model# 44, Biro Mfg. Co. Marblehead, OH), vacuum packaged and stored frozen (-23°C) until used.

Turkey Sausage Link Manufacture

Control batches were formulated with 80% turkey breast (10.89 kg) and 20% MDTM (2.72 kg) for the meat block with no added antioxidant (Table 1). Treatment batches were formulated with 80% turkey breast and 20% MDTM for the meat block with either dried plum powder at 3% (0.41 kg), rosemary extract at 0.05% (0.009 kg), or a combination of dried plum powder (3%) and rosemary extract (0.05%; Table 1). Turkey breasts and MDTM were ground (Biro Model 10-56, Biro Mfg. Co. Marblehead, OH) separately through a 1.3 cm plate. The ground turkey breast, MDTM, and non meat ingredients were then weighted according to the appropriate formulation. The pH and temperature of the turkey breast and MDTM were recorded. All of the rosemary extract and half of the amount of dried plum powder were hand mixed for approximately 30 seconds with the MDTM according to each treatment formulation (Table 1). Ground turkey breasts were mixed for 2 min in a paddle mixer (Butcher Boy Model 150, Lasar MFG Inc., Los Angeles, CA) while encapsulated salt (1%), sausage seasoning (2.3%), and ½ of the ice water slush was added. Next, the hand-mixed MDTM (with rosemary extract, dried plum powder, or both) and the remaining amount of dried plum powder and ice water were added to the paddle mixer and mixed 1 min. Upon completion of mixing, the batter was placed into a plastic meat lug and the batter weight, pH and temperature were recorded. Product was ground a second time through a 0.48 cm grinder plate and the weight, pH, and temperature were recorded. The sausage batter was transferred to

a vacuum stuffer (Handtmann Vacuum Stuffer, Model VF612, Riss, Germany) and stuffed into 19mm clear collagen casings (DeWied Inc., San Antonio, TX). Vacuum stuffer settings were: 100% vacuum, 28 g link portions, 2.5 twists per link and 64 link strands per stuffing cycle. Sample links of both control and treatment sausages were collected for raw protein, moisture, and fat determinations. Sausage links were weighed for stuffing yield, and then placed on plastic trays and crust frozen for 30 min in a -23°C freezer before packaging. Sausage links from the control and treatment batches were divided into 3 groups based on the shelf-life storage conditions, 64 links for raw refrigerated, 150 links for raw frozen, and 130 links for precooked frozen. A total of 3 replications were preformed over 3 consecutive days.

Thermal Processing, Chilling and Cook Yield

Turkey sausage links (130) from the control and each treatment were weighed in groups of 10, placed on a raised wire rack sitting on a sheet pan (18”x13”x1”) then cooked in a gas oven (Kenmore model 665-72012100 ultra bake gas range) to an internal temperature of 74°C according to AMSA (1995) guidelines. Two thermocouples (Omega Thermometer, Model HH501BT, Type T connector, Iron & Constantan) were inserted into the geometric center of two links to monitor product temperature during cooking. Links were re-weighed after cooking and allowed to cool to 22°C before being placed in plastic-lined cardboard boxes layered with plastic coated freezer paper and stored at -23˚C for up to 56 days to determine shelf-life stability. Percent cook yield was determined by dividing the cooked weight by the raw weight then multiplying by 100.

Raw Refrigerated Retail Shelf-Life Study

Sausage links (64) from each control and treatment batch were separated into 4 groups (day 0, 3, 6, and 9) of 16 links each. The groups of 16 links were separated into 2 sub groups (A, B) of 8 links each and were placed styrofoam trays then overwrapped with plastic (Resinite RMF 61-HY stretch film, AEP Industries, Inc., Hackensack, NJ). Samples were stored at 6°C in a cooler under fluorescent lights (Philips F40T12-CWT) at an intensity of 1900 Lux to simulate retail storage. Light intensity was measured using a light probe (Sper, Model 850075, Sper Scientific, LTD, Scottsdale, AZ) attached to an environmental quality meter (Sper, Model 850071, Sper Scientific, LTD, Scottsdale, AZ). The trays were stored for either 0, 3, 6, or 9 days before being removed for analysis. Each sample was analyzed for objective color, pH, lipid oxidation, aerobic plate count (APC) and enumeration of lactic acid bacteria (LAB).

Raw and Precooked Frozen Shelf-Life Study

Raw (150) and precooked (130) sausage links from the control and treatment batches were placed in plastic-lined cardboard boxes layered with plastic coated freezer paper and stored at -23˚C for up to 56 days to determine frozen shelf-life stability. Samples were analyzed on storage days 0, 7, 14, 28, and 56 for objective color, pH, lipid oxidation, and sensory attributes. Additional analyses for precooked frozen links were re-heat yields and shear values.

Microbiological Analysis of Refrigerated Retail Links

At each refrigerated storage period (day 0, 3, 6, and 9), overwrapped sausage link packages from each control and treatment were sanitized by wiping each package with a paper towel, moistened with 70% ethanol. Each package was opened aseptically

using flame sterilized forceps and scalpel. A 10 gram sample was placed into a sterile stomacher bag to which 90 ml of 0.1% peptone diluent was added. The samples were macerated for 2 min using a Stomacher 400 Circulator (Seward Medical, West Sussex, United Kingdom). APCs were determined by plating 1 ml of the sample rinse and 1 ml of the appropriate 10-fold dilutions of the same on Petrifilm™ aerobic count plates (3M Corp., St. Paul, MN). LAB counts were determined simultaneously by dispensing 1 ml of the sample rinse and the appropriate 10-fold dilutions of the same into sterile petri dishes prepared with Lactobacilli MRS Agar (Difco, Detroit, MI) with overlay. Both Petrifilm™ and MRS plates were incubated at 30^{o}C for 72 h before counting and reporting colony forming units (CFU) per gram.

Determination of pH

The pH of refrigerated retail and frozen raw and precooked turkey sausage links was determined using a pH meter (IQ Model IQ150 IQ Scientific Instruments, Inc., Reston, VA) and internal probe (Piercing tip micro probe w/ heavy duty handle, Model PH57-SS, IQ Scientific Instruments, Inc., Reston, VA) calibrated with buffers 4.01 and 7.0.

Proximate Composition

Percent moisture and fat were determined using modified AOAC (2000) air-dry oven and soxhlet ether extraction methods, respectively (AOAC, 2000, 950.46 & 985.15). Raw and precooked turkey sausage links were cut into approximately 1 cm^{3} pieces and submerged in liquid nitrogen with a metal strainer, to freeze the samples. Fully frozen the samples were transferred into a metal waring blender to pulverize the samples. Samples were then placed in Whirl Pak® bags and promptly placed in frozen

storage (-23°C) to prevent thawing and clumping of the frozen powder. Powdered raw and precooked turkey sausage link samples (~2.5 g) were placed in pre-weighed, previously dried paper thimbles (Whatman #2 filter paper) and the thimble plus sample weights were recorded. Samples were dried for 16 h at 100°C, cooled to room temperature in a desiccator, and the dried thimble plus sample weights recorded. Percent moisture was calculated by the difference between wet weight and dried sample weight divided by sample weight. Oven dried samples were then extracted with petroleum ether for 12 h, the thimbles dried for 16 h to remove excess moisture, and percent fat calculated by the difference between dried sample weight and extracted sample weight divided by sample weight. Percent protein was determined by AOAC (2000) method 992.15, using a LECO FP-528 (LECO Corporation, St. Joseph, MI) nitrogen analyzer which vaporized powdered samples of 0.15 gram to release total nitrogen. Percent protein was calculated as 6.25 times the percent nitrogen.

Objective Color Determinations

Color measurements for the refrigerated retail shelf-life (0 ,3, 6 and 9 days at 6^{o}C) were taken on the exterior and interior surfaces of three turkey sausage links from each treatment and control at two points on each link. Color measurements were taken with a Hunter Miniscan XE (Model 45/O-L, Hunter Associates Laboratory, Inc. Reston, VA) using a 1.54 cm aperture, calibrated with white and black standards. CIE *L*, a*,* and *b** color space values were calculated using illuminant A and a 10° observer.

Frozen raw and precooked turkey sausage links were allowed to thaw for 2 h at 6°C. Color measurements for the raw sausages were taken on the exterior and interior surface of three turkey sausage links from each treatment at two places on each link.

Precooked links were only measured internally, due to loosening of the collagen casing following chilling making it difficult to obtain accurate readings. Color measurements were taken with a Hunter Miniscan XE (Model 45/O-L, Hunter Associates Laboratory, Inc. Reston, VA) using a 1.54 cm aperture, calibrated with white and black standards. CIE *L*, a*,* and *b** color space values were calculated using illuminant A with a 10° observer (raw) and D with a 65° observer (precooked).

Lipid Oxidation

Lipid oxidation was determined by the thiobarbituric acid (TBA) test of Tarladgis et al. (1960) as modified by Rhee (1978) on raw refrigerated retail (0 ,3, 6 and 9 days at 6^{o}C) and frozen (0, 7, 14, 28, and 56 days at -23^{o}C) raw and precooked frozen turkey sausage links. Sixty gram samples were taken from each control and treatment links and blended with 90 ml of distilled water and 30 ml of antioxidant solution (0.5% propyl gallate and 0.5% ethylenediamine tetraacetic acid). Thirty grams of the blended samples were collected and combined with 77.5 ml of distilled water and 2.5 ml of 4 N HCl in a Kjeldahl flask. The acidified sample was placed on the distillation unit (Open Kjeldahl Apparatus, Model 21277-02, Labconco. Corp, Kansas City, MO) and 50 ml of distillate was collected. Following distillation, 5 ml of distillate was pipetted into a glass test tube (Pyrex No. 9825) with 5 ml of 0.02 M TBA reagent and heated in boiling water for 35 min to develop the color reaction. Absorbance was measured at 530 nm using an UV-visible spectrophotometer (Model Cary 300 Bio, Varian Instruments, Sugarland, TX). Results were reported as mg of malonaldehyde per kilogram of meat.

Reheated and Held Cooked Yields

Six precooked frozen control and treatment sausage links were sampled in duplicate for re-heat and hold yields. Links were weighed in groups of three and placed on a full sheet pan with a raised wire rack and designated to be held for either 15 or 30 min. Sausage links were re-heated (Hatco Cook & Hold Oven, Model # CSC-10, Hatco Inc., Milwaukee, WI) from a frozen (-23°C) state to an internal temperature of 74˚C and held at temperature for the previously stated time, while being monitored with two thermocouples (Omega Thermometer, Model HH501BT, Type T connector, Iron & Constantan) inserted into the geometric center of two links. After the designated time, the links were removed from the oven and allowed to cool to 22°C before being re-weighed.

Allo-Kramer Shear Force Determinations

Frozen raw turkey sausages were cooked to an internal temperature of 74˚C and allowed to cool to 22°C. Precooked turkey sausage links were re-heated and held at 74˚C according to AMSA (1995) guidelines for 15 and 30 min and allowed to cool to approximately 22°C. Links were cut into 63mm long pieces. The pieces were weighed in grams and shear values were recorded using an Instron Universal Testing Machine (Instron Corp., Canton, MA., U.S.A.) equipped with a 10-blade Allo–Kramer shear compression cell using a 5000-kg load cell with a load range of 5000 kg and a crosshead speed of 500 mm/min. Shear values are reported as Newtons/gram.

Trained Sensory Panel Analysis

A trained descriptive attribute sensory panel was used to evaluate frozen cooked and re-heated turkey sausage links for texture, aromatics, basic tastes, mouth feel, and

aftertastes. Five panelists were selected and trained according to AMSA (1995) guidelines and Meilgaard et al. (2007). Training and ballot development sessions were conducted prior to testing to familiarize the panelist with the attributes of the cooked and re-heated turkey sausage links. Cooked and re-heated turkey sausage samples were evaluated for texture (springiness, fracturability, hardness, cohesiveness, and juiciness), aromatics (cooked turkey lean, cooked turkey fat, plum, rosemary, spice complex, chemical, cardboard, painty, fishy, and other), basic tastes (sweet, salt, bitter, and sour), mouth feel (metallic, spice burn, and astringent), and aftertastes (burn, acid, sour, bitter, sweet, spice, warmed over flavor, and other). All samples were scored using the 15 point Spectrum universal intensity scale (Meilgaard et al., 2007) where 0 = absence of an attribute and 15 = extremely intense. (A sample ballot and attribute table can be found in appendix A and B). Panelists evaluated 24 samples (8 samples per day for 3 days). Frozen turkey sausage links were allowed to thaw for 2 h at 6°C before being cooked to 74°C in a Kenmore (Model 665-72012100) ultra bake gas range monitored by thermocouples (Omega Thermometer, Model HH501BT, Type T connector, Iron & Constantan) according to AMSA (1995), cut into 1.27 cm slices and served to the panelists in plastic serving dishes under red lights. Each panelist was seated in individual testing booths, which were separated from the sample preparation area. Nine samples (3 slices per sample) were given per session (24 hours between sessions) at 10 minute intervals.

Statistical Analysis

Proximate composition, pH, cook yield, microbiological analysis, objective color, lipid oxidation, reheat yields, shear force and sensory data were statistically analyzed as

a completely randomized block design using the Mixed Model procedure of the Statistical Analysis System (Version 9.2, SAS Institute, Inc., Cary, NC). The model for all dependant variables had a fixed effect of antioxidant treatment and a block effect of replication. Data which included repeated measures accounted for the fixed effect of storage day, which was defined as a repeated effect; and the interaction between storage day and antioxidant treatment. Sensory variables were analyzed for a significant interaction between panelist and both antioxidant treatment and storage type (raw or precooked) prior to being pooled across all panelists. Differences between antioxidant treatment means were separated with Tukey's studentized range test only when significant ($P < 0.05$) differences were reported in the analysis of variance.

CHAPTER III

RESULTS AND DISCUSSION

Overview

Antioxidant activity of dried plum powder (DPP) was compared to rosemary extract (RE) in turkey breakfast sausage through three storage conditions: raw refrigerated (RR; 6°C), raw and precooked frozen (RF and PF, respectively; -23°C). Analyses included pH, proximate composition, objective color, lipid oxidation (TBARS), aerobic plate count (APC) and enumeration of lactic acid bacteria (LAB), sensory, reheat yields and shear force. All RR treatments surpassed the threshold of 3 for TBARS by day 6. Spoilage occurred by day 3 for all RR treatments (> 6.0 $\log_{10}$). Treatments containing DPP had lower TBARS values for RF ($P < 0.05$) and PF ($P < 0.01$). DPP containing treatments had lower L* external and internal and a* values while b* values were higher. Sensory scores for plum and sweet were higher, while cardboard and rancidity were lower in treatments containing DPP. Sensory scores for cardboard and rancidity were lower for RF and higher for PF treatments.

Introduction

Consumers have less free time to prepare meals at home due to increased work load, city congestion such as traffic, and other everyday factors, increasing the demand for quick and convenient alternatives to a home cooked meal. Consumers are not only looking for food that they can prepare in minutes, they are also concerned about health and the cost. More attention has been given by consumers to organic or natural products containing fewer synthetic additives. Increased demand for convenient, healthy and low cost meat products has resulted in the development of low-fat sausage products containing alternative protein sources, such as mechanically separated turkey meat (MSTM). Although the use of these alternative protein sources reduces the cost of the product, MSTM is highly prone to lipid oxidation due to its method of manufacture and level of unsaturated fatty acids (Mielnik, Abay, Rolfsen, Ellekjar & Nilsson, 2002).

Lipid oxidation is the primary cause of sensory quality degradation of attributes such as color, flavor, texture, and odor in processed meats. Lipid oxidation of more concern in MSTM due to the increased product temperature during manufacture and/or exposure to oxygen (Ladikos et al., 1990; Britt, Gomaa, Gray & Booren, 1998; Yanishlieva & Marinova, 2001; Erickson, 2002; Sebranek, Sewalt, Robins & Houser, 2005). This is a major cause of concern for meat product processors due to the negative impact lipid oxidation can have on consumer acceptance (Karpinska, Borowski & Oziewicz, 2001). Inclusion of natural antioxidants into processed meat products is an effective way to control lipid oxidation and increase shelf-life, while maintaining the quality and acceptability expected by the consumer. (McCarthy, Kerry, Kerry, Lynch, & Buckley, 2001; Sebranek et al., 2005; Capitani, Carvalho, Rivelli, Barros, & Castro, 2009).

Dried plums have been reported to have a high antioxidant capacity which is attributed to their high phenolic content and may serve as a natural alternative to synthetic antioxidants (Gil, Barberan, Pierce & Kader, 2002; Kayano, Kikuzaki, Fukutsuka, Mitani & Nakatani, 2002; Piga, Caro & Corda, 2003; Cevallos-Casals, Byrne, Okie & Zevallos, 2006). Nunez, Hafley, Boleman, Miller, Rhee, & Keeton (2008a) reported that the use of a dried plum puree at 3 and 6% in pork sausage products was as effective at suppressing lipid oxidation as BHA and BHT. Similar results have been reported in precooked pork patties with dried plum puree at 3%. This use of fresh or dried plum products has been shown to decrease lipid oxidation and extend the shelf-life of precooked roasts (Nunez, Boleman, Miller, Keeton, & Rhee, 2008b). Lipid oxidation has also been reduced in irradiated turkey breast rolls with the addition of 2% plum extract (Lee & Ahn, 2005). The purpose of this study was to evaluate the antioxidant effect of dried plum powder, as compared to rosemary extract, in a turkey breakfast sausage manufactured with MSTM.

Materials and Methods

Raw Material Preparation: Fresh lean turkey (boneless, skinless young turkey breast half without ribs, NAMP P2015, Cargill, Waco, TX) and partially frozen mechanically deboned turkey meat (MDTM, Cargill, Wichita, KS) were received at Rosenthal Meat Science and Technology Center, Texas A&M University (College Station, TX). Samples were taken, ground (Biro Model 10-56, Biro Mfg. Co. Marblehead, OH) separately through a 1.3 cm plate and part of the samples were analyzed for fat, moisture, and protein content prior to sausage formulation. The remaining turkey breast was portioned into 12.3 kg lots, vacuumed packaged, then stored frozen (-23°C) until used. The

remaining MDTM was cut into 5.1 x 10.2 cm blocks (Biro Meat Saw model# 44, Biro Mfg. Co. Marblehead, OH), vacuum packaged and stored frozen (-23°C) until used.

Turkey Sausage Link Manufacture: Control batches were formulated with 80% turkey breast (10.89 kg) and 20% MDTM (2.72 kg) of the meat block weight with no added antioxidant (Table 1). Treatment batches contained either dried plum powder (DPP; Low moisture prune powder, Sunsweet Growers Inc., Yuba City, CA) at 3% (0.41 kg), rosemary extract (RE; Herbalox Type HT-25, Kalsec Inc., Kalamazoo, MI) at 0.05% (0.009 kg), or a combination of DPP (3%) and RE (0.05%) added (Table 1). Turkey breasts and MDTM were ground (Biro Model 10-56, Biro Mfg. Co. Marblehead, OH) separately through a 1.3 cm plate. The ground turkey breast, MDTM, and non meat ingredients were then weighted according to the appropriate formulation. The appropriate amount of DPP and all the RE were hand mixed with the MDTM for approximately 30 seconds according to each treatment formulation (Table 1). Ground turkey breasts were mixed for 2 min in a paddle mixer (Butcher Boy Model 150, Lasar MFG Inc., Los Angeles, CA) while encapsulated salt (1%, AC Legg Inc., Longview, TX), sausage seasoning (2.3%, AC Legg Inc., Longview, TX), and ½ of the ice water slush was added. Next the hand-mixed MDTM (with RE, DPP, or both) and the remaining DPP and ice water were added to the paddle mixer and mixed 1 min. Upon completion of mixing, the batter was ground a second time through a 0.48 cm grinder plate and then transferred to a vacuum stuffer (Handtmann Vacuum Stuffer, Model VF612, Riss, Germany) and stuffed into 19 mm clear collagen casings (DeWied Inc., San Antonio, TX). Vacuum stuffer settings were: 100% vacuum, 28 g link portions, 2.5 twists per link and 64 link strands per stuffing cycle. Sausage links were placed on plastic trays and

crust frozen for 30 min in a -23°C freezer before being packaged and divided between shelf-life studies.

Thermal Processing, Chilling, and Cook Yield: Turkey sausage links from the control and each treatment were weighed in groups of 10, placed on a raised wire rack sitting on a sheet pan (18”x13”x1”) then cooked in a gas oven (Kenmore model 665-72012100 ultra bake gas range) to an internal temperature of 74°C according to AMSA (1995) guidelines. Two thermocouples (Omega Thermometer, Model HH501BT, Type T connector, Iron & Constantan) were inserted into the geometric center of two links to monitor product temperature during cooking. Links were re-weighted after cooking and allowed to cool to 22°C before being placed in plastic-lined cardboard boxes layered with plastic coated freezer paper and stored at -23˚C for up to 56 days to determine shelf-life stability. Percent cook yield was determined by dividing the cooked weight by the raw weight then multiplying by 100.

Raw Refrigerated Retail Shelf-life Study: Sausage links from each control and treatment batch were placed into plastic overwrapped (Resinite RMF 61-HY stretch film, AEP Industries, Inc., Hackensack, NJ) styrofoam trays. Samples were stored at 6°C in a cooler under fluorescent lights (Philips F40T12-CWT) at an intensity of 1900 Lux. Light intensity was measured using a light probe (Sper, Model 850075, Sper Scientific, LTD, Scottsdale, AZ) attached to an environmental quality meter (Sper, Model 850071, Sper Scientific, LTD, Scottsdale, AZ). The trays were stored for either 0, 3, 6, or 9 days before being removed for analysis. Each sample was analyzed for objective color, pH,

lipid oxidation, and aerobic plate count (APC) and enumeration of lactic acid bacteria (LAB).

Raw and Precooked Frozen Shelf-life Study: Raw and precooked sausage links from the control and treatment batches were placed in plastic-lined cardboard boxes layered with plastic coated freezer paper and stored at -23˚C for up to 56 days to determine frozen shelf-life stability. Samples were analyzed on storage days 0, 7, 14, 28, and 56 for objective color, pH, lipid oxidation, and sensory attributes. Additional analyses for precooked frozen links were re-heat yields and shear values.

Microbiological Analysis of Refrigerated Retail Links: At each refrigerated storage period (day 0, 3, 6, and 9), a 10 gram sample was removed aseptically from the overwrapped packages and placed into a sterile stomacher bag to which 90 ml of 0.1% peptone diluent was added. The samples were macerated for 2 min using a Stomacher 400 Circulator (Seward Medical, West Sussex, United Kingdom). APCs were determined by plating 1 ml of the sample rinse and 1 ml of the appropriate 10-fold dilutions of the same on Petrifilm™ aerobic count plates (3M Corp., St. Paul, MN). LAB counts were determined simultaneously by dispensing 1 ml of the sample rinse and the appropriate 10-fold dilutions of the same into sterile petri dishes prepared with Lactobacilli MRS Agar (Difco, Detroit, MI) with overlay. Both Petrifilm™ and MRS plates were incubated at 30^{o}C for 72 h before counting and reporting colony forming units (CFU) per gram.

Determination of pH: The pH of refrigerated retail and frozen raw and precooked turkey sausage links was determined using a pH meter (IQ Model IQ150 IQ Scientific

Instruments, Inc., Reston, VA) and internal probe (Piercing tip micro probe w/ heavy duty handle, Model PH57-SS, IQ Scientific Instruments, Inc., Reston, VA) calibrated with buffers 4.01 and 7.0.

Proximate Composition: Percent moisture and fat were determined using modified AOAC (2000) air-dry oven and soxhlet ether extraction methods, respectively (AOAC 2000, Methods 950.46 & 985.15). Percent protein was determined by AOAC (2000) method 992.15, using a LECO FP-528 (LECO Corporation, St. Joseph, MI) nitrogen analyzer which vaporized powdered samples of 0.15 gram to release total nitrogen. Percent protein was calculated as 6.25 times the percent nitrogen.

Objective Color Determinations: Color measurements were taken on the exterior and interior surfaces of the refrigerated retail turkey sausage links using a Hunter Miniscan XE (Model 45/O-L, Hunter Associates Laboratory, Inc. Reston, VA) using a 1.54 cm aperture, calibrated with white and black standards. CIE *L*, a*,* and *b** color space values were calculated using illuminant A and a 10° observer.

Frozen raw and precooked turkey sausage links were allowed to thaw for 2 h at 6°C. Color measurements for the raw sausages were taken on the exterior and interior surfaces of the turkey sausage links. Precooked links were only measured internally, due to loosening of the collagen casing following chilling making it difficult to obtain accurate readings. Color measurements were taken with a Hunter Miniscan XE (Model 45/O-L, Hunter Associates Laboratory, Inc. Reston, VA) using a 1.54 cm aperture, calibrated with white and black standards. CIE *L*, a*,* and *b** color space values were

calculated using illuminant A with a 10° observer (raw) and D with a 65° observer (precooked).

Lipid Oxidation: Lipid oxidation was determined by the thiobarbituric acid (TBA) test of Tarladgis, Watts, & Younathan (1960) as modified by Rhee (1978). Absorbance was measured at 530 nm using an UV-visible spectrophotometer (Model Cary 300 Bio, Varian Instruments, Sugarland, TX). Results were reported as mg of malonaldehyde per kilogram of meat.

Reheated and held Cooked Yields: Precooked frozen sausage links were re-heated (Hatco Cook & Hold Oven, Model # CSC-10, Hatco Inc., Milwaukee, WI) from a frozen (-23°C) state to an internal temperature of 74˚C and held for 15 or 30 min, Temperature was monitored using two thermocouples (Omega Thermometer, Model HH501BT, Type T connector, Iron & Constantan) inserted into the geometric center of two links. After the designated time (15 or 30 min), the links were removed from the oven and allowed to cool to 22°C before being re-weighed.

Allo-Kramer Shear Force Determinations: Frozen raw turkey sausages were cooked to an internal temperature of 74˚C and allowed to cool to 22°C. Precooked turkey sausage links were re-heated and held at 74˚C according to AMSA (1995) guidelines for 15 and 30 min and allowed to cool to approximately 22°C. Samples were cut into 63mm long pieces. The pieces were weighed in grams and shear values were recorded using an Instron Universal Testing Machine (Instron Corp., Canton, MA., U.S.A.) equipped with a 10-blade Allo–Kramer shear compression cell using a 5000-kg load cell with a load

range of 5000 kg and a crosshead speed of 500 mm/min. Shear values are reported as Newtons/gram.

Trained Sensory Panel Analysis: A trained descriptive attribute sensory panel was used to evaluate frozen cooked and re-heated turkey sausage links for texture, aromatics, basic tastes, mouth feel, and aftertastes. Five panelists were selected and trained according to AMSA (1995) guidelines and Meilgaard, Civille, & Carr (2007). Training and ballot development sessions were conducted prior to testing to familiarize the panelist with the attributes of the cooked and re-heated turkey sausage links. Cooked and re-heated turkey sausage samples were evaluated for texture (springiness, fracturability, hardness, cohesiveness, and juiciness), aromatics (cooked turkey lean, cooked turkey fat, plum, rosemary, spice complex, chemical, cardboard, painty, fishy, and other), basic tastes (sweet, salt, bitter, and sour), mouth feel (metallic, spice burn, and astringent), and aftertastes (burn, acid, sour, bitter, sweet, spice, warmed over flavor, and other). All samples were scored using the 15 point Spectrum universal intensity scale (Meilgaard et al., 2007) where 0 = absence of an attribute and 15 = extremely intense. Panelists evaluated 24 samples (8 samples per day for 3 days). Frozen turkey sausage links were allowed to thaw for 2 h at 6°C before being cooked to 74°C in a Kenmore (Model 665-72012100) ultra bake gas range, monitored by thermocouples (Omega Thermometer, Model HH501BT, Type T connector, Iron & Constantan) according to AMSA (1995) guidelines, cut into 1.27 cm slices and served to the panelists in plastic serving dishes under red lights. Each panelist was seated in individual testing booths, which were separated from the sample preparation area. Nine samples (3 slices per sample) were given per session (24 hours between sessions) at 10 minute intervals.

Statistical Analysis: Proximate composition, pH, cook yield, microbiological analysis, objective color, lipid oxidation, reheat yields, shear force and sensory data were statistically analyzed as a completely randomized block design using the Mixed Model procedure of the Statistical Analysis System (Version 9.2, SAS Institute, Inc., Cary, NC). The model for all dependant variables had a fixed effect of antioxidant treatment and a block effect of replication. Data which included repeated measures accounted for the fixed effect of storage day, which was defined as a repeated effect; and the interaction between storage day and antioxidant treatment. Sensory variables were analyzed for a significant interaction between panelist and both antioxidant treatment and storage type (raw or precooked) prior to being pooled across all panelists. Differences between antioxidant treatment means were separated with Tukey's studentized range test only when significant ($P < 0.05$) differences were reported in the analysis of variance.

Results and Discussion

Proximate Composition, pH, Cook Yield and Time: Proximate composition, pH, cook yield and cook time results are presented in Table 2. Data for proximate composition of raw and cooked sausage links, percent fat, protein and moisture, were not significantly different ($P < 0.05$) across treatments. However the raw links containing DPP had slightly lower fat, protein and moisture content than the control and RE links. The addition of DPP may have caused a dilution effect on the meat block. Nunez et. al (2008b) found similar results regarding percent fat when they added a dried plum puree to raw and precooked pork sausage. Our cooked sausages fat and protein percentages were higher than the raw sausage while the moisture percentage was lower. This was likely caused by moisture loss during cooking.

The pH values for raw refrigerated, raw frozen and precooked frozen turkey breakfast sausage were significantly different ($P < 0.05$) between treatments containing DPP and treatments without. The raw pH values for control and RE were higher than DPP and DPP/RE for all shelf-life studies, but the precooked RE pH was not significantly different from other treatments.

The control links had the lowest overall cook yield, significantly different ($P < 0.05$) than both treatments containing RE. Other cook yields were not significantly different ($P < 0.05$) from each other. Cook times were not significantly different among controls or treatments.

Lipid Oxidation: The 2-thiobarbituric acid reactive substances (TBARS) values for the raw refrigerated (RR; Figure 1), precooked frozen (PF; Figure 2), and raw frozen (RF) turkey breakfast sausages are presented in Table 3. There was a significant ($P < 0.05$)

two-way interaction between treatment and storage day for the RR and PF shelf-life studies; the RF links had significant ($P < 0.05$) main effects of treatment and storage day.

TBARS values were similar across treatments for RR links on storage day 0 and 3. By day 6, TBARS values had increased significantly ($P < 0.001$) compared to day 0 and 3, and would be considered rancid according to standards explained by Melton (1983). Melton (1983) stated that a TBARS value greater than 3 for poultry would be considered rancid. On storage day 9, TBARS values for the control links had decreased significantly ($P < 0.05$) and values for RE links decreased slightly compared to day 6. This may be a result of malonaldehyde (a secondary by-product of lipid oxidation) reactions with proteins, according to Melton (1983) (Nassu, Aparecida,Goncalves, Silva, & Beserra 2003).

On storage day 0, PF DPP and DPP/RE links had lower TBARS values than the control ($P < 0.05$). With increased storage, control and RE sausage link TBARS values increased. Sausage containing DPP and DPP/RE had lower TBARS values throughout PF storage ($P < 0.05$). Nunez, et. al (2008b) referenced McCarthy et. al (2001) who stated that TBARS values of precooked and frozen pork sausage patties increased 4 times due to cooking when compared to raw patties. Nunez et. al (2008b) hypothesized that lipid oxidation is accelerated during cooking due to potential disruption of muscle membranes, release of protein bound iron through heating, and possible inactivation of antioxidant enzymes present in meat. This accelerated lipid oxidation was also observed in our study as evidenced by the TBARS values of the PF control and RE links over the 56 day shelf-life compared to the RF study. The addition of 3% DPP or 3% DPP plus RE were effective treatments for limiting lipid oxidation in a precooked turkey

sausage. Treatments containing DPP did not differ across storage days. TBARS values for the control links were static from 0 – 28 days but increased on day 56. TBARS values for links containing RE increased incrementally from 0 – 28 days and were higher by day 56. Both the control and RE links would be considered rancid with TBARS values ≥ 3.

During RF storage, links containing DPP/RE had lower TBARS values ($P < 0.05$) than all other links. This is possibly due to a synergistic effect between DPP and RE to reduce TBARS values. TBARS values were lowest on day 0 and increased by day 7 and during subsequent storage. The cause of this fluctuation over storage day is not known. TBARS values ranged from 0.26 to 0.70 for all treatments across all storage days. None of the treatments reached a TBARS value greater than 3 and would not be considered rancid. Nunez et. al (2008a) reported that fresh and dried plum ingredients significantly decreased TBARS values in beef roast containing 2.5% and 5% DP compared to controls. Nunez et. al (2008b) also stated that the use of 3% and 6% dried plum puree in pork sausage were as effective as synthetic antioxidants (BHT & BHA).

Microbiological Analysis of Refrigerated Retail Links: Aerobic plate counts (APC; Figure 3 and Table 4) were not significantly different ($P < 0.05$) on storage day 0 across treatments. However, on storage day 3 the links containing DPP and DPP/RE had lower APCs. With increased storage, APCs increased concomitantly for all treatments and all treatments were considered spoiled by storage day 3 with a log value greater than 10^6, according to Jay, Loessner, & Golden (2005) and Moir (2001).

Lactic acid bacteria (LAB) counts in DPP links were lower than the control. LAB counts increased with storage day and the product was considered spoiled by storage

day 6, due to growth to levels greater than 10^6 (Jay et al., 2005; Moir, 2001). Cevallos-Casals et. al (2006) noted that plum genotypes high in phenolic compounds may inhibit growth of microorganisms at a concentration of 2.6 to 5.6 mg/ml. The total phenolic content in plums ranges from 298 to 563 mg/100g (*prunus salicina*) and from 160 to 300mg/100g (*prunus domestica;* Cevallos-Casals et. al, 2006). The slight inhibition or decrease of APC and LAB counts for sausages containing DPP may have been related to the phenolic content. However, the exact phenolic content of the DPP used in this study is unknown.

Objective Color Determinations: Interactions for treatment and storage day were significant ($P < 0.05$) for external and internal color space values for RR, RF, and PF turkey breakfast sausages (Figures 4, 5, & 6 and Tables 5 & 6). Lightness (L*) values for links containing DPP were lower ($P < 0.05$) overall for both external and internal readings, than the control and RE links. However on storage day 9 the external L* values compared to the control and internal L* values compared to the control and RE links were not different ($P > 0.05$). Across storage days the internal L* values for all treatments decreased until day 9 when they had a significant increase in L* value ($P < 0.05$). External a* values did not differ visually among treatments, but decreased with storage time from day 0 to 6. A similar trend was noted for the internal a* (redness) values. Yellowness (b*) values for both external and internal readings of the control and RE links were consistently lower than DPP and DPP/RE and different ($P < 0.05$) throughout storage, except on day 0 for DPP/RE links were not different. Yellowness values were the highest on day 0 and decreased over storage for all links.

It was expected that the lightness (L*) values for both external and internal color would be lower for the links containing DPP, due to the inherently dark color of the product. This trait was also noticed in other studies using dried plum ingredients. Nunez et. al (2008a) reported in a study on the antioxidant properties of plum concentrates and powder on precooked roasts, the fresh and dried plum ingredients had slightly lower L* values and were darker than the controls. Lee et. al (2005) also reported a decrease in L* values causing the color of their turkey rolls containing 3% plum puree to be darker, due to the original purple color of the plum. Nunez et. al (2008b, 2009) reported similar results regarding L* lightness values in products contains DP.

Lightness (L*) values for the external and internal surface of the RF and PF (Figures 5 & 6 and Table 6) DPP and DPP/RE links were darker ($P < 0.05$) than the other treatments on days 0 and 7. Although, on days 14, 28, and 56 the lightness values were not different among treatments except for the external surface of the RF DPP/RE links on day 56. External redness (a*) values for the RF control and RE links are consistently higher than links containing DPP. Internal redness values for RF control and RE links tended to be higher than DPP containing links until day 28; while the internal redness for PF DPP and DPP/RE were higher ($P < 0.05$) on days 0 and 7. Redness values for all treatments decreased over storage days. External yellowness (b*) values for all RF links were not different on days 0 and 7. Internal yellowness values for both RF and PF links containing DPP were higher ($P < 0.05$) than the control and RE treatment across all storage days. Only the external RF DPP/RE links did not differ in yellowness values over storage. This is contrary to what Lee et al. (2005) reported showing an increase in a* and b* values in turkey rolls containing 3% DPP.

Reheated and Held Cook Yield and Allo-Kramer Shear: Re-heated cook yields (Table 7) increased across storage days, with day 0 being the lowest and day 56 the highest. Our hypothesis as to why day 56 appears to have a higher cook yield than day 0, is due to loss of yield during frozen storage. The bulk packaging method used is thought to have resulted in moisture loss through frozen storage, causing a loss in product yield from day 0 to day 56. Therefore, the product yields appear to increase over storage day. Even with this suspected loss of yield through storage, the product that was held for 15 min at 74°C retained a higher percent yield than the product held for 30 min.

Allo-Kramer shear values (Figure 7 and Table 7) for the RF product tested on day 1 ranged from 36.46 to 39.31 n/gm. Both treatments containing DPP had lower shear values then the control and RE, possibly from the DPP acting as a humectant, binding more moisture. Lee et. al (2005) stated that >2% DP decreased hardness and increased juiciness by binding moisture and improving texture. While Nunez et al. (2009) claimed that the addition of 5% DPP from 2.5% resulted in a decrease in moisture and increase in shear force values. Shear values for product held for 15 min ranged from 46.14 to 163.83 n/gm and 46.59 to 242.01 n/gm for product held 30 min. In general, shear values gradually increased across storage day for each treatment. Day 0 values were the lowest for product held for 15 and 30 min, also treatments containing DPP had shear values lower than the control and RE treatment. PF shear values on day 0, when compared to RF shear values, are higher on an average by 13.40 and 19.25 n/gm for the 15 and 30 min hold times. Over the course of the storage period, the shear values increased most likely from a loss of moisture from frozen storage.

Trained Sensory Panel Analysis: Main effect means for sensory attributes are presented in Table 8. RF links were springier, less cohesive, and juicier compared to the PF links. They also scored higher for cooked turkey lean, cooked turkey fat, plum flavor aromatics, and lower for cardboard aromatic and rancidity aftertaste, compared to the PF links. These differences are most likely caused by the variation in storage type between the RF and PF turkey sausages. Precooking then freezing the product could have contributed to the loss of juiciness, degradation in texture, flavor and the heightened cardboard flavor and rancid flavor related to lipid oxidation.

Treatment did not affect texture attributes; cooked turkey lean, cooked turkey fat, rosemary, chemical and cardboard flavor aromatics; salt, bitter and sour basic tastes; mouthfeels; and aftertastes, except sweet aftertastes. Turkey links containing DPP and DPP/RE were higher in plum aromatic and sweet basic taste and aftertastes as would be expected as these treatments contained DDP. The DPP/RE links had lower spice complex then control links. Nunez et. al (2008b) found similar results in raw and precooked pork sausage patties containing DPP stating that sweet and prune aromatics were more pronounced. The addition of DPP was thought to may mask other flavors such as spicy/peppery, which a slight decrease had been noticed in treatments containing DPP compared to the control and RE. Nunez et. al (2008a) reported a similar effect with the addition of DP and an increase in plum flavor along with sweetness at high concentrations.

Conclusion

The addition of DPP at 3% into a turkey breakfast sausage had an inhibitory effect on lipid oxidation in a raw and precooked frozen form. It is apparent that DPP when combined with RE had a more synergistic effect on preventing lipid oxidation in turkey sausage links during raw frozen storage, than the use of DPP alone. However, with the inclusion of DPP, the product was noticeably darker in color as shown by the external and internal L* (lightness) values, due to the inherent color of the DPP. As well as significantly increasing the internal b* (yellowness) values. This may or may not have a negative impact depending on the desired end product. It was also determined the sausage links containing DPP had a sweeter and detectable plum flavor among a trained sensory panel. This has been noticed in other studies conducted using DPP (Lee et. al, 2005; Nunez et. al, 2008a, 2008b). Aerobic plate counts and lactic acid bacteria counts for sausage links containing DPP were lower than that of the treatments without DPP, showing a possible antimicrobial effect, which is supported by Cevallos-casals et. al (2006). Therefore, the inclusion of 3% DPP for use as a natural antioxidant is beneficial for suppressing the effects of lipid oxidation on raw and precooked and frozen turkey breakfast sausages made from a mixture of turkey breasts and mechanically deboned turkey meat.

CHAPTER IV

CONCLUSIONS

The addition of dried plum powder at a level of 3% in turkey breakfast sausage, both raw and precooked frozen, made from raw materials having an increased susceptibility to lipid oxidation was successful in providing an inhibitory or preventative effect against the development of lipid oxidation. It was made apparent that dried plum powder when combined with rosemary extract had a synergistic effect on the prevention of lipid oxidation during the raw frozen storage, compared to the use of dried plum powder alone. This represents a synergistic relationship from the combination of these two products on lipid oxidation prevention.

While the inclusion of dried plum powder was more effective in preventing lipid oxidation the product was a noticeably darker as shown by the L* (lightness) values. This darkened color was expected due to the brown, caramel color of the dried plum powder. The darkening effect of dried plum powder may or may not be desired depending on the product. Other potentially desirable sensory attributes that were detectable by a trained sensory panel from the addition of the dried plum powder were a sweet and plum flavor. In addition dried plum showed a slight masking effect of other flavors such as spice complex. This has been noticed in other studies conducted using dried plum powder (Lee et. al, 2005; Nunez et. al, 2008a, 2008b). Aerobic plate counts and counts of lactic acid bacteria for treatments containing dried plum powder were lower than that of the treatments without dried plum powder, showing a possible antimicrobial effect, which is supported by Cevallos-Casals et. al (2006). Therefore, the inclusion of 3% dried plum powder for use as a natural antioxidant is beneficial for suppressing the effects of lipid oxidation on raw or precooked and frozen turkey

breakfast sausages made from a mixture of turkey breasts and mechanically deboned turkey meat, which is highly susceptible to lipid oxidation.

Future studies involving dried plum powder could be very beneficial. One possible area of focus would be the further extraction of the phenolic compounds in plums and dried plum powder to isolate and refine their antioxidant ability. Another area of focus could be the use of dried plum powder or plum products in the suppression of microbial growth in processed meat products. As well as the use of dried plum powder and plum products to improve moisture retention and product yield, possibly comparing them to phosphates in injected meats.

REFERENCES

Ahn, J., Gruen, I.U., & Fernando, L.N. (2002). Antioxidant properties of natural plant extracts containing polyphenolic compounds in cooked beef. *Journal of Food Science,* 67, 1364-1369.

Followed by (AMSA). (1995). Research Guidelines for Cookery, Sensory Evaluation and Instrumental Measurements of Fresh Meat. Chicago, IL.: *American Meat Science Association and National Livestock and Meat Board*.

Followed by (AOAC). (2000). Meat and meat products. In Cunniff, P.(ed) *Official methods of analysis of AOAC International,* (pp. 1-23). Washington, D.C.: AOAC International.

Baggio, S.R., Vicente, E., & Bragagnolo, N. (2002). Cholesterol oxides, cholesterol, total lipid, and fatty acid composition in turkey meat. *Journal of Agricultural and Food Chemistry,* 50, 5981-5986.

Barbut, S., Josephson, D.B., & Maurer, A.J. (1985). Antioxidant properties of rosemary oleoresin in turkey sausage. *Journal of Food Science,* 50, 1356-1359.

Britt, C., Gomaa, E.A., Gray, J.I., & Booren, A.M. (1998). Influence of cherry tissue on lipid oxidation and heterocyclic aromatic amine formation in ground beef patties. *Journal of Agriculture and Food Chemistry*, 46, 4891-4897.

Cadenas, E. (1997). Basic mechanisms of antioxidant activity. *IOS Press BioFactors*, 6, 391-397.

Capitani, C.D., Carvalho, A.C.L., Rivelli, D.P., Barros, S.B.M., & Castro, I.A. (2009). Evaluation of natural and synthetic compounds according to their antioxidant activity using a multivariate approach. *European Journal of Lipid Science and Technology*, 111, 1-10.

Castaldi, P., & Degen, J.M. (2003). Dried plums: Natural solutions to improve the quality, nutrition and safety of foods in space travel. SAE International.

Cevallos-Casals, B.A., Byrne, D., Okie, W.R., & Zevallos, L.C. (2006). Selecting new peach and plum genotypes rich in phenolic compounds and enhanced functional properties. *Journal of Food Chemistry*, 96, 273-280.

Chang, S.S., Ostric-matijasevic, B., Hsieh, O.A.L, & Huang, C.L. (1977). Natural antioxidants from rosemary and sage. *Journal of Food Science*, 42(4), 1102-1106.

Coronado, S.A., Trout, G.R., Dunshea, F.R., & Shah, N.P. (2002). Antioxidant effects of rosemary extract and whey powder on the oxidative stability of wiener sausages during 10 months frozen storage. *Meat Science*, 62, 217-224.

Donovan, J.L., Meyer, A.S., & Waterhouse, A.L. (1998). Phenolic composition and antioxidant activity of prunes and prune juice (prunus domestica). *Journal of Agriculture and Food Chemistry,* 46, 1247-1252.

Erickson, M.C. (2002). Lipid Oxidation of Muscle Foods. In C.C. Akoh, *Food Lipids* (pp 365-411). New York: Marcel Dekker, Inc.

Fang, N., Yu, S., & Prior, R.L. (2002). LC/MS/MS characterization of phenolic constituents in dried plums. *Journal of Agriculture and Food Chemistry,* 50, 3579-3585.

Faustman, C., Cassens, R.G., Schaefer, D.M., Buege, D.R., Williams, S.N., & Scheller, K.K. (1989). Improvements of pigment and lipid stability in Holstein steer beef by dietary supplementation with vitamin E. *Journal of Food Science* 42, 665-669.

Fennema, O.R., Damodaran, S., & Parkin, K.L. (2008). Fennema's Food Chemistry (pp 1119). NewYork: CCR Press.

Fernandez, J., Perez-Alvarez, J.A., & Fernandez-Lopez, J.A. (1997). Thiobarbituric acid test for monitoring lipid oxidation in meat. *Journal of Food Chemistry,* 59(3), 345-353.

Formanek, Z., Lynch, A., Galvin, K., Farkas, J., & Kerry, J.P. (2003). Combined effects of irradiation and the use of natural antioxidants on the shelf life stability of overwrapped minced beef. *Meat Science,* 63, 433-440.

Furchner-Evanson, A., Petrisko, Y., Howarth, L.S., Nemoseck, T., & Kem, M. (2009) Snack selection influences satiety responses in adult women. *The Federation of American Societies for Experimental Biology Journal,* 23, 545.11.

Gray, J.I. (1978). Measurement of lipid oxidation: a review. *Journal of American Oil Chemistry,* 55, 539-546.

Gil, M.I., Barberan, F.A.T., Pierce, B.H., & Kader, A.A. (2002). Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. *Journal of Agriculture and Food Chemistry,* 50, 4976-4982.

Ho, C.T., Wang, M., Wei, G.J., Huang, T.C., & Huang, M.T. (2000). Chemistry and antioxidative factors in rosemary and sage. *IOS Press BioFactors,* 13, 161-166.

Howarth, L.S., Petrisko, Y., Furchner-Evanson, A., Nemoseck, T., & Kem, M. (2009). Snack selection influences nutrient intake, metabolism and bowel habits in adult women. *The Federation of American Societies for Experimental Biology Journal,* 23, 545.9

Huang, D., Ou, B., & Prior, R.L., (2005). The chemistry behind antioxidant capacity assays. *Journal of Agriculture and Food Chemistry,* 53, 1841-1856.

Iverson, F. (1995). Phenolic antioxidants: health protection branch studies on butylated hydroxyanisole. *Cancer Letters,* 49-54.

Jay, J.M., Loessner, M.J., & Golden, D.A., (2005). Modern Food Microbiology Seventh Edition (Ch 4) (pp 63-99). New York NY.: Springer Science & Business Media, Inc.

Jayathilakan, K., Sharma, G.K., Radhakrishna, K., & Bawa, A.S. (2007). Antioxidant potential of synthetic and natural antioxidants and its effect on warmed-over-flavour in different species of meat. *Journal of Food Chemistry,* 105, 908-916.

Jimenez-Colmenero, F., Carballo, J., & Cofrades, S. (2001). Healthier meat and eat products: their role as functional foods. *Journal of Meat Science,* 59, 5-13.

Karpinska, M., Borowski, J., & Oziewicz, M.D. (2001). The use of natural antioxidants in ready-to-serve food. *Journal of Food Chemistry,* 72, 5-9.

Kayano, S., Kikuzaki, H., Fukutsuka, N., Mitani, T., & Nakatani, N. (2002). Antioxidant activity of prune (prunus domestica L.) constituents and a new synergist. *Journal of Agriculture and Food Chemistry,* 50, 3708-3712.

Kim, D.O., Jeong, S.W., & Lee, C.Y. (2003). Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Journal of Food Chemistry,* 81, 321-326.

Ko, S.H., Choi, S.W., Ye, S.K., Cho, B.L., Kim, H.S., & Chung, M.H. (2005). Comparison of the antioxidant activities of nine different fruits in human plasma. *Journal of Medical Food,* 8(1), 41-46.

Kumar, A., Hooshmand, S., & Arjmandi, B.H. (2009). Dried plum polyphenols decreased markers of inflammation and lipid peroxidation in RAW264.7 macrophage cells. *The Federation of American Societies for Experimental Biology Journal,* 23, 547.4.

Ladikos, D., & Lougovois, V. (1990). Lipid oxidation in muscle foods: a review. *Journal of Food Chemistry,* 35, 295-314.

Lee, E.J., & Ahn, D.U. (2005). Quality characteristics of irradiated turkey breast rolls formulated with plum extract. *Meat Science,* 71(2), 300-305.

Leheska, J.M., Boyce, J., Brooks, J.C., Hoover, L.C., Thompson, L.D., & Miller, M.F. (2006). Sensory attributes and phenolic content of precooked pork breakfast sausage with fruit purees. *Journal of Food Science,* 71(3), 249-252.

Lindberg, M.H., Andersen, L., Christiansen, L., Brockhoff, P., & Bertelsen, G. (1996.) Antioxidative activity of summer savory (satureja hortensis L) and rosemary (Rosmarinus officinalis L) in minced, cooked pork meat. *Zeitschrift fuer lebensmittel-untersu-chung und-forschung,* 203, 333-338.

Lule, S.U., & Xia, W. (2005). Food phenolics, pros and cons: a review. *Taylor & Francis Group: Food Reviews International,* 21, 367-388.

McCarthy, T.L., Kerry, J.P., Kerry, J.F., Lynch, P.B., & Buckley, D.J. (2001). Evaluation of the antioxidant potential of natural food/plant extracts as compared with synthetic antioxidants and vitamin E in raw and cooked pork patties. *Meat Science,* 57, 45-52.

Meilgaard, M., Civille, G. V., & Carr, B. T. (2007). Sensory Evaluation Techniques. Boca Raton, FL.: *CRC Press.*

Melton, S.L. (1983). Methodology for following lipid oxidation in muscle foods. *Journal of Food Technology,* 37, 105-111.

Mercier, Y., Gatellier, P., Vincent, A., & Renerre, M. (2001). Lipid and protein oxidation and microsomal fraction from turkeys: influence of dietary fat and vitamin E supplementation. *Meat Science,* 58, 125-134.

Mielnik, M.B., Aaby, K., Rolfsen, K., Ellekjaer, M.R., & Nilsson, A. (2002). Quality of comminuted sausages formulated from mechanically deboned poultry meat. *Meat Science,* 61, 73-84.

Mielnik, M.B., Aaby, K., & Skrede, G. (2003). Commercial antioxidants control lipid oxidation in mechanically deboned turkey meat. *Meat Science,* 65, 1147-1155.

Moir, C.J. (2001). Spoilage of Processed Foods: Causes and Diagnosis (Ch. 3.11) (pp 201-207). Waterloo DC.: N.S.W., AIFST (NSW Branch), Food microbiology Group.

Moreno, S., Scheyer, T., Romano, C.S., & Vojnov, A.A. (2006). Antioxidant and antimicrobial activities of rosemary extracts linked to their polyphenol composition. *Taylor & Francis Group, Free Radical Research,* 40(2), 223-231.

Nassu, R.T., Aparecida, L., Goncalves, G., Silva, M.A.A.P.D., & Beserra, F.J. (2003). Oxidative stability of fermented goat meat sausage with different levels of natural antioxidant. *Meat Science,* 63, 43-49.

Negrao, C.C., Mizubuti, I.Y., Morita, M.C., Colli, C., Ida, E.I., & Shimokomaki, M. (2005). Biological evaluation of mechanically deboned chicken meat protein quality. *Journal of Food Chemistry,* 90, 579-583.

Nunez, M.T.D.G., Hafley, B.S., Boleman, R.M., Miller, R.K., Rhee, K.S., & Keeton, J.T. (2008a). Antioxidant properties of plum concentrates and powder in precooked roast beef to reduce lipid oxidation. *Meat Science,* 80, 997-1004.

Nunez, M.T.D.G., Boleman, R.M., Miller, R.K., Keeton, J.T., & Rhee, K.S. (2008b). Antioxidant properties of dried plum ingredients in raw and precooked pork sausage. *Journal of Food Science,* 73(5), 63-71.

Nunez, M.T.D.G., Hafley, B.S., Boleman, R.M., Miller, R.K., Rhee, K.S., & Keeton, J.T. (2009). Qualitative effects of fresh and dried plum ingredients on vacuum-packaged, sliced hams. *Journal of Meat Science,* 83, 74-81.

Olsson, M.E., Gustavsson, K.E., Andersson, S., Nilsson, A., & Duan, R.D. (2004). Inhibition of cancer cell proliferation in vitro by fruit and berry extracts and correlations with antioxidant levels. *Journal of Agriculture and Food Chemistry,* 52, 7264-7271.

Palic, A., & Lucan, Z.D. (1995). Antioxidative effect of “herbalox” on edible oils. *Journal of Fat Science and Technology,* 97(10), 379-381.

Patton, S. (1974). Ibid 54, 114.

Peroxide Value. (1997). Peroxide Value. Meat & Livestock Australia: Processing and product Innovation.

Pettersen, M.K., Mielnik, M.B., Eie, T., Skrede, G., & Nilsson, A. (2004). Lipid oxidation in frozen, mechanically deboned turkey meat as affected by packaging parameters and storage conditions. *Journal of Poultry Science,* 83, 1240-1248.

Piga, A., Caro, A.D., & Corda, G. (2003). From plums to prunes: influence of drying parameters on polyphenols and antioxidant activity. *Journal of Agriculture and Food Chemistry,* 51, 3675-3681.

Pussa, T., Pallin, R., Raudsepp, P., Soidla, R., & Rei, M. (2008). Inhibition of lipid oxidation and dynamics of polyphenol content in mechanically deboned meat supplemented with sea buckthorn (hippophae rhamnoides) berry residues. *Journal of Food Chemistry,* 107, 714-721.

Rhee, K. S. (1978). Minimization of further lipid peroxidation in the distillation 2-thiobarbituric acid test of fish and meat. *Journal of Food Science,* 43, 1776-1781.

Riznar, K., Celan, S., Knez, Z., Skerget, M., Bauman, D., & Glaser, R. (2006). Antioxidant and antimicrobial activity of rosemary extract in chicken frankfurters. *Journal of Food Science,* 71(7), 425-429.

Sallam, K.I., Ishioroshi, M., & Samejima, K. (2004). Antioxidant and antimicrobial effects of garlic in chicken sausage. *Swiss Society of Food Science and Technology,* 37, 849-855.

Sebranek, J.G., Sewalt, V.J.H., Robins, K.L., & Houser, T.A. (2005). Comparison of a natural rosemary extract and BHA/BHT for relative antioxidant effectiveness in pork sausage. *Meat Science,* 69, 289-296.

Shahidi, F., & Wanasundara, P.K.J.P.D. (1992). Phenolic antioxidants. *CRC Press, Reviews in Food Science and Nutrition,* 32, 67-103.

Shelton, J.R. (1959). Mechanism of antioxidant action in the stabilization of hydrocarbon systems. *Journal of Applied Polymer Science,* 2(6), 345-350.

Tarladgis, B.G., Watts, B.M., & Younathan, M.T. (1960). A distillation method for the quantitative determination of malonaldehyde in rancid foods. *Journal of American Oil Chemistry,* 37, 44-48.

Tims, M.J., & Watts, B.M. (1958). Relationship of meat pigments to lipid oxidation. *Institute Food Technology, 728-734.*

Williams, S.K., Lee, T.G., Sloan, D., & Littell, R. (1997). Development and evaluation of a chicken breakfast sausage manufactured with mechanically deboned chicken meat. *Journal of Poultry Science,* 76, 415-421.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R., & Enser, M. (2003). Effects of fatty acids on meat quality: a review. *Journal of Meat Science,* 66, 21-23.

Wu, J.W., Lee, M.H., Ho, C.T., & Chang, S.S. (1982). Elucidation of the chemical structures of natural antioxidants isolated from rosemary. *JAOCS,* 59(8), 339-345.

Yanishlieva, N.V., & Marinova, E.M. (2001). Stabilization of edible oils with natural antioxidants. *European Journal of Lipid Science and Technology,* 103, 752-767.

Yanishlieva, N.V., Marinova, E., & Pokorny, J. (2006). Natural antioxidants from herbs and spices. *European Journal of Lipid Science and Technology,* 108, 776-793.

Yu, L., Scanlin, L., Wilson, L., & Schmidt, G. (2002). Rosemary extracts as inhibitors of lipid oxidation and color change in cooked turkey products during refrigerated storage. *Journal of Food Science,* 67(2), 582-585.

APPENDIX A

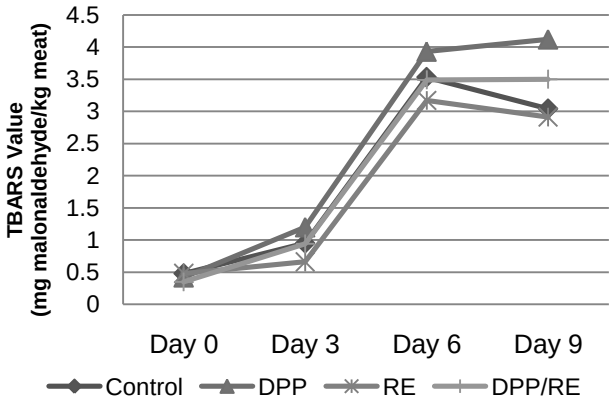

Figure 1. Least squares means of the 2-thiobarbituric acid reactive substances (TBARS) for raw refrigerated (6°C, days 0, 3, 6, 9) turkey breakfast sausage

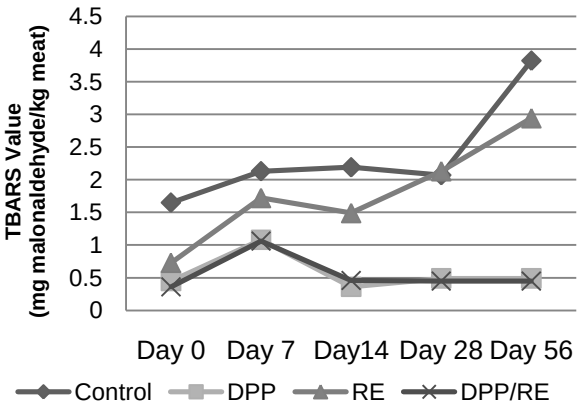

Figure 2. Least squares means of the 2-thiobarbituric acid reactive substances (TBARS) for precooked frozen (-23°C, days 0, 7, 14, 28, 56) turkey breakfast sausage

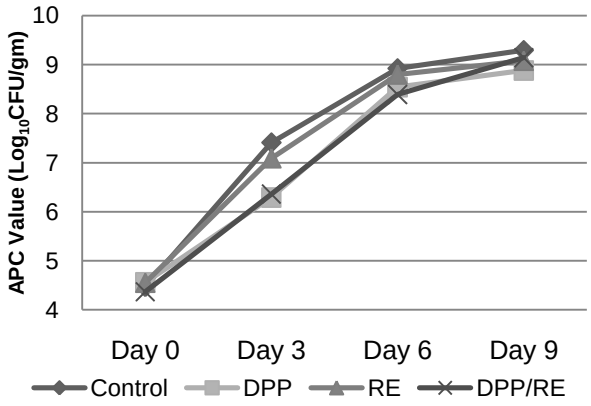

Figure 3. Least squares means of aerobic plate count (APC) values (Log_{10}CFU/gm), of raw refrigerated turkey breakfast sausage at days 0, 3, 6, and 9

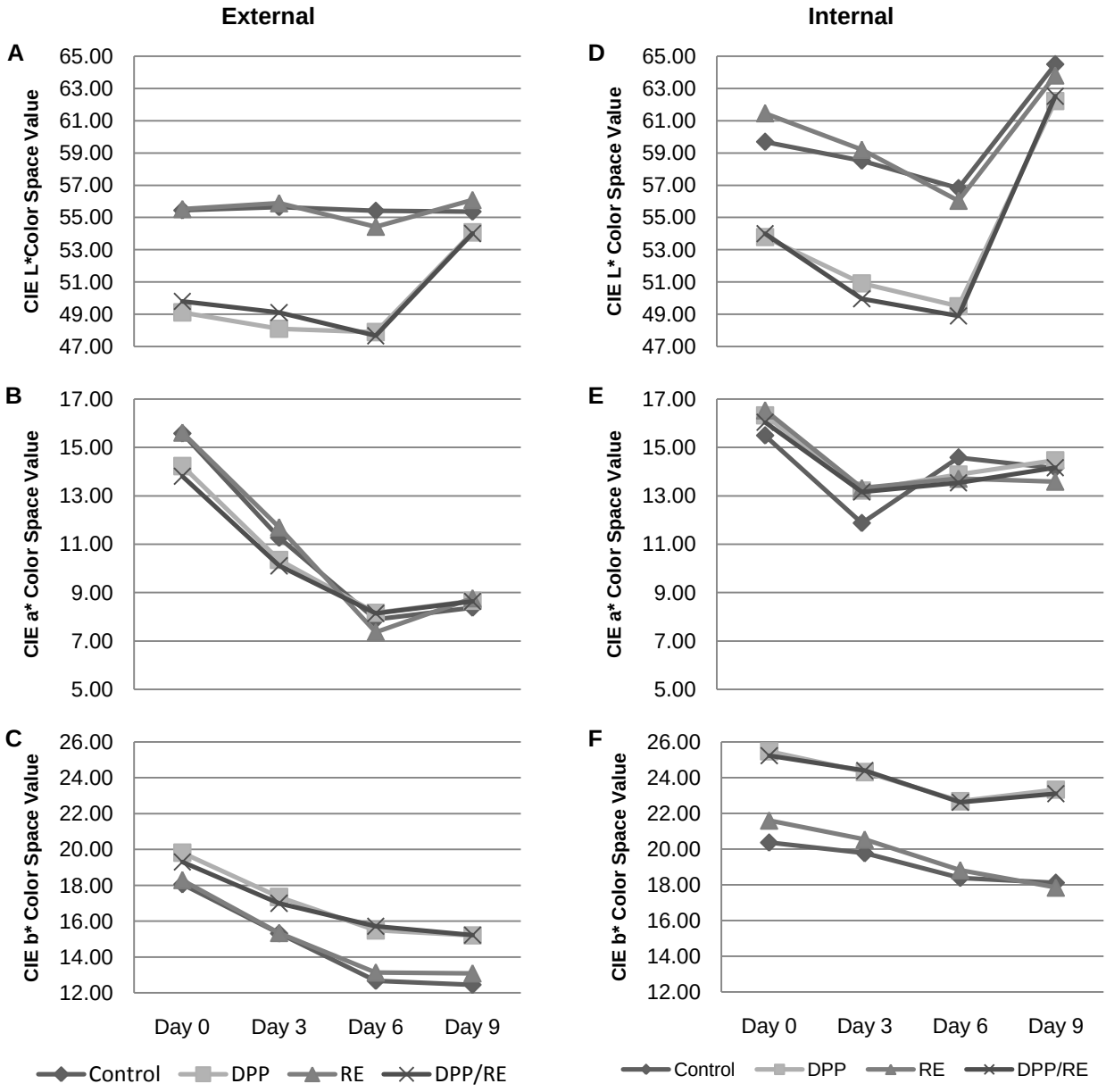

Figure 4. Least square means of external (A-C) and internal (D-F) L*, a*, and b* values, on raw refrigerated turkey breakfast sausage at days 0, 3, 6, and 9

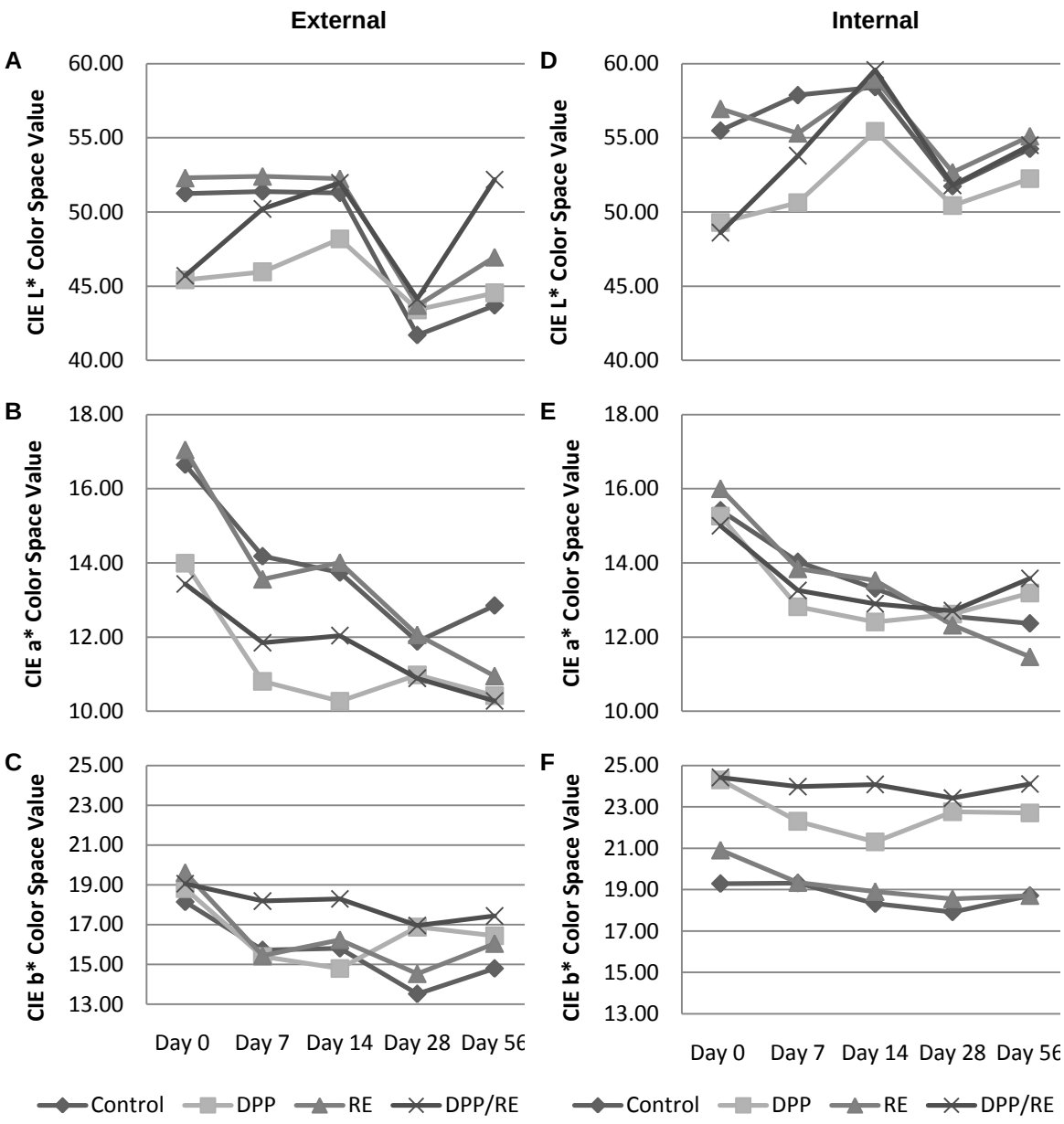

Figure 5. Least squares means of external (A-C) and internal (D-F) *L*, a*,* and *b** values, on raw frozen (-23°C) turkey breakfast sausage at days 0, 7, 14, 28, and 56

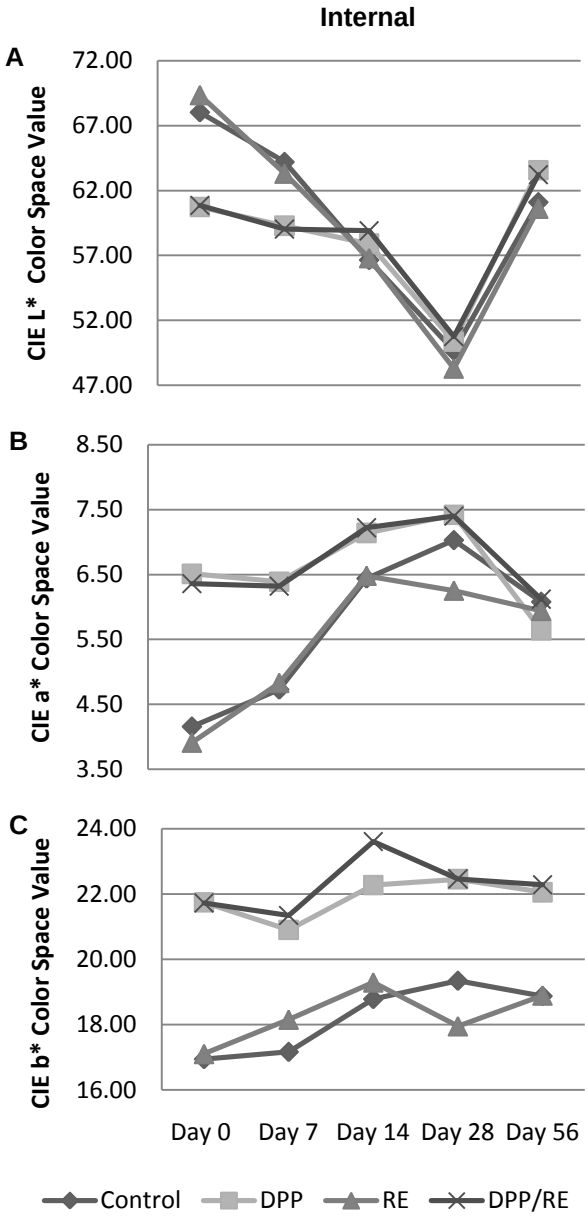

Figure 6. Least squares means of internal (A-C) *L*, a*,* and *b** values, precooked frozen (-23°C) turkey breakfast sausage at days 0, 7, 14, 28, and 56

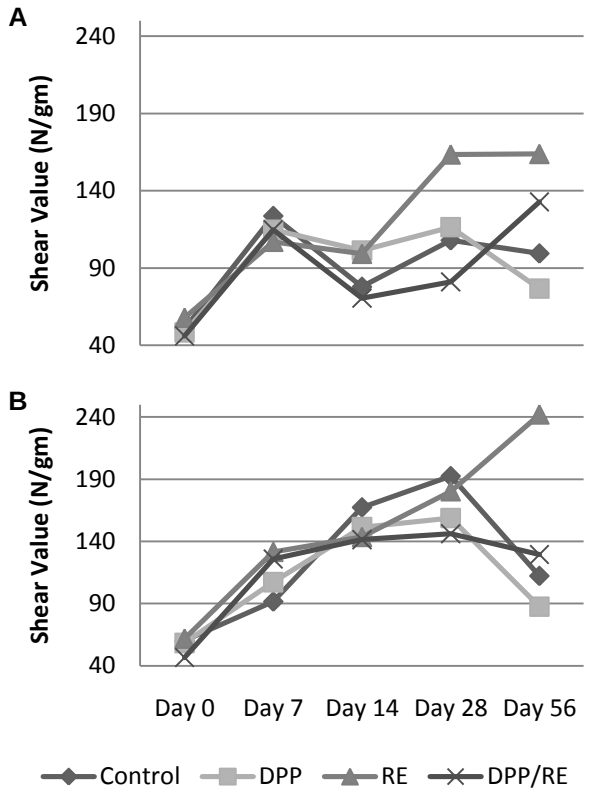

Figure 7. Least square means of shear values (N/gm) of precooked frozen (-23°C) turkey breakfast sausage, re-heated and held for 15 (A) or 30 (B) minutes at days 0, 7, 14, 28, and 56

Table 1. Formulation weights (kg) for manufacture of turkey breakfast sausages containing no antioxidants (Control), 3% dried plum powder (DPP), 0.05% rosemary extract (RE), or a blend of 3% dried plum powder and 0.05% rosemary extract (DPP/RE)

	Treatment			
Meat Block (kg)	**Control**	**DPP**	**RE**	**DPP/RE**
Ground Turkey Breast	10.89	10.89	10.89	10.89
MDTM	2.72	2.72	2.72	2.72
Non Meat Ingredients (kg)				
AC Legg Sausage Seasoning	0.06	0.06	0.06	0.06
Encapsulated Salt	0.14	0.14	0.14	0.14
Rosemary Extract	0	0	0.009	0.009
Dried Plum Powder	0	0.41	0	0.41
Ice Water	0.41	0.41	0.41	0.41
Total Weight (kg)	14.22	14.63	14.23	14.64

Table 2. Least squares means of proximate composition, pH, cook yield, and cook time of raw and/or cooked turkey breakfast sausage at day 0

	Treatments				
Raw	**Control[f]**	**DPP[g]**	**RE[h]**	**DPP/RE[i]**	**SEM[e]**
Fat %	3.43[a]	3.14[a]	3.20[a]	3.04[a]	0.11
Protein %	21.36[a]	21.03[a]	21.47[a]	20.97[a]	0.13
Moisture %	74.33[a]	74.02[a]	74.24[a]	73.45[a]	0.27
Cooked					
Fat %	4.12[a]	4.71[a]	4.75[a]	4.38[a]	0.17
Protein %	27.45[a]	27.66[a]	28.94[a]	26.79[a]	0.59
Moisture %	67.46[a]	65.26[a]	65.51[a]	65.98[a]	0.64
pH					
Raw Refrig.	5.83[a]	5.69[b]	5.83[a]	5.70[b]	0.01
Raw Frozen	5.85[a]	5.73[b]	5.84[a]	5.73[b]	0.01
Precooked Frozen	6.05[a]	5.95[b]	6.01[ab]	5.94[b]	0.02
Cooked					
Yield %	85.85[b]	87.13[ab]	88.80[a]	88.84[a]	0.65
Time (min)	21.38[a]	21.33[a]	23.50[a]	23.40[a]	1.10

[a-d]Means in a row with different superscripts are significantly different ($P < 0.05$)
[e]SEM = standard error of the mean
[f]Control = no antioxidant
[g]DPP = 3% dried plum powder
[h]RE = 0.05% rosemary extract
[i]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Table 3. Least squares means of the 2-thiobarbituric acid reactive substances (TBARS, mg malonaldehyde/kg meat) for raw refrigerated[l] (6°C, days 0, 3, 6, 9), precooked frozen (-23°C, days 0, 7, 14, 28, 56) turkey breakfast sausage and TBARS for raw frozen (-23°C, days 0, 7, 14, 28, 56) turkey breakfast sausage

TBARS Raw Refrigerated

Treatment	Day 0	Day 3	Day 6	Day 9	SEM[g]
Control[h]	0.48[a]	0.95[a]	3.53[bcd]	3.04[bf]	0.16
DPP[i]	0.42[a]	1.20[a]	3.93[cd]	4.12[d]	0.17
RE[j]	0.48[a]	0.66[a]	3.17[bc]	2.91[b]	0.16
DPP/RE[k]	0.35[a]	0.94[a]	3.49[bcd]	3.50[bcd]	0.17

TBARS Precooked Frozen

Treatment	Day 0	Day 7	Day14	Day 28	Day 56	SEM[g]
Control[h]	1.65[bcd]	2.13[de]	2.19[de]	2.07[de]	3.82[f]	0.18
DPP[i]	0.45[a]	1.08[abc]	0.36[a]	0.49[a]	0.49[a]	0.18
RE[j]	0.73[ab]	1.72[cd]	1.49[bcd]	2.13[de]	2.94[ef]	0.18
DPP/RE[k]	0.36[a]	1.06[abc]	0.46[a]	0.45[a]	0.45[a]	0.18

TBARS Raw Frozen

Treatment	Control[j]	DPP[k]	RE[l]	DPP/RE[m]		SEM[g]
	0.58[a]	0.43[a]	0.56[a]	0.38[b]		0.03
Storage Day	**0**	**7**	**14**	**28**	**56**	**SEM[g]**
	0.36[c]	0.57[a]	0.48[b]	0.48[b]	0.54[ab]	0.03

[a-f]Means with the same letter in a row and column are not significantly different ($P < 0.05$)
[g]SEM = standard error of the mean
[h]Control = no antioxidant
[i]DPP = 3% dried plum powder
[j]RE = 0.05% rosemary extract
[k]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[l]Refrigerated = under fluorescent lights (1900 Lux)

Table 4. Least squares means of aerobic plate count (APC) values (Log_{10}CFU/gm) and lactic acid bacteria (LAB) values (Log_{10}CFU/gm), for turkey breakfast sausages stored raw, refrigerated[k] (6°C, days 0, 3, 6, and 9)

APC Values					
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**SEM[f]**
Control[g]	4.47[a]	7.41[c]	8.92[de]	9.29[e]	0.10
DPP[h]	4.56[a]	6.29[b]	8.54[d]	8.88[de]	0.10
RE[i]	4.55[a]	7.09[c]	8.80[de]	9.08[e]	0.10
DPP/RE[j]	4.37[a]	6.36[b]	8.39[d]	9.14[e]	0.10
LAB Values					
Treatment	**Control[j]**	**DPP[k]**	**RE[l]**	**DPP/RE[m]**	**SEM[f]**
	6.44[a]	5.82[b]	6.32[ab]	5.94[ab]	0.11
Storage Day	**0**	**3**	**6**	**9**	**SEM[f]**
	4.19[d]	4.99[c]	7.43[b]	7.90[a]	0.10

[a-e]Means with the same letter in a row and column are not significantly different ($P < 0.05$)
[f]SEM = standard error of the mean
[g]Control = no antioxidant
[h]DPP = 3% dried plum powder
[i]RE = 0.05% rosemary extract
[j]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[k]Refrigerated = under fluorescent lights (1900 Lux)

Table 5. Least square means of external and internal L*, a*, and b* values, on turkey breakfast sausage stored raw, refrigerated[o] (6°C, days 0, 3, 6, and 9)

Day 0	Control[k]	DPP[l]	RE[m]	DPP/RE[n]	SEM[j]
Ex.L*	55.45^{cd}	49.12^{ab}	55.53^{cd}	49.80^{b}	0.45
Ex.a*	15.58^{g}	14.23^{fg}	15.61^{g}	13.81^{f}	0.31
Ex.b*	18.06^{cd}	19.82^{e}	18.29^{cd}	19.30^{de}	0.28
In.L*	59.69^{efg}	53.79^{b}	61.46^{fgh}	54.00^{b}	0.58
In.a*	15.49^{ef}	16.32^{f}	16.53^{f}	16.04^{f}	0.29
In.b*	20.37^{bcd}	25.47^{h}	21.60^{de}	25.23^{h}	0.35
Day 3					
Ex.L*	55.65^{cd}	48.10^{ab}	55.89^{cd}	49.11^{ab}	0.37
Ex.a*	11.27^{de}	10.35^{de}	11.70^{e}	10.11^{cd}	0.28
Ex.b*	15.32^{b}	17.35^{c}	15.34^{b}	17.00^{c}	0.25
In.L*	58.52^{cde}	50.92^{a}	59.20^{def}	49.96^{a}	0.48
In.a*	11.87^{a}	13.22^{b}	13.32^{bc}	13.16^{b}	0.24
In.b*	19.77^{bc}	24.31^{gh}	20.54^{cd}	24.39^{gh}	0.29
Day 6					
Ex.L*	55.42^{cd}	47.90^{ab}	54.43^{c}	47.67^{a}	0.35
Ex.a*	7.90^{ab}	8.17^{ab}	7.37^{a}	8.14^{ab}	0.27
Ex.b*	12.68^{a}	15.49^{b}	13.14^{a}	15.72^{b}	0.24
In.L*	56.81^{cd}	49.50^{a}	56.04^{bc}	48.90^{a}	0.45
In.a*	14.58^{de}	13.88^{bcd}	13.71^{bcd}	13.54^{bcd}	0.22
In.b*	18.39^{a}	22.68^{ef}	18.82^{ab}	22.62^{ef}	0.27
Day 9					
Ex.L*	55.37^{cd}	54.08^{c}	56.09^{d}	54.01^{c}	0.35
Ex.a*	8.38^{ab}	8.66^{abc}	8.77^{bc}	8.64^{ab}	0.27
Ex.b*	12.46^{a}	15.21^{b}	13.09^{a}	15.23^{b}	0.24
In.L*	64.50^{i}	62.22^{ghi}	63.80^{hi}	62.52^{hi}	0.45
In.a*	14.14^{bcd}	14.47^{cde}	13.59^{bcd}	14.16^{bcde}	0.22
In.b*	18.12^{a}	23.32^{fg}	17.85^{a}	23.10^{efg}	0.27

[a-l]Means with the same letter and of like type are not significantly different ($P < 0.05$)
[j]SEM = standard error of the mean
[k]Control = no antioxidant
[l]DPP = 3% dried plum powder
[m]RE = 0.05% rosemary extract
[n]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[o]Refrigerated = under fluorescent lights (1900 Lux)

Table 6. Least squares means of external and internal *L*, a*,* and *b** values, on raw frozen (-23°C) and internal precooked frozen (-23°C) turkey breakfast sausage at days 0, 7, 14, 28, and 56

Day 0		**Control[k]**	**DPP[l]**	**RE[m]**	**DPP/RE[n]**	**SEM[j]**
Raw	Ex.L*	51.25^{def}	45.43^{abcd}	52.30^{f}	45.70^{abcd}	1.02
	Ex.a*	16.65^{h}	13.99^{efg}	17.05^{h}	13.43^{cdefg}	0.38
	Ex.b*	18.14^{bcdefg}	18.80^{efg}	19.61^{g}	19.05^{fg}	0.68
	In.L*	55.49^{efghi}	49.29^{ab}	56.96^{fghi}	48.61^{a}	1.00
	In.a*	15.42^{i}	15.26^{i}	16.00^{i}	15.00^{hi}	0.22
	In.b*	19.29^{ab}	24.30^{e}	20.91^{bc}	24.42^{e}	0.39
Precooked	In.L*	68.03^{f}	60.73^{cde}	69.36^{f}	60.86^{cde}	0.77
	In.a*	4.16^{ab}	6.51^{efgh}	3.91^{a}	6.36^{def}	0.19
	In.b*	16.94^{a}	21.74^{fg}	17.10^{ab}	21.72^{fg}	0.34
Day 7						
Raw	Ex.L*	51.37^{ef}	45.97^{abcd}	52.41^{f}	50.21^{def}	0.84
	Ex.a*	14.18^{g}	10.81^{a}	13.56^{cdefg}	11.85^{ab}	0.33
	Ex.b*	15.72^{bcdef}	15.39^{abcd}	15.43^{abcde}	18.18^{cdefg}	0.62
	In.L*	57.88^{ghi}	50.63^{abcd}	55.31^{efghi}	53.79^{bcdefg}	0.84
	In.a*	14.03^{gh}	12.82^{bcde}	13.84^{fg}	13.26^{bcdefg}	0.18
	In.b*	19.31^{ab}	22.30^{cd}	19.34^{ab}	23.98^{de}	0.33
Precooked	In.L*	64.20^{e}	59.29^{bc}	63.31^{de}	59.04^{bc}	0.63
	In.a*	4.73^{abc}	6.39^{efg}	4.83^{bc}	6.32^{def}	0.17
	In.b*	17.16^{ab}	20.90^{ef}	18.15^{abcd}	21.34^{fg}	0.29
Day 14						
Raw	Ex.L*	51.28^{ef}	48.19^{cdef}	52.25^{f}	51.97^{f}	0.86
	Ex.a*	13.74^{defg}	10.27^{a}	14.01^{fg}	12.04^{abcd}	0.34
	Ex.b*	15.80^{bcdef}	14.79^{abc}	16.23^{bcdef}	18.29^{defg}	0.63
	In.L*	58.42^{hi}	55.44^{efghi}	58.95^{hi}	59.58^{i}	0.84
	In.a*	13.31^{cdefg}	12.41^{abc}	13.53^{defg}	12.90^{bcdef}	0.18
	In.b*	18.32^{a}	21.31^{bc}	18.90^{a}	24.08^{de}	0.33
Precooked	In.L*	56.65^{b}	57.91^{bc}	56.80^{b}	58.90^{bc}	0.63
	In.a*	6.44^{efg}	7.14^{fghi}	6.48^{efg}	7.22^{ghi}	0.17
	In.b*	18.78^{bcd}	22.27^{gh}	19.29^{d}	23.60^{h}	0.29
Day 28						
Raw	Ex.L*	41.70^{a}	43.41^{ab}	43.70^{abc}	44.15^{abc}	0.84
	Ex.a*	11.88^{abc}	10.98^{a}	12.06^{abcde}	10.89^{a}	0.33
	Ex.b*	13.51^{a}	16.87^{bcdefg}	14.52^{ab}	16.95^{bcdefg}	0.62
	In.L*	51.74^{abcde}	50.44^{abc}	52.68^{abcdef}	51.79^{abcde}	0.84
	In.a*	12.56^{bcd}	12.62^{bcde}	12.32^{ab}	12.71^{bcde}	0.18
	In.b*	17.92^{a}	22.76^{cde}	18.55^{a}	23.42^{de}	0.33
Precooked	In.L*	49.67^{a}	50.36^{a}	48.30^{a}	50.76^{a}	0.63
	In.a*	7.03^{fghi}	7.42^{i}	6.25^{def}	7.40^{hi}	0.17
	In.b*	19.34^{de}	22.45^{gh}	17.95^{abc}	22.46^{gh}	0.29
Day 56						
Raw	Ex.L*	43.70^{abc}	44.55^{abc}	46.96^{bcde}	52.19^{f}	0.84
	Ex.a*	12.85^{bcdef}	10.42^{a}	10.95^{a}	10.28^{a}	0.33
	Ex.b*	14.79^{abc}	16.44^{bcdefg}	16.04^{bcdef}	17.43^{bcdefg}	0.62
	In.L*	54.26^{bcdefg}	52.24^{abcdef}	55.11^{defghi}	54.50^{cdefgh}	0.84
	In.a*	12.37^{ab}	13.19^{bcdefg}	11.47^{a}	13.58^{efg}	0.18
	In.b*	18.71^{a}	22.70^{cde}	18.71^{a}	24.10^{de}	0.33
Precooked	In.L*	61.10^{cde}	63.57^{de}	60.61^{cd}	63.22^{de}	0.63
	In.a*	6.08^{de}	5.64^{cd}	5.94^{de}	6.12^{de}	0.17
	In.b*	18.87^{cd}	22.05^{fgh}	18.89^{cd}	22.28^{gh}	0.29

[a-i]Means with the same letter and of like type are not significantly different ($P < 0.05$)
[j]SEM = standard error of the mean
[k]Control = no antioxidant
[l]DPP = 3% dried plum powder
[m]RE = 0.05% rosemary extract
[n]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Table 7. Least square means of shear values (N/gm) and storage day on cook yields, of precooked frozen (-23°C), re-heated and held (15 or 30 min) turkey breakfast sausage at days 0, 7, 14, 28, and 56, and shear values (N/gm) of raw frozen (-23°C) turkey breakfast sausage at day 1

15 min Held Shear Values						
Treatment	**Day 0**	**Day 7**	**Day 14**	**Day 28**	**Day 56**	**SEM[g]**
Control[i]	50.85^{abc}	123.72^{bcd}	77.87^{abc}	107.97^{abcd}	99.45^{abcd}	16.12[h]
DPP[j]	48.41^{ab}	114.72^{bcd}	101.36^{abcd}	116.39^{bcd}	76.78^{abc}	16.05
RE[k]	57.96^{abc}	107.03^{abcd}	99.26^{abcd}	163.51^{d}	163.83^{d}	16.05
DPP/RE[l]	46.14^{a}	114.71^{bcd}	70.47^{abc}	81.04^{abc}	132.77^{cd}	16.05
30 min Held Shear Values						
Treatment	**Day 0**	**Day 7**	**Day 14**	**Day 28**	**Day 56**	**SEM[g]**
Control[i]	60.14^{abc}	91.69^{abcd}	167.33^{def}	192.40^{ef}	112.28^{abcde}	17.39
DPP[j]	58.31^{ab}	107.22^{abcde}	151.43^{de}	158.71^{def}	87.53^{abcd}	17.47[h]
RE[k]	61.73^{abc}	131.53^{bcde}	143.49^{bcde}	180.24^{ef}	242.01^{f}	17.39
DPP/RE[l]	46.59^{a}	125.85^{abcde}	141.42^{bcde}	146.23^{cde}	129.47^{bcde}	17.39
Reheated & Held Cook Yields						
Hold Time	**Day 0**	**Day 7**	**Day 14**	**Day 28**	**Day 56**	**SEM[g]**
15 min	77.50^{c}	79.26^{bc}	76.92^{c}	82.48^{b}	89.29^{a}	1.02
30 min	74.94^{c}	77.78^{bc}	75.16^{c}	81.86^{b}	88.29^{a}	1.15
Raw Shear Values						
Treatments	**Control[i]**	**DPP[j]**	**RE[k]**	**DPP/RE[l]**		**SEM[g]**
	37.88^{a}	36.11^{a}	39.31^{a}	36.46^{a}		1.56

[a-f]Means with the same letter are not significantly different ($P < 0.05$)
[g]SEM = standard error of the mean
[h]SEM values for treatment are high due to missing data point
[i]Control = no antioxidant
[j]DPP = 3% dried plum powder
[k]RE = 0.05% rosemary extract
[l]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Table 8. Least squares means of descriptive attribute sensory panel scores for texture, aromatics, basic tastes, mouthfeels, and aftertastes on raw and precooked frozen (-23°C) turkey breakfast sausage at day 28

	Type			Treatment				
Texture	**Raw Frozen**	**Precooked Frozen**	**SEM[i]**	**Control[j]**	**DPP[k]**	**RE[l]**	**DPP/RE[m]**	**SEM[i]**
Springiness	3.02[a]	2.35[b]	0.18	2.97[e]	2.60[e]	2.67[e]	2.50[e]	0.25
Fracturability	3.02[a]	2.95[a]	0.17	3.00[e]	2.77[e]	3.20[e]	2.97[e]	0.24
Hardness	4.98[a]	5.60[a]	0.25	5.00[e]	5.10[e]	5.87[e]	5.20[e]	0.35
Cohesiveness	7.93[b]	8.37[a]	0.14	7.87[e]	8.07[e]	8.63[e]	8.03[e]	0.20
Juiciness	3.55[a]	2.02[b]	0.23	3.03[e]	2.83[e]	2.47[e]	2.80[e]	0.32
Aromatics								
Cook Turkey Lean	4.78[a]	4.40[b]	0.08	4.80[e]	4.57[e]	4.63[e]	4.37[e]	0.12
Cook Turkey Fat	1.08[a]	0.72[b]	0.07	0.90[e]	0.93[e]	0.97[e]	0.80[e]	0.10
Plum	1.15[a]	0.85[b]	0.09	0.10[f]	1.90[e]	0.23[f]	1.77[e]	0.13
Rosemary	0.65[a]	0.58[a]	0.11	0.77[e]	0.67[e]	0.37[e]	0.67[e]	0.15
Spice Complex	4.57[a]	4.32[a]	0.10	4.73[e]	4.37[ef]	4.53[ef]	4.13[f]	0.13
Chemical	0.00[a]	0.02[a]	0.01	0.00[e]	0.03[e]	0.00[e]	0.00[e]	0.02
Cardboardy	0.03[b]	0.37[a]	0.10	0.37[e]	0.10[e]	0.23[e]	0.10[e]	0.15
Basic Tastes								
Sweet	0.67[a]	0.57[a]	0.06	0.13[f]	1.10[e]	0.13[f]	1.10[e]	0.08
Salt	2.08[a]	2.15[a]	0.04	2.08[e]	2.08[e]	2.25[e]	2.04[e]	0.06
Bitter	1.72[a]	1.68[a]	0.07	1.70[e]	1.63[e]	1.87[e]	1.60[e]	0.10
Sour	0.73[a]	0.87[a]	0.05	0.67[e]	0.87[e]	0.93[e]	0.73[e]	0.07
Mouthfeels								
Metallic	1.63[a]	1.55[a]	0.05	1.57[e]	1.60[e]	1.73[e]	1.47[e]	0.08
Spice Burn	3.65[a]	3.55[a]	0.13	3.83[e]	3.57[e]	3.83[e]	3.17[e]	0.18
Astringent	1.23[a]	1.27[a]	0.07	1.23[e]	1.23[e]	1.33[e]	1.20[e]	0.10
Aftertastes								
Burn	3.12[a]	3.05[a]	0.13	3.27[e]	3.07[e]	3.13[e]	2.87[e]	0.19
Acid	0.20[a]	0.22[a]	0.02	0.23[e]	0.23[e]	0.17[e]	0.20[e]	0.03
Sour	0.48[a]	0.53[a]	0.06	0.40[e]	0.63[e]	0.47[e]	0.53[e]	0.09
Bitter	1.12[a]	1.00[a]	0.05	1.07[e]	1.07[e]	1.07[e]	1.03[e]	0.08
Sweet	0.13[a]	0.10[a]	0.04	0.00[f]	0.20[ef]	0.00[f]	0.27[e]	0.05
Spice	2.30[a]	2.03[a]	0.14	2.33[e]	2.17[e]	2.13[e]	2.03[e]	0.20
Rancidity	0.30[b]	0.90[a]	0.19	0.70[e]	0.47[e]	0.83[e]	0.40[e]	0.27

[a-d] 'Type' means in a row with different superscripts are significantly different (P < 0.05)

[e-h] 'Treatment' means in a row with different superscripts are significantly different (P < 0.05)

[i]SEM=standard error of the mean

[j]Control = no antioxidant

[k]DPP = 3% dried plum powder

[l]RE = 0.05% rosemary extract

[m]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

APPENDIX B

Ballot used for descriptive sensory analysis of turkey sausage links

DPP Turkey Breakfast Sausage
Flavor/Texture Profile Ballot

Name:_____
Date:_____
Session:_____

SAMPLE ID #:	W/U	257	629	538	617	831	746	348	722
TEXTURE:									
Springiness									
Fracturability									
Hardness									
Cohesiveness									
Juiciness									
AROMATICS:									
Cooked Turkey Lean									
Cooked Turkey Fat									
Plum									
Rosemary									
Spice Complex									
Chemical									
Cardboard									
Painty									
Fishy									
Other (Describe)									
TASTES:									
Sweet									
Salt									
Bitter									
Sour									
MOUTHFEELS:									
Metallic									
Spice Burn									
Astringent									
AFTERTASTES:									
Other (Describe)									
Burn									
Acid									
Sour									
Bitter									
Sweet									
Spice									
Rancid Flavor									

Springiness	**Fracturability**	**Hardness**	**Cohesiveness**	**Juiciness**
0.0 Cream Cheese	1.0 Corn Muffin	1.0 Cream Cheese	1.0 Corn Muffin	1.0 Banana
5.0 Frankfurter	4.0 Graham Crackers	3.0 American Processed Cheese	4.0 American Processed Chesse	2.0 Carrot
9.5 Marshmallow	5.0 Rye Wafers	5.0 Frankfurter	8.0 Dried Fruit - raisin	4.0 Fresh Mushroom
15.0 Jello	7.0 Ginger Snaps	7.0 Olives	10.0 Soft Pretzel	8.0 Cucumber
	9.0 Melba Toast	9.0 Peanut	12.0 Candy Chews - Starburst	10.0 Apple
	13.0 Peanut Brittle	11.0 Carrots	15.0 Chewing gum	12.0 Honeydew Melon
	15.0 Hard Candy	14.5 Hard Candy - Lifesaver		15.0 Watermelon

APPENDIX C

Textures, aromatics, tastes, mouthfeels, and aftertastes attribute definitions, references, and intensity based on a 15-point scale used for descriptive sensory analysis of turkey sausage links

Attribute	Description	Reference/Value		Brand/Type
Textures				
Springiness	The degree to which the sample retains its shape after compression	Cream Cheese	0.0	Philadelphia
		Frankfurter	5.0	Hebrew National
		Marshmallow	9.5	Kraft Foods
		Gelatin Dessert	15.0	Jell-O
Fracturability	The degree of force it takes to break/bite the sample	Corn Muffin	1.0	Jiffy
		Graham Crackers	4.0	Nabisco
		Rye Wafers	5.0	Finn Crisp
		Ginger Snaps	7.0	Nabisco
		Melba Toast	9.0	Plain, rectangular
		Peanut Brittle	13.0	Brand available
		Hard Candy	15.0	Life Savers
Hardness	The degree of force it takes to compress sample	Cream Cheese	1.0	Philadelphia
		Cheese	3.0	Yellow American
		Frankfurter	5.0	Hebrew National
		Olives	7.0	Goya Foods
		Peanut	9.0	Planters
		Carrots	11.0	Fresh
		Hard Candy	14.5	Life Savers
Cohesiveness	The degree the sample deforms before breaking	Corn Muffin	1.0	Jiffy
		Cheese	4.0	Yellow American
		Raisin, Dried	8.0	Sun-Maid
		Soft Pretzel	10.0	Soft-Pretzel
		Candy Chews	12.0	Starburst
		Chewing Gum	15.0	Wrigley
Juiciness	The amount of juice/moisture perceived in the mouth	Banana	1.0	Fresh
		Carrot	2.0	Fresh
		Mushroom	4.0	Fresh
		Cucumber	8.0	Fresh
		Apple	10.0	Red Delicious
		Honeydew Melon	12.0	Fresh
		Watermelon	15.0	Fresh, Seedless

Attribute	Description	Reference/Value		Brand/Type
Aromatics				
Cooked Turkey Lean	The aromatic associated with cooked turkey muscle	Ground Turkey	15.0	90/10, Cooked
Cooked Turkey Fat	The aromatic associated with cooked turkey fat	Ground Turkey Drippings	15.0	90/10, Cooked
Plum	The aromatic associated with dried plum powder	Plum Powder	15.0	SunSweet, Inc.
Rosemary	The aromatic associated with rosemary extract	Rosemary Extract	15.0	Herbalox
Spice Complex	The aromatic associated with sausage spice blend	Breakfast Sausage Seasoning	15.0	AC Legg's
Chemical	The aromatic associated with the burn/heat form spice blend	Standard Solution	15.0	Capsaicin
Cardboard	The aromatic associated with stale meat, wet cardboard and slightly rancid fat	Wet cardboard placed in the mouth and air drawn over	15.0	Cardboard
Painty	The aromatic associated with rancid fat	Linseed oil	15.0	Linseed oil
Fishy	The aromatic associated with some rancid fats	Catfish	15.0	Catfish
Tastes				
Sweet	The taste stimulated by sugars like glucose, fructose, and sucrose	Standard solution	2.0 5.0 10.0 15.0	Sugar
Salt	The taste stimulated by sodium salts, sodium chloride and sodium glutamate, and other salts	Standard Solution	2.5 5.0 8.5 15.0	Sodium Chloride
Bitter	The taste stimulated by substances such as quinine, caffeine and hop bitters	Standard Solution	2.0 5.0 10.0 15.0	Caffeine
Sour	The taste stimulated by acids, such as citric, malic, phosphoric, etc	Standard Solution	2.0 5.0 10.0 15.0	Citric Acid

Attribute	Description	Reference/Value		Brand/Type
Mouthfeels				
Metallic	The sensations on the tongue associated with metals such as iron or copper	Cooked liver	15.0	Beef liver
Spice Burn	The shrinking or puckering of the tongue surface caused by substances such as tannin or alum	Standard Solution	4.0 7.5 11.0 15.0	Capsaicin
Aftertastes				
Burn	Degree of hot sensations that linger after tasting sample	Standard Solution	4.0 7.5 11.0 15.0	Capsaicin
Acid	Taste associated with sour and astringent sensations	Standard Solution	2.0 5.0 10.0 15.0	Citric Acid
Rancid Flavor	Taste associated with cardboard, fishy, and painty aromatics and staled meat/ fat			

APPENDIX D

SOP for Turkey Sausage Shelf Life Samples

1. Sausage samples were received at the Food Microbiology Laboratory (Room 305 Kleberg) and assigned a laboratory identification number.
2. The exterior of the sample package was disinfected by wiping the PVC overwrap with a paper towel moistened with 70% ethanol.
3. The package containing samples was then aseptically opened using flame sterilized forceps and scalpel and exposing half of the product for sampling by folding back the PVC overwrap.
4. A total of 10 g were taken from two links using flame sterilized forceps and scalpel and placed into a sterile stomacher bag to which 90 ml of 0.1% peptone diluent was added.
5. The samples were macerated for 2 minutes using a Stomacher 400 Circulator (Seward Medical, West Sussex, United Kingdom).
6. Aerobic plate counts were determined by plating 1 ml of the sample rinse and the appropriate 10-fold dilutions of the same onto Petrifilm™ aerobic count plates.
7. Lactic acid bacteria counts were determined simultaneously by dispensing 1 ml of the sample rinse and the appropriate 10-fold dilutions of the same into sterile petri dishes and adding Lactobacilli MRS agar. After the plates solidified a MRS overlay was added.
8. All plates were incubated at 30^{o} C for 72 h before counting and reporting CFU per package.

Microbiological Analysis. Upon arrival at the Food Microbiology Laboratory at Texas A&M University (College Station, TX) turkey sausage packaged in Styrofoam trays with PVC overwrap were sanitized by wiping the PVC with paper towel moistened with 70% ethanol. The packages were then opened aseptically using flame sterilized forces and scalpels and exposing half the product for sampling by folding back the PVC overwrap. A 10 gram sample was placed into a sterile stomacher bag to which 90 ml of 0.1% peptone diluent was added. The samples were macerated for 2 minutes using a Stomacher 400 Circulator (Seward Medical, West Sussex, United Kingdom). Aerobic plate counts were determined by plating 1 ml of the sample rinse and 1 ml of the appropriate 10-fold dilutions of the same on Petrifilm™ aerobic count plates (3M, St. Paul, MN). Lactic acid bacteria counts were determined simultaneously by dispensing 1 ml of the sample rinse and the appropriate 10-fold dilutions of the same into sterile petri dishes to which Lactobacilli MRS Agar (Difco, Detroit, MI) was added and allowed to solidify. An additional MRS overlay was added to each plate. Both Petrifilm™ and MRS plates were incubated at 30^{o}C for 72 h before counting and reporting CFU per package.

APPENDIX E

CRUDE FAT DETERMINATION – AOAC PROCEDURE

EQUIPMENT:
Whatman® filter paper, 22 x 40 mm
Stapler
Aluminum dishes, 50 mm diameter x 40 mm deep
Desiccator with desiccant
Tongs
Analytical balance/ Scale
Convection oven
Soxhlet apparatus
Fume hood
Boiling chips

REAGENTS:
Ether (diethyl or petroleum)

PROCEDURE:

1. Construct thimbles from Whatman 22 x 40 mm filter paper folded into a sleeve open at one end and stapled at the other end. Dry thimbles overnight at 100^{o}C using air dry oven. (Samples dried previously by the Air Oven method may be used.)
2. Cool thimbles in desiccator for 30 minutes.
3. Weigh thimble and record the weight (Beginning thimble weight). Put 2 to 3 grams of stirred sample into the thimble and seal. Record the weight to the nearest 0.0001 g (Beginning thimble and sample weight).
4. Dry overnight at 100^{o}C.
5. Cool in desiccator for at least 30 minutes prior to reweighing.
6. Weigh the sample and record the weight (Dried thimble and sample weight).
7. Extract on the Soxhlet apparatus for 12 hours at an ether (diethyl or petroleum) drip rate of approximately 4 drops per second.
8. Allow sample to evaporate under the hood until thoroughly dry (no detectable ether odor) ** This is very important to avoid an explosion or flash fire**
9. Dry in the oven overnight at 100^{o}C.
10. Cool in the desiccator of 30 minutes or until the sample cools to room temperature (this could be a long as one hour).
11. Weigh the sample and record (Fat free thimble and sample weight).

CALULATIONS:

$$\textbf{Percent Fat Content} = \frac{\textbf{(B-C)} \times 100}{\textbf{A}}$$

Where: **A = Sample Weight**
B = Dried thimble and sample weight
C = Fat free thimble and sample weight

APPENDIX F

MOISTURE ANALYSIS – AOAC PROCEDURE

EQUIPMENT:
Whatman® filter paper, 22 x 40 mm
Stapler
Aluminum dishes, 50 mm diameter x 40 mm deep
Desiccator
Convection oven
Food Processor
Tongs
Analytical balance/ Scale

PROCEDURE:

1. Filter paper/extraction thimbles consisting of Whatman 22 x 40 mm filter paper folded in to a sleeve open at one end and stapled at the opposite end, or a covered aluminum dish at least 50 mm in diameter and not greater than 40 mm deep.
2. Mechanical convection oven, preferably one equipped with a booster heater.
3. Accurately weigh sample to the fourth decimal place (+/- 0.0001). Sample should weigh approximately 2 g. Then place sample into a previously dried and desiccated sleeve, paper thimble or a covered aluminum dish that has been dried and desiccated.

   Note: handle sample container with tongs to avoid moisture from your fingers. Never handle sample containers with gloved or ungloved hands for the most accurate results.

4. Dry sample for 16 to 18 hours at 100 to 102^{o}C, or for four hours at 125^{o}C, in the mechanical convection oven. Drying at higher temperature (125^{o}C) may cause the fat to oxidize (vaporize) creating excessive fat loss and inaccurate fat percentages.
5. Cool the samples in a desiccator (with desiccant) to room temperature so that no additional moisture is absorbed by the sample. Reweigh the dried sample.

CALCULATIONS:

$$\textbf{Percent Moisture} = \frac{100\,(B-C)}{A}$$

Where: **A = Sample weight**
B = Weight of dish/thimble + sample before drying
C = Weight of dish/thimble + sample after drying

APPENDIX G

RAPID NITROGEN/PROTEIN ANALYSIS PROCEDURE
LECO FP-528

EQUIPMENT:
LECO FP-528 System
Analytical balance

REAGENTS:
Oxygen gas
Helium Gas
Air

PROCEDURE:
Instrument Start-Up:

Assumes instrument switch has been turned "ON", but gases have been turned "OFF". In the "OFF" mode, no helium is flowing.

QUICK MENU – First Screen

1. Perform leak detection – See operation manual for this procedure.
2. Standard parameter settings for the LECO FP528 Nitrogen/Protein System:

Gases	**Pressure**
Oxygen	40 psi
Air	40 psi
Helium	40 psi

When gas tanks reach 300 psi – **CHANGE TO NEW TANK**
Combustion Tube Temperature – 850ºC

•**Furnace Filter** – Change when the metal shavings have begun to rust ~1" down the tube. Change daily if the machine is used 8 hr/day.

•**Filter Materials**

Anhydrone (Mg Perchlorate) – Absorbs H2O
LecoSorb (NaOH with silica coating) – Absorbs CO2

•**Thermal Conductivity Cell**

Reference flow of Helium = 30 cc
Sample Flow = 200 cc/min – Red line is the indicator

3. To turn gases "ON"

NOTE: Superscript "S" denotes prompts on the LECO FP528 Screen while superscript "B" denotes Button below screen.

[ANALYZE]^{S} → [l]^{S} → [MENU]^{B} → [5]^{S} → [CARRIER GASES]^{S} →
(ANALYZE) (SYSTEM CONTROLS)
[ON]^{B} → [EXIT]^{B}

4. To calibrate the BLANKS prior to standardization and analysis

[l]^{B} → [SELECT]^{B}* → [NEXT]^{B}** → [START]^{B} → [EXIT]^{B} →

[3]^{S} → [YES]^{B***}→ [MENU]^{B} → [6]^{S} → [EXIT]^{B****}→ TO QUICK MENU
(CALIBRATE) (CALIBRATE BLANK)

*Press key two times to move to ID Code; Input Code by pressing key pad buttons until appropriate letter or number appears.
**Press key to input multiple blanks >5.
***Press to select each blank to be run.
****Press 2 times.

(Allow 5 or more blanks to run until blank values are near zero (0), i.e., 0.012 or -0.012).

5. To Run Standards:

[l]^{S} → [WEIGHT]^{S*} → [SELECT]^{B**} → [NEXT]^{B***} → [WEIGHT]^{S****} → (ANALYZE)

[NEXT]^{B*****} → [ENTER REMAINDER OF STD'S] → [START]^{B}
Runs Standard

*Enter weight of standard
**Press 2 times and input ID Cod, i.e. "Oats"
***Press 1x to enter
****Enter 2nd weight of standard
*****Enters 2nd standard

6. To Delete Blanks:

[PREVIOUS]^{B} to select for DELETION
[NEXT]

[ANALYZE]^{B} → [SELECT]^{B} → (Change any blanks as needed) →
Scrolls through [MENU]^{B} → [l]^{S} DELETE

ID Code, Weight, P Factor

[EXIT]^{B} TO MAIN MENU

7. To Run Samples:

Weigh ~0.5000 g of sample into gel cap.

Under the ANALYZE menu, press SELECT to obtain
"Weight Input"

[l]^{S} → [WEIGHT]^{S*} → [SELECT]^{B**} → [NEXT]^{B} → [WEIGHT]^{S} →
Press #1 (ANALYZE) | Press 1x to enter | Enter 2nd wt of Sample

[NEXT]^{B} → [ENTER REMAINDER OF SAMPLES]^{S} → [START]^{B}
Enter 2nd Sample | (Maximum sample number is 10) | Runs samples

*Enter weight of sample.
**Press 1, 2 etc.times and input ID Code, i.e. "Oats" or other sample name.

APPENDIX H

LIPID OXIDATION ANALYSIS PROCEDURE FOR UNCURED MEATS

Apparatus:

500 or 800 ml Kjeldahl flasks
Spectrophotometer with 1 cm cells
Hot plate or Bunsen burner
Waring Blender
Boiling chips
250 ml beakers
Balance / Scale
400 ml beakers
Screw cap test tubes
Test tube rack
Graduated cylinder
Timer
Pipette

Reagents:

0.02 M 2-Thiobarbituric Acid (1.442 g 2-Thiobarbituric acid in 500 ml distilled water). Heat just enough to dissolve, DO NOT BOIL.

0.5% Propyl gallate (PG) and 0.5% ethylenediamine tetraacetic acid (EDTA) solution (5g PG + 5 g EDTA made up to 1 liter distilled water, heat just enough to dissolve, DO NOT BOIL).

4 N HCL (1 volume concentrated HCL and 2 volumes of distilled water) or (384 g conc. HCL in 1 liter dd-water)

Slipicone® Spray (reduces foaming)

PROCEDURE:

Sample/Extraction Solution Combinations for Decreasing Sample Sizes (for Step #1)

Meat (g)	**60**	50	40	30	20	10	2
dd-water (ml)	**90**	75	60	45	30	15	3
PG + EDTA (ml)	**30**	25	20	15	10	5	1

(First choice of reagents is in Bold)

1. Blend 60 g of meat with 90 ml of 50^{o}C distilled water and 30 ml of 0.5% solution of PG and EDTA for 2 min.
2. Weight 30 g of slurry into a 250 ml beaker.
3. Quantitatively transfer beaker contents into a 500 ml Kjeldahl flask rinsing with 77.5 ml of 50^{o}C distilled water.
4. Add 2.5 ml of 4 N HCL to the Kjeldahl flask along with 5-6 boiling chips. Spray Slipicone® into the neck of the Kjeldahl flask.

5. Turn on cooling water in the distillation unit.
6. Connect the flask to the Kjeldahl distillation unit. Turn on heat and collect 50 ml of distillate (12 – 15 min) in a graduated cylinder.
7. Remove distillate and replace with a beaker containing 400 ml of distilled water. Turn off the heat and allow water to be drawn back through the distillation apparatus. Then turn off the cooling water.
8. Add 5 ml of the distillate to a screw cap test tube along with 5 ml of the 0.02 M TBA reagent. Mix and heat in boiling water for 35 min to develop the color. For the blank, use 5 ml distilled water + 5 ml TBA reagent and heat with sample.
9. Cool in tap water for 10 min, place sample in a cuvette, then read the sample absorbance in the spectrophotometer at 530 nm. Then blank should be read first and set at 0 absorbance.

NOTE: For accurate results, a standard curve should be run for quantities of malonaldehyde over the expected range of values.

CALCULATION OF TBA NUMBER:

TBA number = O.D. x K

Where K = 7.8, which was determined for the distillation set up in the lab.

Specifically,

TBA number = Abs 530λ x 7.8 (conversion factor) mg malonaldehyde/kg sample

Standard deviations of the duplicates should be approximately ±0.2 TBA Value.

Slight changes occur in the K value from laboratory to laboratory. Therefore, the K value or standard curve for known dilutions of 1, 1, 3, 5 tetraethyoxypropane should be calculated in each laboratory. K=7.0 is an average value that can be used but may not be the most accurate (Tarladgis et al., 1960).

APPENDIX I

HUNTER LAB MINI SCAN XE PLUS STANDARD OPERATING PROCEDURES

** Always handle the black and white standardization plates with care. Do not scratch or chip them.
Plug Mini Scan into electrical outlet.
Wipe the black plate with a Kimwipe to insure it is clean and place the black plate on the circle of the calibration tile holder.
Place the Mini Scan on the calibration tile holder so the two rubber feet are in the two holes of the holder and the aperture is centered on the black plate. The aperture should fit flatly on the black plate to insure that there is no interference when taking readings.
Push the lightning bolt key on the Mini Scan to turn the unit on.
Make sure that the XYZ values on the screen correspond to the XYZ values listed on the back of the white plate.
You are now ready to standardize the unit. Press the lightning bolt key and the Mini Scan will read the black plate.
When the reading is complete, the screen will indicate that the machine is ready to read the white plate.
Remove the black plate from the calibration tile holder and replace it with the white plate. Wipe the white plate with a Kimwipe. Make sure that the aperture of the Mini Scan sits flatly on the white plate.
Press the lightning bolt key to read the white plate.
Press the lightning bolt key three times and the MiniScan will be ready to read the first sample.
The Tristimulus values L*a*b* will be recorded.
Position the aperture of the Mini Scan on the part of the meat sample to be tested. Be sure that the aperture fits flatly on the meat but do not apply pressure. The spot to be tested should be representative of the **muscle** tissue. There should not be a lot of connective tissue, seam fat or subcutaneous fat where the color reading is taken.
To take a reading, press the lightning bolt key.
Record the L*a*b* values
The Mini Scan is now ready to read the next sample. Repeat the process.
Before taking readings on the second meat sample, make sure the aperture is clean and free of fat or anything that might interfere with a clean reading.
When all readings are complete, unplug it from the electrical source.
Be sure that the Mini Scan is clean and that the aperture is clean before putting the machine away.

VITA

Name:	Robert Matthew Merrill
c/o:	Dr. Wesley N. Osburn
Address:	Department of Meat Science Texas A&M University College Station TX 77840-2471
Email Address:	rob@kingcon.com rmerrill100785@neo.tamu.edu
Education:	M.S., Food Science & Technology, Texas A&M University, 2010 B.S., Culinary Nutrition, Johnson & Wales University, 2007 A.S., Culinary Arts, Johnson & Wales University, 2005
Associations:	Research Chef Association Institute of Food Technologists American Meat Science Association