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

A Final Report to the

California Dried Plum Board
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I. Abstract

Consumer demand for convenient and low cost meat products has resulted in the development of low fat sausage products containing alternative protein sources, such as mechanically separated turkey (MST). Products containing MST are susceptible to lipid oxidation due to stress and aeration during machine separation leading to undesirable sensory properties. Antioxidants, especially those of natural origin, may be used to inhibit lipid oxidation. Our objective was to evaluate the antioxidant activity of dried plum powder (DPP) compared to rosemary extract (RE) in low fat (3.5%) turkey breakfast sausage. Batches were formulated with 80% turkey breast and 20% MST to produce 13.61 kg of meat block with either 3% DPP, 0.05% RE, or 3% DPP combined with 0.05% RE (DPP/RE) added, while the control (C) had no added antioxidant. Edible collagen casings (19mm) were stuffed to produce links weighing ~28 g. Sausages were assigned to multiple shelf-life treatments: (RR) packaged raw in styrofoam trays overwrapped with polyvinyl chloride film (6°C/42°F/0, 3, 6, 9 days), (RF) packaged raw in interwoven paper in plastic lined cardboard boxes and frozen (-23˚C/0, 7, 14, 28, 56 days), and (PF) precooked (74°C/165°F) and frozen (-23˚C/-10°F/0, 7, 14, 28, 56 days). Sausages were analyzed for pH, color (CIE L*, a*, b*), lipid oxidation, microbial growth, sensory attributes, reheat yields and shear force.

The 2-thiobarbituric acid reactive substance (TBARS) values (mg malonaldehyde/kg of meat) for RR samples were not different ($P>0.05$) on days 0-6, although on day 9, C and RE had lower ($P<0.01$) TBARS values than DPP samples. All TBARS values were greater than 1 on day 6 and were considered rancid. TBARS values for RF DPP (0.43) and DPP/RE (0.38) were lower ($P<0.05$) than C (0.58) and RE (0.56) up to 56 days of storage. The PF DPP and DPP/RE had lower TBARS values ($P<0.01$) than C and RE samples on days 14, 28, and 56.

External and internal L* values for RR ($P<0.0001$/0, 3, 6 days), RF ($P<0.05$) and PF ($P<0.01$) samples containing DPP were darker compared to C and RE samples. Redness values for RR and RF C and RE were higher ($P<0.05$) than samples containing DPP, however the PF DPP links had higher a* values than C and RE ($P\leq0.01$) at 0, 7, and 28 days of frozen storage. DPP samples from each storage type had higher b* values overall.

Descriptive sensory data indicated differences ($P<0.05$) between RF and PF sausages in springiness, juiciness, cohesiveness, cook turkey lean, cooked turkey fat, plum, cardboard, and warmed over flavor. Precooking, freezing and reheating sausage links appeared to slightly

decrease overall sensory attributes, with a noticeable decrease in juiciness and slight increase in warmed over flavor, compared to RF links cooked prior to serving. Samples containing DPP had higher ($P<0.0001$) values for plum and sweet tastes, and lower ($P<0.02$) values for spice complex when compared to C and RE.

The addition of 3% DPP alone and combined with 0.05% RE for use as an alternative natural antioxidant suppressed the effects of lipid oxidation while maintaining acceptable sensory attributes over long term frozen storage when compared to RE and C sausage links. It was also observed that DPP darkened the external and internal sausage link color compared to RE and C links.

Keywords: Antioxidant, Dried Plum, Turkey Sausage

II. Stated Objective:

To evaluate the antioxidant activity of DPP compared to a natural antioxidant (rosemary extract) in fresh and precooked turkey sausage breakfast links made from raw materials highly susceptible to lipid and color oxidation.

III. Background Information

Consumers are spending more time away from home and less time in the kitchen in part to busier work schedules, longer commutes, involvement in activities outside of the home, and other factors. With consumers spending less time preparing meals and eating more meals on-the-go, interest and demand in convenience foods has been trending upward. Increases in convenience food sales have been reported in both foodservice and retail outlets. In foodservice outlets, interest lies in portioned, partially cooked, and ready-to eat meat products. These products allow the food service operation to minimize preparation and cooking time and serve the customer more quickly.

Along with the need for easily prepared food items many consumers are looking for healthier foods containing less fat and fewer calories. Formulations for processed meats have been modified so that reduced fat versions can be produced to meet consumer interest. Of the processed meat products, deli meats and sandwich products appear to be one of the most popular types of ready-to-eat meat products, likely due to growth in sales in sandwich outlets.

In retail outlets, consumer interest and sales in food products requiring minimal preparation and cooking time is also trending upward. Pre-cooked, partially-cooked, and ready-to-eat meats are becoming more common in the freezer, refrigerator, and deli sections of grocery stores, being found in individual frozen dinners, frozen family dinner kits, refrigerated meals and snacks, and other food products. With the availability of such products, a meal can virtually be prepared and ready to eat in minutes.

Consumer interest in health has increased along with access to unlimited health and wellness information, leading to greater consumer awareness of the effects of food on health. Some consumers question the healthfulness of some ingredients such as artificial colorings, flavorings and preservatives. Interest in the use of more natural ingredients in the production and preservation of food products has grown, and sales of food products that are “organic,” “natural,” and that contain “no artificial ingredients” have increased. Scientists have explored the use of

dried plums in meat products to maintain or improve the quality of the finished product. Research has indicated that dried plums are very high in antioxidants and can be used effective in retarding lipid oxidation, the cause of off-flavors, off-odors, changes in color, and overall deterioration of quality in pre-cooked meats products. Dried plums are naturally sweet, rich in fiber, and virtually fat-free. The acid profile (malic acid), humectancy, antioxidant and sorbitol content, and natural sweetness are all attributes that may make dried plums a very functional ingredient in meat products. Because of these properties, the inclusion of dried plum powder in meat products manufactured for breakfast chains and other outlets could enhance the quality and perceived healthfulness of the meat product, thus making it more desirable to consumers.

Health professionals encourage the consumption of fruits and vegetables for their vitamins, minerals, fiber, and other nutritional benefits. Dried plum powders' nutrients are concentrated due to the removal of moisture from the fresh plums. Compounds such as sorbitol, malic acid, phenolic compounds, fiber, glucose, and fructose, may potentially provide an added health benefit in the diet, reducing the risk of diseases from aging, promoting bowel regularity, bone formation and retarding formation of atherosclerotic plaques. Dried plums were shown to have the highest oxygen radical absorbance capacity (ORAC) value among commonly eaten fruits and vegetables (Cao et al., 1996; Wang et al., 1996). Foods that have a high ORAC value may reduce the risks of diseases from aging more so than foods having a low ORAC value, according to previous work done at the agricultural research service's Jean Mayer Human Nutrition Center on aging at Tufts University in Boston. ORAC has recently been accepted as an industry standard for measuring antioxidant activity, by evaluating the time for an antioxidant to react and the total antioxidant capacity. Along with the possible reduction in diseases from aging, the antioxidants in dried plums may also be beneficial to cardiovascular health (Tinker et al., 1991; Lucas et al., 2000) by retarding the oxidation of cholesterol and other fatty acids which could lead to the formation of atherosclerotic plaques (Wright, 2002; Byers, 1993; Gryglewski et al., 1987).

Research has suggested the incorporation of dried plums into meat products may be effective in retarding lipid oxidation, limit microbiological growth, increase moisture content, and enhance the flavor of the meat products (Stacewice-Sapuntzakis et al., 2001; Donovan et al., 1998; Guo et al., 1997). One specific study has shown that the addition of 3% dried plum puree

to per-cooked fresh pork sausage patties was effective in limiting lipid oxidation, comparable to butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) (Keeton et al., 2001).

The use of dried plum powder in various food products may be more desirable, because of its nutritional profile, positive effect on health, as well as being a natural antioxidant alternative (Movileanu, 2002; Keeton et al., 2001). Dried plums are a natural ingredient for use by meat and poultry processors when marketing their products to foodservice or retail outlets. As little as 3% added dried plum powder could address some of the food safety and quality issues pressing the industry today. A wide range of prune derived products are available such as dried plum purees, powders, juice concentrates, and blends of plum extracts. Their potential has yet to be fully explored, thus we are hopeful to work with and explore the new possibilities of dried plum as it pertains to meat and poultry products.

IV. Materials and Methods

Non Meat Ingredients

Dried plum powder (Low moisture prune powder, Sunsweet Growers Inc., Yuba City, CA) was received for use as the principle antioxidant in the study. Rosemary extract (Herbalox Type HT-25, Kalsec Inc., Kalamazoo, MI) was received and 0.05% was used in the treatment formulations for a comparison and to test for synergistic effects with the dried plum powder. Fresh sausage seasoning and encapsulated salt were received from AC Legg Inc. (Longview, TX). Collagen casings (19mm clear) were ordered from DeWied Inc. (San Antonio, TX).

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. Once received samples were taken from the turkey breast and MDTM, ground (Biro Model 10-56, Biro Mfg. Co. Marblehead, OH) separately through a ½ inch (1.3cm) plate to be analyzed for fat, moisture, and protein content prior to sausage formulation. The remaining turkey breast was portioned into 27 lb (12.3 kg) and were vacuumed packaged, then frozen until ready for product manufacture. The MDTM was cut into 2 x 4 inch (5.1 x 10.2 cm) blocks (Biro Meat Saw model# 44, Biro Mfg. Co. Marblehead, OH), vacuum packaged and frozen until product manufacture.

Turkey Sausage Link Control Manufacture

Control batches were formulated with 80% turkey breast (24 lb, 10.89 kg) and 20% MDTM (6 lb, 2.72 kg) with no added antioxidant (Table 1). Treatment batches were formulated with 80% turkey breast and 20% MDTM with either dried plum powder (product description and were procured) at 3% (0.90 lb, 0.41 kg), rosemary extract (product description and location) at 0.05% (0.02 lb, 0.009 kg), or a combination of dried plum powder (3%) and rosemary extract (0.05%) (Table 1). Crust frozen turkey breasts and MDTM were ground (Biro Model 10-56, Biro Mfg. Co. Marblehead, OH) separately through a ½ inch (1.3cm) plate. The ground turkey breast, MDTM, and non meat ingredients were then weighed according to the appropriate formulation. The pH and temperature were recorded for the turkey breast and MDTM. Rosemary extract and half of the dried plum powder were hand mixed with the MDTM according to the required amounts for 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, sausage seasoning, and ½ of the ice water slush was added.

Table 1. Formulation weights (lb/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	**Control**		**DPP**		**RE**		**DPP/RE**	
Ground Turkey Breast	24	10.89	24	10.89	24	10.89	24	10.89
MDTM	6	2.72	6	2.72	6	2.72	6	2.72
Non Meat Ingredients								
AC Legg Sausage Seasoning	0.13	0.06	0.13	0.06	0.13	0.06	0.13	0.06
Encapsulated Salt	0.31	0.14	0.31	0.14	0.31	0.14	0.31	0.14
Rosemary Extract	0	0	0	0	0.02	0.009	0.02	0.009
Dried Plum Powder	0	0	0.90	0.41	0	0	0.90	0.41
Ice Water	0.90	0.41	0.90	0.41	0.90	0.41	0.90	0.41
Total Weight (lbs)	31.35	14.22	32.25	14.63	31.37	14.23	32.28	14.64

The MDTM with hand mixed with appropriate amounts of rosemary extract and/or the remaining amounts of DPP and ice water was added to the turkey breast mixture and mixed for

an additional 1 min. Upon completion of mixing, the batter was transferred into a plastic meat lug and the batter weight, pH and temperature were recorded. Product was ground a second time through a 3/16 inch (0.48 cm) grinder plate and the weight, pH, and temperature 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, Int., San Antonio, TX). Vacuum stuffer settings were: 100% vacuum, 28 g link portions, 2.5 twists per link and 64 linked strands per stuffing cycle. Sample links of both control and treatment sausages were collected for raw protein, moisture, and fat determination. Sausage links were weighed for stuffing yield, then placed on plastic trays and crust frozen for 30 min in a -10°F (-23°C) freezer before packaging. Sausage links from the control and treatment batches were divided into 3 groups, 64 links for raw refrigerated, 150 links for raw frozen, and 130 links for cooked frozen shelf life stability.

Turkey Sausage Link Thermal Processing and Chilling

Turkey sausage links (130) from the control and each treatment were weighed in groups of 10, placed on a raised wire rack sitting on ½ sheet pan then cooked in a gas oven (Kenmore model 665-72012100 ultra bake gas range) to an internal temperature of 165°F (74°C) according to AMSA (1995). Two thermal couples (Omega Thermometer, Model HH501BT) 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 72°F (22°C) before being placed in plastic-lined cardboard boxes layered with plastic coated freezer paper and stored at -10°F (-23˚C) for up to 56 days to determine shelf life stability.

Refrigerated Retail and Frozen Turkey Sausage Link 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 groups (A, B) of which 8 links were placed into plastic overwrapped (Resinite RMF 61-HY stretch film, AEP Industries, Inc. Hackensack NJ) trays. Samples were stored at 42.8°F (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 used for objective color, pH, lipid oxidation, and micro analysis.

Raw (150) and cooked (130) sausage links from the control and treatment batches that were placed in plastic-lined cardboard boxes layered with plastic coated freezer paper and stored at -10°F (-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. Additional analyses for cooked frozen links were re-heat yields and shear values.

Micro Analysis of Refrigerated Retail Links

At each refrigerated storage period (day 0, 3, 6, and 9) plastic film overwrapped sausage link trays from each control and treatment were sterilized by wiping each package with a paper towel moistened with 70% ethanol. Each package was opened aseptically using flame sterilized forceps and scalpels, exposing half the product for sampling by folding back the film. 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). 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 Corp., 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 prepared with Lactobacilli MRS Agar (Difco, Detroit, MI) which was added and allowed to solidify. An additional MRS overlay was added to each plate to promote anaerobic conditions. Both Petrifilm™ and MRS plates were incubated at 30^{o}C for 72 h before counting and reporting colony forming unit (CFU) per gram.

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 42.8°F (6^{o}C)) and frozen (0, 7, 14, 28, and 56 days at -10°F (-23^{o}C)) raw and precooked frozen turkey sausage links. Sixty grams 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 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.

pH and Proximate Composition

The pH of refrigerated retail and frozen raw and cooked 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.

Percent moisture and fat was determined using modified AOAC (2000) air-dry oven and soxhlet ether extraction methods, respectively (AOAC 2000). Powdered raw and cooked 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 hours at 212°F (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 hours, the thimbles dried for 16 hours 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 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 42.8°F (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 hours at 42.8°F (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 the collagen casing loosening 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).

Reheat and Holding Cooked Yields

Six cooked 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 designated to be held for 15 or 30 min. Sausage links were re-heated (Hatco Cook & Hold Oven, Model # CSC-10, Hatco Inc. Milwaukee, WI) from a frozen (-10°F/-23°C) to an internal temperature of 165°F (74˚C) and held at that temperature while being monitored with two thermal couples (Omega Thermometer, Model HH501BT) inserted into the geometric center of two links. After the designated time the links were removed from the oven and allowed to cool to 72°F (22°C) before being re-weighed.

Allo-Kramer Shear Force Determinations

Frozen raw turkey sausages were cooked to an internal temperature of 165°F (74˚C) and allowed to cool to 72°F (22°C). Precooked turkey sausage links were re-heated and held at 165°F (74˚C) according to AMSA (1995) for 15 and 30 minutes and allowed to cool to approximately 72°F (22°C). Samples were cut into 63mm long pieces. The samples were weighed in grams and shear values were recorded using an Instron Universal Testing Machine (Instron Corp., Canton, Mass., 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 Analyses

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) and Meilgaard et al. (2007). Training was 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 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 hours at 42.8°F (6°C) before being cooked to 165°F (74°C) in a Kenmore (model 665-72012100) ultra bake gas range according to AMSA (1995), cut into ½ inch slices and served to the panelists in plastic serving dishes. Each panelist received three slices per sample.

Statistical Analyses

Data were statistically analyzed as a completely randomized block design using the Mixed Model procedure of the Statistical Analysis System (Version 9.1, SAS Institute, Inc., Cary, NC) with three replications of the turkey breakfast sausage 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) Means were separated with Tukey's Studentized Range Test for significant main effects at $P \leq 0.05$.

V. Results and Discussion.

Proximate Composition and pH

Main effect least squares means for fat, moisture and protein percentages are presented in Table 2. Data showed that raw and cooked turkey breakfast sausages were not significantly different ($P<0.05$). Raw sausage links containing DPP had lower percent fat, protein and moisture content than the control and the treatment containing rosemary extract. This is probably due to a dilution effect of the meat block, from the addition of DPP. Keeton et. al (2001) found similar results regarding percent fat when they added a dried plum puree to raw and precooked pork sausage. Control links had the highest percent fat among the raw treatments; while cooked control links had the lowest percent fat compared other treatments. Raw and Cooked RE links had the highest percent protein while the DPP/RE links had the lowest protein percent. Moisture percentage for cooked control was slightly higher than that of the other treatment links. It appears that the addition of DPP in a precooked sausage helps to retain more

fat but reduces moisture compared to the control. DPP/RE combined reduced the percent fat, protein, and moisture in both raw and precooked sausage links.

The pH of raw refrigerated, raw frozen and cooked frozen turkey breakfast sausage was significantly different ($P < 0.05$) between treatments containing dried plum powder and treatments without dried plum powder. Raw refrigerated pH values for the control (5.83) and rosemary extract (5.83) were higher than that of the treatments containing dried plum powder (5.69) and the combination of dried plum powder and rosemary extract (5.70). Raw frozen pH values for the control (5.85) and rosemary extract (5.84) were again higher than the dried plum (5.73) and combination of dried plum and rosemary extract (5.73). The same pattern is present in the cooked frozen pH values; control (6.05) and rosemary extract (6.01) were higher than the dried plum (5.95) and the combination of dried plum and rosemary extract (5.94).

Table 2. Least square means for the main effect of treatment on proximate composition and pH of raw and cooked turkey breakfast sausage at day

	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 Refrigerated.	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
Cooked Frozen	6.05[a]	5.95[b]	6.01[ab]	5.94[b]	0.02

[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 (Low moisture prune powder, Sunsweet Growers Inc.)
[h]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[i]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Cooked Yields

Percent cook yield (Table 3) for the control was lower than all other treatments and significantly different than both treatments containing rosemary extract. All cook yields for the treatments (DPP, RE, and DPP/RE) were not significantly different from each other. Cook times required to reach 165°F (74°C) were not significantly different among controls or treatments.

Table 3. Least square means for the main effect interaction of treatment on cook yield and cook time of raw turkey breakfast sausage at day 0

Treatment	Cook Yield	SEM[e]	Cook Time[f]	SEM[g]
Control[h]	85.85[b]	0.64	21.38[a]	1.08
DPP[i]	87.13[ab]	0.67	21.33[a]	1.13
RE[j]	88.80[a]	0.65	23.50[a]	1.09
DPP/RE[k]	88.84[a]	0.64	23.40[a]	1.08

[a-d]Means in a column with different superscripts are statistically different (P<0.05)
[e]SEM = standard error of the mean for cook yield
[f]Cook Time = the amount of time in minutes for the product to reach an internal temperature of 74°C (165°F)
[g]SEM = standard error of the mean for cook time
[h]Control = no antioxidant
[i]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[j]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[k]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Raw Refrigerated Shelf Life Study

Comparison of TBA values

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 3, 6, 9) was significant for 2-thiobarbituric acid reactive substances (TBARS) values of the raw refrigerated turkey breakfast sausage control and treatments (Table 4). TBA values for all treatments increased between days 0, 3, and 6 with no significant difference across treatments for each day. However on day 9 of storage TBA values for the control and rosemary extract treatment dropped slightly. This is thought to be a result of malonaldehyde (a secondary byproduct of lipid oxidation) reactions with proteins, according to Melton (1983) (Nassu et.al, 2002). TBA values on day 0 for treatments containing dried plum powder were slightly lower than treatments without. Although the treatment containing rosemary extract was consistently lower than the other treatments. All TBA values by day 6 of storage had increased significantly. Products are considered rancid when they have a TBA value greater than 1, according to Tarladgis (1960).

Table 4. Least squares means for the 2 way interaction of antioxidant treatment x storage day of the 2-thiobarbituric acid reactive substances (TBA) and aerobic plate count (APC) values (Log/gm), on raw refrigerated turkey breakfast sausage at days 0, 3, 6, and 9 of refrigerated storage[n].

Treatment	Day 0	Day 3	Day 6	Day 9	SEM[i]
TBA Values					
Control[j]	0.48[be]	0.95[be]	3.53[ae]	3.04[af]	0.16
DPP[k]	0.42[be]	1.20[be]	3.93[ae]	4.12[ae]	0.17
RE[l]	0.48[be]	0.66[be]	3.17[ae]	2.91[af]	0.16
DPP/RE[m]	0.35[be]	0.94[be]	3.49[ae]	3.50[aef]	0.17
APC Values					
Control[j]	4.47[ce]	7.41[be]	8.92[ae]	9.29[ae]	0.10
DPP[k]	4.56[ce]	6.29[bf]	8.54[ae]	8.88[ae]	0.10
RE[l]	4.55[ce]	7.09[be]	8.80[ae]	9.08[ae]	0.10
DPP/RE[m]	4.37[de]	6.36[cf]	8.39[be]	9.14[ae]	0.10

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e-h]Means with the same letter within a column are not significantly different ($P < 0.05$)
[i]SEM = standard error of the mean for antioxidant treatment by storage day
[j]Control = no antioxidant
[k]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[l]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[m]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[n]Refrigerated storage = 6°C under fluorescent lights (1900 Lux)

Aerobic Plate Count and Lactic Acid Bacteria Raw Refrigerated Shelf Life

Aerobic plate count least square means (Table 4) were significant for the two way interaction between antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 3, 6, 9). There was no significant difference in APC values on day 0, 6, and 9. However, on storage day 3 treatments containing dried plum powder were significantly lower than the other treatments. All treatments were considered spoiled by storage day 3 with a log value of greater than 10^6, according to Jay (2005) and Moir (2001).

Lactic acid bacteria least square means (Table 5) were significant for the main effect of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 3, 6, 9). Treatments containing dried plum powder were significantly lower than the control and rosemary extract treatment. Lactic acid bacteria values increased significantly with each storage day and the product was considered spoiled by storage day 6, due to a log value greater than 10^6 according to Jay (2005) and Moir (2001). According to Cevallos-casals et. al (2005) plum genotypes high in phenolic compounds may inhibit growth of microorganisms at a concentration of 2.6 to 5.6 mg/ml. Total phenolic content in plums ranged from 298 to 563 mg/100g (*prunus salicina*) and

160-300mg/100g (*prunus domestica*). The slight inhibition of APC and LAB values found in the treatments containing DPP may have been related to the phenolic content; however the exact phenolic content of the DPP used in this study was not determined.

Table 5. Least square means for the main effect interaction of storage day and antioxidant treatment, on lactic acid bacteria (LAB) values (Log/gm), of raw refrigerated turkey breakfast sausage at days 0, 3, 6, and 9 of refrigerated storage[k].

Treatment					Storage Day				
Control[g]	**DPP[h]**	**RE[i]**	**DPP/RE[j]**	**SEM[e]**	**0**	**3**	**6**	**9**	**SEM[f]**
6.44[a]	5.82[b]	6.32[ab]	5.94[ab]	0.11	4.19[d]	4.99[c]	7.43[b]	7.90[a]	0.10

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e]SEM = standard error of the mean for antioxidant treatment
[f]SEM = standard error of the mean for storage day
[g]Control = no antioxidant
[h]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[i]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[j]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[k]Refrigerated storage = 6°C under fluorescent lights (1900 Lux)

External and Internal Color of Raw Refrigerated Storage

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 3, 6, 9) was significant for external color of the raw refrigerated turkey breakfast sausage (Table 6). L* (lightness) values for treatments containing DPP were darker than the control and RE treatment and were significantly different. Values ranged from 47.67 to 56.09 between treatments and across storage days. a* (redness) values on day 0 ranged from 15.58 to 13.81, the control and RE had the greatest redness and were significantly different from the DPP and DPP/RE treatments. Redness values decreased over storage days and were not significantly different on days 6 and 9. b* (yellowness) values for the control and RE treatment were both consistently lower than the DPP and DPP/RE treatments. Yellowness values ranged from 12.46 to 19.82 across treatments and storage days, all values decreased over storage day.

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 3, 6, 9) was significant for internal color of the raw refrigerated turkey breakfast sausage (Table 6). L* (lightness) values for treatments containing DPP were not as light as the treatments without DPP and are significantly different on days 0, 3, and 6. On day 9 all L* values for each treatment were not significantly different. All L* values decreased from day 0 to day 6, then increased on day 9 and were significantly higher than the day 0 values. All a*

(redness) values were not significantly different across day except the control on day 3 was lower in redness. a* (redness) values ranged from 11.87 to 16.53, values were the highest on storage day 0. b* (yellowness) values for treatments containing DPP were significantly different from the control and RE treatment over days 0, 3, 6, and 9. All b* Values were the highest on day 0 and decreased over days 3 and 6, however yellow increased slightly on day 9 for treatments with DPP.

It was expected that the L* (lightness) values for both external and internal color would be lower for the treatments 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 (2008) 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 he controls. Lee and Ahn (2005) also reported that the color of their turkey rolls with plum puree at 3% was darker in color, due to the original purple color of the plum. Keeton et. al (2001) reported similar results regarding L* lightness values in products contains DP.

Extended Shelf Life Study Raw & Cooked Frozen Storage

Comparison of TBA values during raw frozen storage

The main effects of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 7, 14, 28, 56) were significant at $P < 0.05$ (Table 7), for TBA values of raw frozen turkey breakfast sausage. Both treatments containing DPP were lower than the control and RE treatments. It was reported by Nunez et. al (2008) that fresh and dried plum ingredients significantly decreased TBA values in beef roast containing 2.5% and 5% DP compared to controls. Keeton et. al (2001) stated that the use of 3% and 6% Dried plum puree in pork sausage were as effective as synthetic antioxidants (BHT & BHA). The treatment containing DPP/RE had the lowest least square mean and is significantly different compared to the other treatments. This is possibly due to a synergistic effect between DPP and RE on the reduction of TBA values. TBA values on day 7 were significantly higher than days 0, 14, and 28, day 0 having the lowest TBA values. TBA values ranged from 0.26 to 0.70 for all turkey breakfast sausage treatments across all storage days. None of the treatments reached a TBA value greater than 1, the point considered to be when product is rancid (Tarladgis et al. 1960).

Table 6. Least square means for the 2 way interaction of antioxidant treatment x storage day of external and internal L*, a*, and b* values, on raw refrigerated turkey breakfast sausage at days 0, 3, 6, and 9 of refrigerated storage[n].

	Control[j]	DPP[k]	RE[l]	DPP/RE[m]	SEM[i]
Day 0					
Ex.L*	55.45^{ae}	49.12^{bf}	55.53^{aef}	49.80^{bf}	0.45
Ex.a*	15.58^{ae}	14.23^{abe}	15.61^{ae}	13.81^{be}	0.31
Ex.b*	18.06^{be}	19.82^{ae}	18.29^{be}	19.30^{abe}	0.28
In.L*	59.69^{af}	53.79^{bf}	61.46^{af}	54.00^{bf}	0.58
In.a*	15.49^{ae}	16.32^{ae}	16.53^{ae}	16.04^{ae}	0.29
In.b*	20.37^{be}	25.47^{ae}	21.60^{be}	25.23^{ae}	0.35
Day 3					
Ex.L*	55.65^{ae}	48.10^{bf}	55.89^{aef}	49.11^{bfg}	0.37
Ex.a*	11.27^{abf}	10.35^{abf}	11.70^{af}	10.11^{bf}	0.28
Ex.b*	15.32^{bf}	17.35^{af}	15.34^{bf}	17.00^{af}	0.25
In.L*	58.52^{afg}	50.92^{bg}	59.20^{af}	49.96^{bg}	0.48
In.a*	11.87^{bg}	13.22^{ag}	13.32^{af}	13.16^{af}	0.24
In.b*	19.77^{be}	24.31^{aef}	20.54^{be}	24.39^{ae}	0.29
Day 6					
Ex.L*	55.42^{ae}	47.90^{bf}	54.43^{af}	47.67^{bg}	0.35
Ex.a*	7.90^{ag}	8.17^{ag}	7.37^{ah}	8.14^{ag}	0.27
Ex.b*	12.68^{bg}	15.49^{ag}	13.14^{bg}	15.72^{ag}	0.24
In.L*	56.81^{ag}	49.50^{bg}	56.04^{ag}	48.90^{bg}	0.45
In.a*	14.58^{aef}	13.88^{afg}	13.71^{af}	13.54^{af}	0.22
In.b*	18.39^{bf}	22.68^{ag}	18.82^{bf}	22.62^{af}	0.27
Day 9					
Ex.L*	55.37^{abe}	54.08^{be}	56.09^{ae}	54.01^{be}	0.35
Ex.a*	8.38^{ag}	8.66^{ag}	8.77^{ag}	8.64^{ag}	0.27
Ex.b*	12.46^{bg}	15.21^{ag}	13.09^{bg}	15.23^{ag}	0.24
In.L*	64.50^{ae}	62.22^{ae}	63.80^{ae}	62.52^{ae}	0.45
In.a*	14.14^{af}	14.47^{af}	13.59^{af}	14.16^{af}	0.22
In.b*	18.12^{bf}	23.32^{afg}	17.85^{bf}	23.10^{af}	0.27

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e-h]Means with the same letter within a column are not significantly different ($P < 0.05$)
[i]SEM = standard error of the mean for antioxidant treatment by storage day
[j]Control = no antioxidant
[k]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[l]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[m]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[n]Refrigerated storage = 6°C under fluorescent lights (1900 Lux)

Table 7. Least square means for antioxidant treatment and storage day of the 2-thiobarbituric acid reactive substance (TBARS) values, on raw frozen turkey breakfast sausage at days 0, 7, 14, 28, 42, and 56 of frozen storage -10°F (-23°C).

	Treatment					Storage Day					
	Control[g]	**DPP[h]**	**RE[i]**	**DPP/RE[j]**	**SEM[e]**	**0**	**7**	**14**	**28**	**56**	**SEM[f]**
TBA Values	0.58[a]	0.43[a]	0.56[a]	0.38[b]	0.03	0.36[c]	0.57[a]	0.48[b]	0.48[b]	0.54[ab]	0.03

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e]SEM = standard error of the mean for antioxidant treatment
[f]SEM = standard error of the mean for storage day
[g]Control = no antioxidant
[h]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[i]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[j]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

External and Internal Color of Raw Frozen Storage

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 7, 14, 28, 56) was significant for external color of the raw frozen turkey breakfast sausage (Table 8). L* (lightness) values for the external surface of the two treatments containing DPP were significantly darker than the other treatments on days 0 and 7. Storage days 14, 28, and 56 the lightness values for all treatments were not significantly different, except the combination treatment of DPP/RE was higher in lightness on day 56. Treatments containing DPP were expected to be darker than the controls due to the inherent color of the product. The darkening caused by the addition of DPP is also observed by keeton, et. al (2001), Nunez, et. al (2008), and Lee, et. al (2005). a* (redness) values on day 0 for the control and RE treatment were the highest and significantly different from the treatments containing DPP. All redness values dropped from day 0 to day 7 significantly then rose slightly for treatment containing RE on day 14. At storage day 56 the control had the highest redness value compared to the other treatments. b* (yellowness) values for all treatment were not significantly different on storage days 0, 7, and 56. Values for all treatments decreased over the storage days compared to day 0. Only the combination treatment of DPP/RE was not significantly different in yellowness values over storage days.

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 7, 14, 28, 56) was significant for internal color of the raw frozen turkey breakfast sausage (Table 8). L* (lightness) values for the two treatments containing DPP were significantly darker on days 0 and 7, and then the control and RE treatment. Again this

darkening of the product caused by the addition of DPP was anticipated due to the inherent color of the product. Lightness values for storage days 14, 28, and 56 were not significantly different between treatments. The change in lightness could have been due how the bulk packaging of the product and its exposure to frozen storage, however this is not known. a* (redness) ranged from 11.47 to 16.00 across treatments and storage day. Values on day 0 and 28 were not significantly different across treatment, although storage day 7, 14, and 56 were significant. Redness values for all treatment decreased over storage days. b* (yellowness) values for both treatments containing DPP were significantly higher than the control and RE treatment across all storage days. The control and DPP/RE treatment were not significantly different over each storage day, where the other treatments had some differences over storage days.

Comparison of TBA values during cooked frozen storage

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 7, 14, 28, and 56) was significant at $P < 0.05$ for the TBA values of cooked frozen turkey breakfast sausage (Table 9). On day 0 treatments containing DPP have the lowest TBA values and are significantly different from the control. This same trend was previously shown in the raw frozen turkey sausages. The control and RE treatment TBA values increase over the course of the 56 day shelf life, while the treatments containing DPP remained consistently lower and significantly different. Keeton, et. al (2001) had referenced McCarthy, et. al (2001) in regards to TBA values on precooked and frozen pork sausage patties increased 4 times due to cooking compared to raw patties. This may also be the case in precooked turkey sausages, as evidence by the TBA values of the control and RE treatment. The addition of 3% DPP is shown to be the most effective for preventing lipid oxidation in a precooked turkey sausage based on the TBA values. Treatments with DPP are not significantly different across storage days and maintained the same TBA value from day 28 to 56. TBA values for the control and RE treatment were not significantly different across storage days and are considered to be rancid with a TBA value >1 (Tarladgis et al. 1960).

Table 8. Least squares means for the 2-way interaction of antioxidant treatment x storage day of external and internal *L*, a*,* and *b** values, on raw frozen turkey breakfast sausage at days 0, 7, 14, 28, 42, and 56 of frozen storage -10°F (-23°C)

	Control[j]	DPP[k]	RE[l]	DPP/RE[m]	SEM[i]
Day 0					
Ex.L*	51.25^{abe}	45.43^{bef}	52.30^{ae}	45.70^{bfg}	1.02
Ex.a*	16.65^{ae}	13.99^{be}	17.05^{ae}	13.43^{be}	0.38
Ex.b*	18.14^{ae}	18.80^{ae}	19.61^{ae}	19.05^{ae}	0.68
In.L*	55.49^{aef}	49.29^{bf}	56.96^{aef}	48.61^{bg}	1.00
In.a*	15.42^{ae}	15.26^{ae}	16.00^{ae}	15.00^{ae}	0.22
In.b*	19.29^{be}	24.30^{ae}	20.91^{be}	24.42^{ae}	0.39
Day 7					
Ex.L*	51.37^{ae}	45.97^{bef}	52.41^{ae}	50.21^{abef}	0.84
Ex.a*	14.18^{af}	10.81^{cf}	13.56^{abf}	11.85^{bcf}	0.33
Ex.b*	15.72^{aef}	15.39^{afg}	15.43^{af}	18.18^{ae}	0.62
In.L*	57.88^{ae}	50.63^{bf}	55.31^{aef}	53.79^{abf}	0.84
In.a*	14.03^{af}	12.82^{bf}	13.84^{af}	13.26^{abf}	0.18
In.b*	19.31^{be}	22.30^{af}	19.34^{bef}	23.98^{ae}	0.33
Day 14					
Ex.L*	51.28^{ae}	48.19^{ae}	52.25^{ae}	51.97^{ae}	0.86
Ex.a*	13.74^{abfg}	10.27^{cf}	14.01^{af}	12.04^{bcef}	0.34
Ex.b*	15.80^{abef}	14.79^{bg}	16.23^{abf}	18.29^{ae}	0.63
In.L*	58.42^{ae}	55.44^{ae}	58.95^{ae}	59.58^{ae}	0.84
In.a*	13.31^{abfg}	12.41^{bf}	13.53^{af}	12.90^{abf}	0.18
In.b*	18.32^{ce}	21.31^{bf}	18.90^{cf}	24.08^{ae}	0.33
Day 28					
Ex.L*	41.70^{af}	43.41^{af}	43.70^{af}	44.15^{ag}	0.84
Ex.a*	11.88^{ah}	10.98^{af}	12.06^{ag}	10.89^{afg}	0.33
Ex.b*	13.51^{cg}	16.87^{abef}	14.52^{abcf}	16.95^{ae}	0.62
In.L*	51.74^{af}	50.44^{af}	52.68^{af}	51.79^{afg}	0.84
In.a*	12.56^{agh}	12.62^{af}	12.32^{ag}	12.71^{af}	0.18
In.b*	17.92^{be}	22.76^{aef}	18.55^{bf}	23.42^{ae}	0.33
Day 56					
Ex.L*	43.70^{bf}	44.55^{bef}	46.96^{bf}	52.19^{ae}	0.84
Ex.a*	12.85^{agh}	10.42^{bf}	10.95^{bg}	10.28^{bg}	0.33
Ex.b*	14.79^{afg}	16.44^{afg}	16.04^{af}	17.43^{ae}	0.62
In.L*	54.26^{af}	52.24^{aef}	55.11^{aef}	54.50^{af}	0.84
In.a*	12.37^{bch}	13.19^{abf}	11.47^{cg}	13.58^{af}	0.18
In.b*	18.71^{be}	22.70^{aef}	18.71^{bf}	24.10^{ae}	0.33

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e-h]Means with the same letter within a column are not significantly different ($P < 0.05$)
[i]SEM = standard error of the mean for antioxidant treatment by storage day
[j]Control = no antioxidant
[k]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[l]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[m]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Table 9. Least squares means for the 2 way interaction of antioxidant treatment x storage day of 2-thiobarbituric acid reactive substances (TBARS) values, on cooked frozen turkey breakfast sausage at days 0, 7, 14, 28, 42, and 56 of frozen storage -10°F (-23°C)

Treatment	Day 0	Day 7	Day14	Day 28	Day 56	SEM[i]
Control[j]	1.65[be]	2.13[be]	2.19[be]	2.07[be]	3.82[ae]	0.18
DPP[k]	0.45[af]	1.08[af]	0.36[af]	0.49[af]	0.49[af]	0.18
RE[l]	0.73[cef]	1.72[bef]	1.49[bce]	2.13[abe]	2.94[ae]	0.18
DPP/RE[m]	0.36[af]	1.06[af]	0.46[af]	0.45[af]	0.45[af]	0.18

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e-h]Means with the same letter within a column are not significantly different ($P < 0.05$)
[i]SEM = standard error of the mean for antioxidant treatment by storage day
[j]Control = no antioxidant
[k]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[l]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[m]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Internal Color of Cooked Frozen Storage

The two way interaction of antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 7, 14, 28, 56) was significant for internal color of the cooked frozen turkey breakfast sausage (Table 10). L* (lightness) values were significantly different between the treatments containing DPP and the treatments without DPP, on days 0 and 7. All treatments decreased in lightness from day 0 to day 28, then increased on day 56. Lightness values ranged from 48.30 to 69.36. As previously stated, it was expected that treatments containing DPP would be darker. a* (redness) values on days 0 and 7 for treatments containing DPP were significantly higher than those without DPP. On day 14 and 56 all redness values were not significantly different. On day 28 the treatment containing only RE was significantly lower than the other treatments. Redness values for all treatments increased from day 0 to day 28 then dropped slightly on day 56 of storage. b* (yellowness) values for treatments containing DPP were significantly higher from the control and RE treatment, across all storage days. Yellowness values ranged from 16.94 to 23.60. Over all treatments there was an increase in yellowness value day 0 compared to day 56.

Table 10. Least squares means for the 2-way interaction of antioxidant treatment x storage day of internal *L*, a*,* and *b** values, on cooked frozen turkey breakfast sausage at days 0, 7, 14, 28, 42, and 56 of frozen storage -10°F (-23°C)

	Control[j]	DPP[k]	RE[l]	DPP/RE[m]	SEM[i]
Day 0					
In.L*	68.03^{ae}	60.73^{bef}	69.36^{ae}	60.86^{bef}	0.77
In.a*	4.16^{bg}	6.51^{afg}	3.91^{bg}	6.36^{af}	0.19
In.b*	16.94^{bf}	21.74^{aef}	17.10^{bg}	21.72^{af}	0.34
Day 7					
In.L*	64.20^{af}	59.29^{bf}	63.31^{af}	59.04^{bf}	0.63
In.a*	4.73^{bg}	6.39^{ag}	4.83^{bf}	6.32^{af}	0.17
In.b*	17.16^{bf}	20.90^{af}	18.15^{befg}	21.34^{af}	0.29
Day 14					
In.L*	56.65^{ag}	57.91^{af}	56.80^{ag}	58.90^{af}	0.63
In.a*	6.44^{aef}	7.14^{aef}	6.48^{ae}	7.22^{ae}	0.17
In.b*	18.78^{be}	22.27^{ae}	19.29^{be}	23.60^{ae}	0.29
Day 28					
In.L*	49.67^{ah}	50.36^{ag}	48.30^{ah}	50.76^{ag}	0.63
In.a*	7.03^{abe}	7.42^{ae}	6.25^{be}	7.40^{ae}	0.17
In.b*	19.34^{be}	22.45^{ae}	17.95^{bfg}	22.46^{aef}	0.29
Day 56					
In.L*	61.10^{af}	63.57^{ae}	60.61^{af}	63.22^{ae}	0.63
In.a*	6.08^{af}	5.64^{ah}	5.94^{ae}	6.12^{af}	0.17
In.b*	18.87^{be}	22.05^{aef}	18.89^{bef}	22.28^{af}	0.29

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e-h]Means with the same letter within a column are not significantly different ($P < 0.05$)
[i]SEM = standard error of the mean for antioxidant treatment by storage day
[j]Control = no antioxidant
[k]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[l]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[m]DPP/RE = 3% dried plum powder & 0.05% rosemary extract

Re-Heated Cook Yields, Allo-Kramer Shear Force and Cooked Frozen Shelf Life

Re-heated cook yields (Table 11) were significant by storage day ($P < 0.05$). Percent cook yield increased across storage days, day 0 having the lowest percent cook yield and day 56 with the highest. The reason day 56 had what appears to be a higher cook yield than day 0, is from loss of yield during frozen storage. The bulk packaging method used could have resulted in moisture loss through frozen storage, causing a loss in product yield from day 0 to day 56. Therefore the product yields to appear to increase over storage day. Even with this suspected loss of yield through storage the product that was held for 15 min at 165°F (74°C) retained a higher percent yield than the product held for 30 min.

Table 11. Least square means for the main effect interaction treatment[f] of cook yields on reheated cooked frozen turkey breakfast sausage held for 15 or 30 minutes at days 0, 7, 14, 28, 42, and 56 of frozen storage -10°F (-23°C)

Hold Time	Day 0	Day 7	Day 14	Day 28	Day 56	SEM[e]
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

[a-d]Means with the same letter within a row are not significantly different (P < 0.05)
[e]SEM = standard error of the mean for storage day
[f] Treatment = Control (no antioxidant), 3 % dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.), 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.), and 3% dried plum powder & 0.05% rosemary extract combined

Allo Kramer Shear Force Values

Least square means for Allo-Kramer shears (Table 12), a measurement of instrumental tenderness, had a significant (P < 0.05) two way interaction between antioxidant treatment (Control, DPP, RE, and DPP/RE) and storage day (0, 7, 14, 28, 56) for both holding times (15 & 30 min). Both treatments containing DPP had lower shear values then the control and RE treatment, possibly from the DPP acting as a humectant, binding more moisture. Lee et. al (2005) stats that >2% DP decreased hardness and increased juiciness by binding moisture and improving texture. 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 increasing 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. Precooked and held values on day 0 compared to the raw cooked values are higher on an average of 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. Data shows that product held for a longer time will have more yield loss and a higher shear value. Overall the shear values for product held 30 min were higher, representing a tougher product; than the product held for 15 min.

Table 12. Least square means for the two-way interaction of treatment x storage day for shear force values (N/gm), on cooked frozen, re-heated and held (15 or 30 min) turkey breakfast sausage at days 0, 7, 14, 28, 42, and 56 days of frozen storage (-10°F /-23°C).

15 min						
Treatment	**Day 0**	**Day 7**	**Day 14**	**Day 28**	**Day 56**	**SEM[i]**
Control[k]	50.85[be]	123.72[ae]	77.87[abe]	107.97[abef]	99.45[abef]	16.12[j]
DPP[l]	48.41[ae]	114.72[ae]	101.36[ae]	116.39[aef]	76.78[ae]	16.05
RE[m]	57.96[be]	107.03[abe]	99.26[abe]	163.51[ae]	163.83[af]	16.05
DPP/RE[n]	46.14[be]	114.71[ae]	70.47[abe]	81.04[abf]	132.77[aef]	16.05
30 min						
	Day 0	**Day 7**	**Day 14**	**Day 28**	**Day 56**	**SEM[i]**
Control[k]	60.14[ce]	91.69[bce]	167.33[abe]	192.40[ae]	112.28[bcf]	17.39
DPP[l]	58.31[be]	107.22[abe]	151.43[ae]	158.71[ae]	87.53[abf]	17.47[j]
RE[m]	61.73[ce]	131.53[bce]	143.49[be]	180.24[abe]	242.01[ae]	17.39
DPP/RE[n]	46.59[be]	125.85[abe]	141.42[ae]	146.23[ae]	129.47[af]	17.39

[a-d]Means with the same letter within a row are not significantly different ($P < 0.05$)
[e-h]Means with the same letter within a column are not significantly different ($P < 0.05$)
[i]SEM = standard error of the mean for antioxidant treatment by storage day
[j]SEM values for treatment are high because one day had 5 samples instead of 6 samples
[k]Control = no antioxidant
[l]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)
[m]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)
[n]DPP/RE = 3% dried plum powder & 0.05% rosemary extract
[o]SEM = standard error of the mean for antioxidant treatment

Sensory Evaluation of Raw & Cooked Frozen Storage

Descriptive sensory data (Table 13) show that the textural attributes of the raw frozen product was significantly higher in springiness (3.02/2.35) and juiciness (3.55/2.02), than the cooked frozen product. However the cohesiveness of the cooked frozen product was significantly higher than the raw frozen product. The raw frozen product had greater fracturability (3.02/2.95) and less hardness (4.98/5.60). These differences are most likely caused by the variation in juiciness between a raw and precooked frozen product, increased juiciness may decreased the hardness and improved the springiness. Aromatics of the raw frozen product were significantly higher in cooked turkey lean (4.78/4.40), cooked turkey fat (1.08/0.72), and plum (1.15/0.85) than the precooked frozen product, representing a slight loss in flavor through precooking. Cooked frozen product was significantly higher in cardboard flavor (0.37/0.03) and warmed over flavor (0.90/0.30) than the raw product, which are both undesirable sensory traits.

DPP and DPP/RE treatments were significantly higher in plum aromatic (1.90/1.77), sweet basic taste (1.10/1.10), sweet aftertaste (0.20/0.27), and also significantly lower in spice complex (4.37/4.13) compared to the control and RE treatment. These differences were expected

due to the addition of DPP and its total sugar content (45%/100g, Sunsweet Growers Inc.). Keeton et. al (2001) had similar results in raw and precooked pork sausage stating that sweet and prune were more pronounced in treatments containing DPP. It was also reported that the addition of DPP may mask other flavors such as spicy/peppery, which I had noticed a slight decrease in treatments containing DPP compared to the control and RE treatment. Nunez et. al (2008) reported a similar effect with the addition of DPP and an increase in plum flavor along with sweetness at high concentrations.

VI. Conclusions

The addition of DPP (Low moisture prune powder, Sunsweet Growers Inc., Yuba City, CA) at 3% into a turkey breakfast sausage (80% turkey breast, 20% mechanically deboned turkey meat) has a preventative effect on lipid oxidation, in raw and cooked frozen form. It is apparent that DPP when combined with RE (Herbalox Type HT-25, Kalsec Inc., Kalamazoo, MI) had a more synergistic effect on preventing lipid oxidation during raw frozen storage (0, 7, 14, 28, and 56 days at -10°F (-23˚C)), than the use of DPP alone. However, with the inclusion of DPP the product was noticeably darker in color as shown by the L* (lightness) values, and a sweeter and detectable plum flavor. This was also observed in other studies conducted using DPP (Keeton et. al, (2001), Nunez et. al, (2008), and Lee et. al, (2005)). Aerobic plate counts (APC) and lactic acid bacteria (LAB) for treatments containing DPP were lower than that of the treatments without DPP, showing a possible antimicrobial effect. This is supported by Cevallos-Casals et. al (2005) who stated plum genotypes high in phenolic compounds may inhibit growth of microorganisms at specific concentrations.

The addition of 3% DPP alone and combined with 0.05% RE for use as an alternative natural antioxidant suppressed the effects of lipid oxidation turkey breakfast sausage made from a mixture of fresh turkey breasts and mechanically deboned turkey meat while maintaining acceptable sensory attributes over long term frozen storage when compared to RE and C sausage links. It was also observed that DPP darkened the external and internal sausage link color compared to RE and C links.

Table 13. Least squares means for the main effect of storage condition and treatment for sensory texture, aromatics, basic tastes, mouthfeels, and aftertastes of raw and cooked frozen turkey breakfast sausage at day 28 of frozen storage -10°F (-23°C)

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

[j]SEM=standard error of the mean for treatment

[k]Control = no antioxidant

[l]DPP = 3% dried plum powder (Low moisture prune powder, Sunsweet Growers Inc.)

[m]RE = 0.05% rosemary extract (Herbalox Type HT-25, Kalsec Inc.)

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

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