Antioxidant Properties of Dried Plum Ingredients in Raw and Precooked Pork Sausage

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ABSTRACT: Raw pork sausages with no antioxidant (control), 3% or 6% dried plum puree (DP), 3% or 6% dried plum and apple puree (DPA), or 0.02% butylated hydroxytoluene and butylated hydroxyanisole (BHA/BHT) were (1) stored raw in chubs at 4 °C (RR) and evaluated weekly over 28 d, (2) cooked as patties, vacuum packaged, and stored at 4 °C (PR) for weekly evaluation over 28 d, or (3) cooked, vacuum packaged, and stored at –20 °C (PF) and evaluated monthly over 90 d. DP at 3% or 6% levels was as effective as BHA/BHT for retarding lipid oxidation in PR sausage patties. Likewise, DP at 3% was equally as effective in PF patties, but DP at 6% was even more effective (lower TBARS values) than BHA/BHT for retarding oxidative rancidity. All treatments decreased the fat and increased moisture content of raw sausages but only 6% DP reduced cooking yields. Inclusion of 6% DP decreased internal redness while both 6% DP and DPA increased yellowness of raw sausage. Trained panel sensory evaluations indicated that DP enhanced sweet taste, decreased salt and bitter tastes, and masked cooked pork/brothy, cooked pork fat, spicy/peppery, and sage flavors. In general, warmed-over flavor notes were not affected by storage treatments. Overall, pork sausage with 3% DP or DPA was as acceptable to consumers as the control or those patties with BHA/BHT, but patties with 6% of either plum product were less desirable. Inclusion of 3% DP was effective as a natural antioxidant for suppressing lipid oxidation in precooked pork sausage patties.

Keywords: BHA, BHT, dried plum puree, lipid oxidation, pork sausage

Introduction

Lipid oxidation is a major cause of deterioration in the quality of prepared meat products and can be accelerated by several factors such as increased levels of unsaturated fats, polyunsaturated fatty acids, oxygen, heat, UV light, metal ions, meat/heme pigments, and oxidative enzymes (Frankel 1998; Morrissey and others 1998). Rancidity in processed meat products causes changes in odor, flavor, taste, color, texture, and appearance (Aguirrezábal and others 2000). Also, it can decrease nutritional quality and safety by the formation of secondary products after cooking and processing (Gray and others 1996; Morrissey and others 1998).

Precooked pork patties are highly sensitive to lipid oxidation with significant development of off-flavor and loss of meat flavor upon reheating following chilled storage (Nissen and others 2004). Various synthetic antioxidants such as butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), and propyl gallate (PG) retard lipid oxidation and extend shelf life in meat products (St. Angelo and others 1990; Güntensperger and others 1998; Aguirrezábal and others 2000; Ahn and others 2002). Utilization of these synthetic antioxidants is regulated on the basis of their effective use level and toxicological safety. Recent consumer concern has favored the inclusion of plant-derived food ingredients that contain naturally occurring antioxidants and may provide an alternative to conventional antioxidants (Johnston and others 2005; Grün and others 2006).

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Sebranek and others (2005) reported that a rosemary extract was more effective than BHA/BHT in maintaining low thiobarbituric acid-reactive substances (TBARS) values in raw frozen sausage. In addition, the inclusion of rosemary extracts has been shown to improve the stability of beef patties containing dietary alpha tocopherol acetate (Formanek and others 2001). Other comparisons of the antioxidant potential of naturally occurring plant extracts or animal products, such as aloe vera, fenugreek, ginseng, mustard, rosemary, sage, soya protein, tea catechins, and whey protein concentrate, have been shown to be effective antioxidants when incorporated into cooked pork patties (McCarthy and others 2001). Similarly, paprika and garlic used in chorizo sausages were as effective as a mixture of nitrate, nitrite, and ascorbic acid for inhibiting lipid oxidation (Aguirrezábal and others 2000). Less obvious ingredients such as cottonseed meal also function as antioxidants in cooked meats (Rhee and others 2001).

It has been proposed that foods with a high oxygen radical absorbance capacity (ORAC) value (Cao and others 1995) may reduce the risk of diseases associated with aging. Previous research has shown that dried plums have one of the highest ORAC values (5770) out of a group of 22 fruits and vegetables studied (Cao and others 1996; Wang and others 1996; McBride 1999). Phenolic compounds in dried plums appear to be the main contributors to their antioxidant capacity. These compounds have been shown to inhibit LDL oxidation *in vitro*, and thus might serve as preventive agents against heart disease and cancer (Stacewicz-Sapuntzakis and others 2001). Because of their antioxidant potential, dried plums may be a useful natural ingredient for retarding lipid oxidation in raw ground or precooked pork sausage that routinely contains higher levels of fat than other processed meat products. Thus, the objective of this study was to determine the antioxidant properties of dried plum

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purees in both raw and precooked pork sausages stored either refrigerated or frozen.

Materials and Methods

Manufacture of pork sausage

Six 22.7-kg batches of pork sausage were formulated to contain one of 6 antioxidant treatments: (1) no antioxidant (control), (2) 3% or 6% dried plum puree (DP), (3) 3% or 6% dried plum and apple puree (DPA), or (4) a BHA/BHT (crystalline, Kosher Tenox®, Eastman Chemical Co., Kingsport, Tenn., U.S.A.) combination (applied at 0.02%, based on sausage fat content). A total of 18 batches (6 treatments × 3 replicates) of pork sausage were manufactured in the entire study. DP and DPA were obtained from California Plum Board (Sunsweet Growers Inc., Yuba City, Calif., U.S.A.). Antioxidant ingredient specifications are shown in Table 1.

Table 1—Chemical and physical specifications of antioxidant ingredients used in pork sausage formulations.

Antioxidant ingredients	Manufacturer specification
Tenox® BHA PM 01787-00	Butlyated hydroxyanisole/025013-16-5 + citric acid/ 000077-91-9 (crystalline) specimen nr 31905/ 00204
Tenox BHT PM 13484-00	3,5-di-tert-butyl-4-hydroxy toluene/000128-37-0 (crystalline) specimen nr 31602/00225
Sunsweet® dried plum puree (DP)	Dark brown Moisture content (30% ± 0.5%) Brix (70° minimum) pH (3.5 to 4.5) Titratable acidity 1.5 to 2.2 (as malic acid, w/w) Viscosity > 1000 cps 1000 ppm maximum potassium sorbate
Sunsweet lighter bake (dried plum puree + dried apple puree) (DPA)	Light brown Moisture content (50% to 56%) Brix (48 to 52°) pH (3.5 to 4.0) Titratable acidity 0.35% to 0.55% (as malic acid, w/w) Viscosity (40000 to 60000 cps at 68 °F) 1000 ppm maximum potassium sorbate Water activity (0.916)

Pork sausage processing was performed in a state-inspected (Texas Dept. of Health) commercial-scale pilot plant located in the Rosenthal Meat Science and Technology Center at Texas A&M Univ. Raw well-chilled pork lean derived from boneless well-trimmed pork shoulders containing approximately 15% fat and fat trim taken from loins, bellies, and shoulders containing approximately 40% fat were purchased from a commercial source 3 to 4 d postmortem. Lean and fat trimmings were coarse ground separately through a 1.27-cm plate. After fat analysis of the pork trimmings, Pearson's square was used to formulate the meat block to a 32% fat endpoint (Table 2). Lean trim (7.3 kg) was combined with 15.4 kg of fat trim in a paddle mixer (Butcher Boy, Model 150, Lasar MFG Inc., Los Angeles, Calif., U.S.A.) to yield a 22.7-kg meat block. Added to this meat block were 453.6 g of a spice preblend (pork sausage seasoning, AC Legg™, Birmingham, Ala., U.S.A.), 3.0% water, and the appropriate antioxidant treatment. DP and DPA products were incorporated directly into the mixer in their original puree forms. A mixture of crystalline BHA (0.01%) and BHT (0.01%) was pulverized and blended with the dry-seasoning preblend to ensure uniform distribution in the paddle mixer. All added ingredients were mixed for 5 min and reground through a 0.635-cm plate.

The pork sausage was vacuum stuffed (Model RS1040C Risco™, Nev Solomon Enterprises, Italy) into 908-g plastic chubs (Poly Tubes 20-30-01 CP, Harbro Packaging Co., Chicago, Ill., U.S.A.) and clipped at each end with metal clips. Ten chubs of pork sausage from each antioxidant treatment were assigned to the raw treatment (RR) and stored at 4 °C for 0, 7, 14, 21, and 28 d. A total of 1008, 1-cm thick patties (168 patties per treatment) of 6.35 cm dia were sliced manually with a knife using a ruler to standardize the thickness and plastic sleeve removed. Patties to be cooked were spaced on a foil-covered baking sheet, placed in a convection oven (Hobart Corp., Troy, Ohio, U.S.A.), and cooked, without turning, for 9 min at 148.9 °C to an internal temperature of 71.1 °C. Internal temperature was monitored with type T thermocouple (Omega Model HH21, Omega Engineering Inc., Stanford, Conn., U.S.A.) inserted into the geometric center of random patties. After cooking, patties were cooled (4 °C) and vacuum packaged (Ultravac® 2100, KOCH Inc., Kansas City, Mo., U.S.A.) in Cryovac® (Cryovac North America, Duncan, S.C., U.S.A.) BW540 bags to 20 mm Hg. A constant vacuum (20 mm Hg) was used to avoid compressing or distorting the patties in the package and to maintain a constant, yet low level of ambient air. At 20 mm Hg, a constant amount of air remained in the package for some promotion of oxidation to challenge the antioxidant treatments. Twenty-one precooked patties from each treatment were assigned to each package and used for subsequent analysis. Five vacuum packages of precooked pork sausage patties (PR) from each antioxidant treatment were packed into cardboard

Table 2—Pork sausage formulations by antioxidant treatments.

	Ingredients					
	Control	BHA/BHT	DP 3%	DP 6%	DPA 3%	DPA 6%
Meat block						
Pork lean trimmings (kg) 85/15 (lean/fat)	7.3	7.3	7.3	7.3	7.3	7.3
Pork fat trimmings (kg) 60/40 (lean/fat)	15.4	15.4	15.4	15.4	15.4	15.4
Pork sausage seasoning blend (kg) (salt, red pepper, sage, sugar, black pepper)	0.4536	0.4536	0.4536	0.4536	0.4536	0.4536
Dried plum puree (DP) (kg)	—	—	0.68	1.36	—	—
Dried plum/apple puree (DPA) (kg)	—	—	—	—	0.68	1.36
BHA/BHT[a] (g)	—	1.45	—	—	—	—
Water (3% of meat block) (kg)	0.68	0.68	0.68	0.68	0.68	0.68
Total (kg)	23.83	23.84	24.51	25.19	24.51	25.19

[a]Crystalline BHA and BHT were powdered and blended with the pork sausage seasoning blend to ensure uniform distribution of the antioxidant during mixing of the meat block.

boxes and stored in the dark at 4 °C for 0, 7, 14, 21, and 28 d, while 3 vacuum packages per treatment were assigned to the precooked, frozen (PF) treatment and stored at –20 °C for 30, 60, and 90 d.

Proximate analysis

Percentages of moisture (AOAC 950.46), fat (AOAC 985.15), and protein (AOAC 992.15) were determined on raw pork sausage from each antioxidant treatment according to AOAC (2000) procedures. Raw patties from each antioxidant treatment at day 0 were homogenized in a food processor (Model DLC-8M, Cuisinart Inc., Norwich, Conn., U.S.A.) before sampling. Percentages of moisture and fat were determined using the convection air-dry oven and Soxhlet ether extraction methods, respectively. Crude protein percentage was determined by Dumas combustion method for gaseous N_2 using a Leco FP-528 protein analyzer (St. Joseph, Mo., U.S.A.). The instrument was standardized with ethylenediamine tetraacetic acid (EDTA) (part nr 502-092, %N = 9.56 ± 0.04) and Orchard leaves (part nr 502-055, %N = 2.4 ± 0.4) after each block of 10 to 12 samples. Crude protein percentage was calculated as 6.25 times the percent nitrogen.

Cook yield

Six 1-cm-thick raw pork sausages patties from each antioxidant treatment were weighed and cooked as described previously. Patties were allowed to cool to room temperature, reweighed, and the weight recorded. The percentage of cooking yield was determined by dividing the cooked product weight by the raw product weight and multiplying by 100.

Color evaluation

Lab color space values (L^*, a^*, and b^*) of the inner and outer surfaces of raw pork sausage chubs from each antioxidant treatment were obtained by reflectance using a Minolta Colorimeter (Model CR-300, Minolta Co., Ramsey, N.J., U.S.A.) with an 8-mm viewing port and illuminant D_{65}. Chubs of pork sausage from each antioxidant treatment, assigned to the RR and stored at 4 °C for 0, 7, 14, 21, and 28 d, were opened and allowed to bloom for a minimum of 30 min prior to color determination on the outer surface. Then, patties from chubs were sliced 6.35 cm thick and the inner surface was measured after 10 min. The colorimeter was calibrated daily to a standard white tile surface ($L^* = 96.66$, $a^* = –0.03$, and $b^* = 1.61$) at channel 00. The colorimeter port was covered with Saran® Wrap and then calibrated, and random readings were taken at 6 separate locations on the inner surface and outer surface of each treatment. The measurements were averaged for each surface and the results were expressed as positive L^* (lightness), a^* (redness), and b^* (yellowness) values.

Lipid oxidation

2-Thiobarbituric acid-reactive substance (TBARS) content of the pork sausage patties from each treatment (antioxidant treatment × storage treatment × storage day) was determined using the TBA distillation procedure of Tarladgis and others (1960) as modified by Rhee (1978). TBARS values for each sample were reported on a sample weight basis (TBARS = mg malonaldehyde/kg sample).

Allo-Kramer shear force

Shear force determinations were performed as described by Lin and Keeton (1994). Allo-Kramer shear force measurements were performed on five 10-mm thick patties from each antioxidant treatment storage combination. RR samples were cooked in a convection oven for 9 min at 148.9 °C to an internal temperature of 71.1 °C and allowed to cool to room temperature. PR and PF samples were reheated for 7 min at 93.3 °C to an internal temperature of 62.8 °C and allowed to cool to room temperature. Patties were weighed and sheared using an Instron universal testing machine (Model 1011, Instron Corp., Houston, Tex., U.S.A.) equipped with a 10-blade Allo-Kramer shear compression using a 500-kg load cell with a 100-kg load range and a 500-mm/min crosshead speed. Kilograms of shear force were recorded and divided by the sample weight to determine the shear force in kilograms per gram of sample.

Descriptive attribute and consumer sensory evaluations

Pork sausage samples from each treatment (antioxidant treatment × storage treatment × storage day) were evaluated by a 7-member trained expert descriptive attribute sensory panel in the Texas A&M Univ. Sensory Testing Facility. The panelists were selected and trained according to the procedures of Cross and others (1978), AMSA (1995), and Meilgaard and others (1999). All panelists had more than 5 y of experience in Spectrum™ descriptive flavor and texture analysis (Meilgaard and others 1999). Panelists underwent ballot development and training sessions using pork sausage without antioxidant (control "as is") and pork sausage with antioxidant treatments (3% or 6% DP, 3% or 6% DPA, and BHA/BHT). Panel-specific training was conducted for 6 d. Panelists underwent performance evaluation as specified in the guidelines developed by AMSA (1995) prior to initiation of the study to assure that the panelists were sufficiently trained. The samples were evaluated for flavor (cooked pork/brothy, cooked pork fat, spicy/peppery, soured, cardboard, painty, fishy, prune/plum, sage, brown/burnt, and vinegar), feeling factors (metallic and astringent), basic tastes (salt, sour, bitter, and sweet), mouth feel (pepper burn), aftertastes (sage, pepper, salt, sweet, prune, and sour), and texture attributes (hardness, springiness, juiciness, cohesiveness, denseness, and fracturability) as defined in Table 3.

All samples were scored using the 0 to 15 Spectrum universal intensity scale (Meilgaard and others 1999) where 0 = absence of an attribute and 15 = extremely intense. In addition, panelists also evaluated texture (springiness, juiciness, hardness, cohesiveness, and denseness) using the 0 to 15 Spectrum universal intensity scale where 0 = not springy, dry, soft, crumbly, and airy, and 15 = very springy, juicy, hard, defined particle size, and dense, for each attribute. Warm 13 mm cubed samples were served to the panelists. The order of the treatments was randomized and a fresh warm-up sample was presented to judges before the sample evaluation to ensure that they were familiar with the treatment attributes to be tested. The stimuli used for warm-up were pork sausage from a control formulation. The samples were coded with a random 3-digit number to mask the treatment identity and placed in clear 6-oz sample cups with lids. Each panelist received at least 2 cubes (13 mm) per sample and evaluated 12 randomly ordered RR or PR samples per day (0, 7, 14, or 21 d) and 6 randomly ordered PF samples (30, 60, or 90 d). Panelists evaluated samples in isolated booths fitted with a breadbox server and red incandescent lighting to mask color differences. Distilled water at room temperature, unsalted crackers, and ricotta cheese were given to judges to cleanse the palate between treatments.

To evaluate the acceptability of pork sausage samples from each antioxidant treatment (control, 3% or 6% PP, 3% or 6% DPA, and BHA/BHT), randomly ordered samples were evaluated by a consumer panel (118 participants) according to the procedures defined by Meilgaard and others (1999). The consumer sample population was selected from students and staff in the Animal

Table 3—Flavors, feeling factors, basic tastes, mouthfeel, aftertastes, and texture attribute definitions, references, and intensity based on a 15-point scale and established after consensus discussions with the expert panel.

Attribute	Definition	Reference products and intensity
Flavors		
Cooked pork/brothy	The aromatic associated with cooked pork muscle meat and brothy/brothlike	Concentrated beef broth (Swanson® beef broth, Campbell Soup Co., Camden, N.J., U.S.A.) = 15
Cooked pork fat	The aromatic associated with cooked pork fat	Cooked pork fat = 15
Spicy/peppery	An overall aroma term associated with spices added to the product	Slight amount of spices placed on the tongue = 15
Cardboard	The aromatic associated with slightly stale pork (refrigerated for a few days only) and associated with wet cardboard and stale oils and fats	Wet cardboard placed in the mouth and air drawn over = 15
Painty	The aromatic associated with rancid oil and fat (distinctly like linseed oil)	Linseed oil = 15
Fishy	The aromatic associated with some rancid fats and oils (similar to old fish)	Catfish = 15
Prune/plum	The aromatic associated with sweet, fruity aromatic of plum or a browned aroma, reminiscent of prunes	Prunes placed in mouth = 15
Sage flavor	The aromatic associated with camphoraceous or eucalyptus-like aromatic associated with sage	Dried sage = 15
Feeling factors		
Metallic	A feeling factor on the tongue stimulated by metal or the aromatics associated with metals	Cooked 1.27-cm sample of liver = 15
Astringent	The shrinking or puckering of the tongue surface caused by substances such as tannins or alum	Lipton black tea (Lipton, Englewood Cliffs, N.J., U.S.A.) bag placed in hot water and allowed to sit for 1 h = 6.5
Basic tastes		
Salt	Taste on the tongue associated with sodium ions	Potato chips (Pringles, Procter & Gamble, Cincinnati, Ohio, U.S.A.) = 13
Sour	Taste on the tongue associated with acids	Lemon juice (Real Lemon®, Mott's Inc., Stanford, Ct., U.S.A.) = 8.0
Bitter	Taste on the tongue associated with bitter agents such as caffeine, quinine, and so on	Caffeine (0.15% solution) = 10.0
Sweet	Taste on the tongue associated with sugars	Chocolate bar (The Hershey Co., Hershey, Pa., U.S.A.) = 10.0
Mouthfeel		
Pepper burn	Mouthfeel sensation characterized by pepper burning in the mouth and throat	Slight amount of cayenne pepper = 15
Aftertastes		
Sage	Aftertastes stimulated by sage	Dried sage = 15
Pepper	Aftertastes stimulated by pepper or spice substances	Spices used in product = 15
Salt	Aftertastes stimulated by sodium salt	Potato chips (Pringles) = 13
Sweet	Aftertastes stimulated by sugars and artificial sweeteners	Chocolate bar (Hershey's) = 10.0
Prune	Aftertastes stimulated by prune fruit	Prunes placed in mouth = 15
Sour	Aftertastes stimulated by acids	Lemon juice (Real Lemon) = 8.0
Textures		
Springiness	Degree to which sample returns to original shape after a certain time period	Marshmallow (miniature, Wal-Mart Inc., Bentonville, Ark., U.S.A.) = 9.5
Juiciness	Amount of wetness/juiciness released from sample	Apples (Red Delicious) = 10.0
Hardness	Force required to bite through sample	Hard candy (Life Savers®, WM. Wrigley JR. Co., Chicago, Ill., U.S.A.) = 14.5
Cohesiveness	The amount the sample deforms rather than shears/cuts	Candy chews (Starburst, Master-*foods* USA™, Hackettstown, N.J., U.S.A.) = 12.5
Denseness	Compactness of the cross section	Malted milk balls (Whopper, The Hershey Co.) = 6.0
Fracturability	The force with which the sample breaks	Hard candy (Life Savers) = 14.5

Science Dept. at Texas A&M Univ. (College Station, Tex., U.S.A.). Only consumers who eat pork sausage at least 2 times weekly and reported no food allergies were selected to participate in the assessment. A moderator oriented consumers to the ballot and test procedures prior to consumers being seated in sensory booths. Overall like/dislike, overall like/dislike of flavor, intensity of the flavor, overall like/dislike of texture, level of tenderness, and level of juiciness attributes were evaluated for each sample using a 9-point scale (Meilgaard and others 1999) where 1 = like extremely or extremely intense/tender/juicy and 9 = dislike extremely or absence of pork sausage flavor or extremely bland/tough/dry. Raw patties (from fresh chubs) that had been frozen prior (for 1 wk) to consumer evaluation were thawed and cooked in a convection oven for 9 min at 148 °C to an internal temperature of 71.1 °C. Warm 13 mm-cubed samples were served to each consumer panelist, with each panelist receiving at least 2 cubes per sample. Consumer panelists were seated in isolated booths under the same environmental conditions as defined for the expert panel.

Statistical analysis

The study was designed as a 6 × 3 × 3 factorial experiment with antioxidant treatment (control, 3% or 6% PP, 3% or 6% DPA, and BHA/BHT), storage treatment (raw/refrigerated at 4 °C, precooked/refrigerated at 4 °C, and precooked/frozen at −20 °C), and storage day (raw and precooked/refrigerated—0, 7, 14, 21, and 28 d, and precooked/frozen—30, 60, and 90 d) as the main effects. Each treatment was replicated 3 times. Analysis of variance (ANOVA) was performed using the PROC GLM procedure of SAS (SAS 1995) to determine statistical differences among the main effects and their interactions at a significance level of $P < 0.05$. Least square means were generated and reported for all main effects and for significant interactions.

Due to cost constraints, consumer evaluations were performed only on 1 replication.

Results and Discussion

Physical and chemical properties

Percentages of moisture, fat, protein, internal and surface color values, and cook yield of raw sausage samples are presented in Table 4. In comparison to the control (49.56% moisture and 34.27% fat), all treatments had higher moisture and lower fat content due to a dilution of the total meat block with the various antioxidant treatments. Of the treated samples, DPA puree had slightly more moisture (53.01% to 53.17%) than the DP treatment (51.05% to 51.43%) and control, but was not different from BHA/BHT. Among the treatments, 3% DP (31.26% fat) was slightly higher ($P < 0.05$) in fat content than 6% DPA (29.26%), but the other treatments were not different from one another. Percent protein of the pork sausage was not affected ($P > 0.05$) by the antioxidant treatments.

Internal L^* values (lightness) decreased ($P < 0.05$) slightly with the addition 3% DP, 6% DP, and 6% DPA when compared to the control, but 3% DPA and BHA/BHT had no effect on the L^* values (Table 4). This is consistent with the L^* values observed for surface color measurements. Inclusion of 3% and 6% DP resulted in a slight, but incremental decrease ($P < 0.05$) in internal lightness, indicating that the darker colored DP caused more of a lightness change than did the lighter colored DPA. This is likely due to a higher pigment content in DP than in DPA. Lee and Ahn (2005) also noted that the color of turkey rolls with plum extract puree (3%) was dark due to the original dark purple color of the plum extract.

Internal a^* values (redness) followed a similar pattern as the L^* values. Internal redness declined ($P < 0.05$) incrementally with the addition of 3% and 6% DP, but to a lesser degree with 3% DPA. Both 6% DPA and BHA/BHT had no effect on internal redness. Internal b^* values (yellowness) were higher ($P < 0.05$) for all treatments than for the control and increased incrementally with 3% and 6% DP, with 6% DP having the highest b^* value. No differences ($P > 0.05$) were found in yellowness among 3% DPA, 6% DPA, and the BHA/BHT treatments. However, yellowness values of raw pork sausage with 6% DP were slightly higher ($P < 0.05$) when compared to the BHA/BHT treatment. Thus, the addition of DP changed the internal color attributes of raw pork sausage patties slightly by darkening the sample, decreasing redness slightly, and increasing yellowness. In general, the internal portions of raw pork sausages containing 6% DPA, 3% DP, and 6% DP were slightly darker and slightly more yellow than the control when measured with a colorimeter. These changes in color of raw pork sausage appear to have been due to the dark brown pigmentation of the dried plum puree compared to the lighter brown color of the dried plum and apple puree blend. As consumers generally associate a darker color with leaner products, such an appearance may in fact be beneficial (Jiménez 1996).

Surface L^* or lightness values were slightly lower or darker for raw sausage patties with 3% DP, 6% DP, and 6% DPA when compared to the control ($P < 0.05$). The addition of 6% DP resulted in the darkest surface color on patties followed by 3% DP, but no differences in surface L^* were noted among the control, 3% DPA or BHA/BHT treatments. It was assumed that the darker color was likely caused by the dried plum material coating the meat particles and absorbing more light.

Surface a^* values (redness) were not different ($P > 0.05$) due to any of the treatments (Table 4). Thus, the addition of dried plum puree products does not appear to affect surface redness of raw pork sausage. Surface b^* values (yellowness) were higher ($P < 0.05$) in 3% DPA, 3% DP, 6% DP, and BHA/BHT treatments

Table 4—Least squares means for moisture, fat, protein, internal color values, surface color values, and cook yield of raw pork sausage with dried plum puree ingredients.

Treatment[e]	Moisture (%)	Fat (%)	Protein (%)	Internal color values			Surface color values			Cook yield (%)
				L^*	a^*	b^*	L^*	a^*	b^*	
Control	49.56^{c}	34.27^{a}	14.75	63.63^{a}	12.59^{a}	13.82^{d}	63.58^{a}	8.23	15.67^{c}	80.35^{a}
DP 3%	51.05^{b}	31.26^{b}	14.83	61.75^{b}	11.22^{c}	15.51^{b}	59.89^{c}	7.74	17.22^{a}	78.65^{a}
DP 6%	51.43^{b}	29.58^{b,c}	14.33	58.28^{c}	10.63^{d}	16.56^{a}	55.47^{d}	8.30	17.62^{a}	75.14^{b}
DPA 3%	53.17^{a}	29.45^{b,c}	15.17	64.21^{a}	11.96^{b}	14.64^{c}	63.42^{a}	8.08	16.19^{b}	79.30^{a}
DPA 6%	53.01^{a}	29.26^{c}	14.33	62.46^{b}	12.15^{a,b}	14.81^{c}	61.49^{b}	8.30	15.86^{b,c}	78.75^{a}
BHA/BHT	52.43^{a,b}	30.52^{b,c}	15.17	64.26^{a}	13.02^{a}	15.12^{b,c}	63.15^{a}	8.33	16.60^{b}	81.56^{a}
SEM[f]	0.55	0.73	0.50	0.29	0.16	0.15	0.34	0.21	0.19	1.25

[a,b,c,d]Least square means in the same column without a common superscript letter differ ($P < 0.05$).
[e]Control = no antioxidant, DP = dried plum puree, DPA = dried plum and apple puree, BHA/BHT = butylated hydroxyanisole and butylated hydroxytoluene.
[f]SEM = standard error of the mean.

when compared to the control. However, no differences ($P > 0.05$) were found among 3% DPA, 6% DPA, and the BHA/BHT treatments. Overall, inclusion of dried plum puree increased yellowness slightly in raw pork sausages with 3% DPA, 3% DP, and 6% DP, but the magnitude of these differences from a consumer's perspective has yet to be determined.

Cooking yields were variable as noted by the standard error mean (1.25%), but did not differ ($P > 0.05$) among the control and treatments (Table 4), except that 6% DP was less (75.14% yield) than the other treatments (78.65% to 81.56%). The cause of the decrease in cooking yield with 6% DP is not known.

The antioxidant treatment by refrigerated storage interaction was not significant ($P > 0.05$); thus the data were pooled and reported over storage days. As shown in Table 5, internal lightness values (L^*) of raw sausage decreased through day 14, then increased as storage progressed. Redness (a^*) values increased to day 14, then declined slightly, but remained higher than day 0 throughout the 28-d storage period. Internal yellowness (b^*) values declined slightly after 21 d of storage. Surface L^* (lightness) values of raw pork patties declined ($P > 0.05$) slightly after 7 d of refrigerated storage, then became slightly lighter by day 28. Surface redness (a^*) values decreased ($P < 0.05$) progressively during 21 d of storage, as did yellowness (b^*). Overall, storage at 4 °C for 28 d resulted in a slight loss of surface redness while internal redness and lightness were enhanced. Cook yields declined after 14 d and decreased ever more after 28 d (84.46% against 70.46%).

TBARS and Allo-Kramer shear force

Significant reductions ($P < 0.05$) in TBARS values were observed for PR and PF patties made with 3% or 6% DP and BHA/BHT when compared to the control (Table 6). However, TBARS values were slightly higher than the control for PR sausages with 3% DPA, but those with 6% DPA were slightly lower. No differences ($P > 0.05$) in TBARS values were observed between the control and antioxidant treatments of the uncooked (RR) sausages. PR patties containing 3% or 6% DP and BHA/BHT had the lowest TBARS values and were equivalent to those observed for the raw storage treatment. PF patties with 6% DP were also not different from RR. TBARS values indicated that the inclusion of 3% or 6% DPA was not as effective as an antioxidant as were the other treatments. Overall, 3% or 6% DP and BHA/BHT were the most effective antioxidants based on TBARS values of precooked pork sausage patties stored under refrigerated or frozen conditions.

Raw pork sausages were not as susceptible to lipid oxidation as the cooked sausages. Previous studies documented that even raw-refrigerated plain pork (with no seasonings or additives) would be resistant to lipid oxidation due to the high levels of endogenous antioxidant enzymes (especially catalase) in the tissues (Rhee and others 1996; Pradhan and others 2000). Precooking accelerated lipid oxidation and was suppressed with the inclusion of 3% or 6% DP, or BHA/BHT. The DPA treatments did not consistently retard lipid oxidation. The lower TBARS values observed for DP may be due to a higher concentration of antioxidants than in the DPA. According to Wang and others (1996), DP has higher ORAC values than apple; thus the DPA would be expected to have less antioxidant capacity. These results indicate that a dried plum puree (DP) ingredient used at 3% or 6% levels was as effective of an antioxidant as a combination of BHA/BHT at 0.02%. Similarly, Sebranek and others (2005) found that the rosemary extract was equally effective as BHA/BHT in maintaining low TBARS values of precooked-frozen pork sausage patties.

Kramer shear values, an instrumental measure of tenderness, were slightly higher ($P < 0.05$) by approximately 0.5 kg/g for RR cooked patties with 3% and 6% DP, but the other treatments were not different. Within the PR or PF categories (Table 6), Kramer shear values were not different except for the 6% DPA PF treatment, which was slightly more tender than the control. PR patties had lower shear values than either the RR or PF patties.

TBARS values (Table 7) of RR patties did not change significantly ($P > 0.05$) with storage. However, storage of PR patties resulted in an increase in TBARS values after 7 d. The highest values for TBARS values were observed in PR patties at day 21. PF patties had incremental increases in TBARS values over a 90-d storage period. Overall, refrigerated storage of RR patties did not appear to increase lipid oxidation, but precooking of pork patties with subsequent refrigerated (PR) and frozen (PF) storage increased lipid oxidation. McCarthy and others (2001) found that cooking pork patties significantly increased TBARS values 4-fold when compared to raw patties. Various hypotheses have been developed as to how cooking accelerates lipid oxidation in meat (Harel and Kanner 1985; Asghar and others 1988; Rhee 1988; Mei and others 1994). These include (1) disruption of muscle membrane systems (thus, loss of structural integrity) that may occur during cooking allowing membrane lipids (highly unsaturated) to be more accessible to lipid oxidation catalysts, (2) increases in ionic iron concentration from heat-induced release of protein-bound iron after cooking, (3) the formation of the hypervalent ferrylmyoglobin (often referred to as activated metmyoglobin) during cooking, which can initiate lipid oxidation, and (4) inactivation of antioxidant enzymes in meat due to cooking. Kanner (1994) also showed that high temperatures decrease the activation energy for oxidation, thus breaking down preformed hydroperoxides that propagate lipid peroxidation and the development of off-flavors. All these may account for the increase in TBARS values of precooked sausages patties under refrigerated or frozen conditions when compared to raw pork sausage.

Allo-Kramer shear force values for stored pork sausage are presented in Table 7. Shear values of RR cooked patties were the most variable and indicated that the patties became incrementally less tender with storage over 28 d. PR patties showed no effects of storage. PF patties, similarly, were not practically different in shear

Table 5—Least squares means for internal and surface color values, and cook yield of raw pork sausage stored under refrigerated conditions.

Storage day	Internal color values			Surface color values			Cook yield (%)
	L^*	a^*	b^*	L^*	a^*	b^*	
0	61.89[a]	11.25[c]	15.67[a]	61.57[b]	12.14[a]	17.50[a]	84.46[a]
7	60.21[d]	12.03[b]	15.34[a]	60.47[c]	8.01[b]	17.72[a]	85.29[a]
14	61.71[c]	12.76[a]	15.58[a]	60.43[c]	7.34[c]	16.53[b]	78.40[b]
21	63.45[b]	11.70[b]	14.44[b]	60.87[b,c]	6.49[d]	15.37[c]	76.17[b]
28	64.68[a]	11.91[b]	14.36[b]	62.50[a]	6.65[d]	15.51[c]	70.46[c]
SEM[e]	0.27	0.15	0.14	0.28	0.17	0.15	1.33

[a,b,c,d]Least square means in the same column without a common superscript letter differ ($P < 0.05$).
[e]SEM = standard error of the mean.

value, but were less tender than the PR treatment. The incremental toughness observed in RR patties may have been related to the corresponding decline ($P < 0.05$) in percent cook yield over storage (Table 5). Loss of moisture and/or fat upon cooking would cause patty toughness to increase as storage progressed.

Table 6—Least squares means for TBARS values and Allo-Kramer shear force values of raw and precooked pork sausage formulated with dried plum puree ingredients.

Storage treatment[g]	Antioxidant treatment[h]	TBARS[i] (mg malonaldehyde/kg sample)	Allo-Kramer shear force value (kg/g)
RR	Control	0.28[f]	2.55[c]
	DP 3%	0.29[f]	3.00[a]
	DP 6%	0.31[f]	3.02[a]
	DPA 3%	0.27[f]	2.70[b,c]
	DPA 6%	0.29[f]	2.62[b,c]
	BHA/BHT	0.29[f]	2.50[c]
	SEM[J]	0.06	0.06
PR	Control	1.00[c,d]	1.85[d]
	DP 3%	0.44[f]	1.90[d]
	DP 6%	0.34[f]	1.95[d]
	DPA 3%	1.29[b]	1.78[d,c]
	DPA 6%	0.72[e]	1.74[d,e]
	BHA/BHT	0.39[f]	1.82[d]
	SEM[J]	0.06	0.06
PF	Control	1.98[a]	3.00[a]
	DP 3%	0.95[d]	2.95[a,b]
	DP 6%	0.46[f]	2.95[a,b]
	DPA 3%	1.46[b]	2.86[a,b]
	DPA 6%	1.86[a]	2.81[b]
	BHA/BHT	1.05[c,d]	2.95[a,b]
	SEM[j]	0.08	0.08

[a,b,c,d,e,f]Least square means in the same column without a common superscript letter differ ($P < 0.05$).
[g]RR = raw pork sausage refrigerated at 4 °C; PR = precooked pork sausage refrigerated at 4 °C; PF = precooked pork sausage frozen at –20 °C.
[h]Control = no antioxidant; DP = dried plum puree; DPA = dried plum and apple puree; BHA/BHT = butylated hydroxyanisole and butylated hydroxytoluene.
[i]TBARS was reported on a sample weight basis.
[j]SEM = standard error of the mean.

Table 7—Least squares means for TBARS values and Allo-Kramer shear force values of raw and precooked pork sausage over storage.

Storage treatment[h]	Storage day[h]	TBARS[i] (mg malonaldehyde/kg sample)	Allo-Kramer shear force value (kg/g)
RR	0	0.25[e]	2.16[f]
	7	0.34[e]	2.14[f]
	14	0.27[e]	2.64[e]
	21	0.26[e]	3.25[b]
	28	0.31[e]	3.47[a]
	SEM[j]	0.07	0.05
PR	0	0.43[e]	1.89[g]
	7	0.69[d]	1.81[g]
	14	0.64[d]	1.87[g]
	21	0.90[c]	1.85[g]
	28	0.82[c,d]	1.83[g]
	SEM[j]	0.07	0.05
PF	30	0.86[c,d]	2.96[c]
	60	1.17[b]	2.82[d]
	90	1.85[a]	2.98[c]
	SEM[j]	0.07	0.05

[a,b,c,d,e,f,g]Least square means in the same column without a common superscript letter differ ($P < 0.05$).
[h]RR = raw pork sausage refrigerated at 4 °C; PR = precooked pork sausage refrigerated at 4 °C; PF = precooked pork sausage frozen at –20 °C.
[i]TBARS was reported on a sample weight basis.
[j]SEM = standard error of the mean.

Sensory evaluation

Descriptive attribute panel. Sensory profile data of pork sausages (Table 8) indicated that the level and type of dried plum puree had an effect ($P < 0.05$) on some sensory flavors, feeling factors, basic tastes, mouthfeel, aftertastes, and texture attributes. The flavors affected ($P < 0.05$) across treatments were cooked pork/brothy (the most dominant flavor note), cooked pork fat, spicy/peppery, prune/plum, and sage flavor. The highest scores for cooked pork/brothy were observed in the control and BHA/BHT treatments. Cooked pork fat, spicy/peppery, and sage flavors were not different among the control, BHA/BHT, and 3% DPA patties. However, the intensity score of such flavor notes decreased as the levels of dried plum puree increased except for prune/plum flavor, which increased. Cooked pork fat flavor intensity of DP and DPA patties declined slightly with increasing levels. As expected, prune/plum flavor was highest in samples with dried plum puree. These results indicate that the dried plum puree may mask or dilute the cooked pork/brothy, cooked pork fat, spicy/peppery, and sage flavors in pork sausage. Moreover, these flavor changes may be associated with a slight reduction in fat content and a corresponding increase in the water content of patties with dried plum purees (Table 4). Samples with 6% DP were slightly less astringent than the other samples.

Salt taste was higher in the control and BHA/BHT treatments, while sweet taste was more pronounced in the DP and DPA samples, which also contained higher levels of sugars. No differences were found in sour tastes among treatments. Pepper burn notes were less noticeable ($P < 0.05$) in the DP samples than the other samples.

All aftertastes were detected at relatively low levels and all, except sour, were affected ($P < 0.05$) slightly by most treatments. The BHA/BHT combination was not different from the control. Scores for sage, pepper, and salt aftertastes ranged from 1.18 to 2.69 and were generally higher in the control and BHA/BHT samples, while sweet and prune aftertastes, which ranged from 0.14 to 1.78, were higher in the DP and DPA treatments.

Springiness and hardness were the only textural attributes affected ($P < 0.05$) by DP or DPA treatments. Springiness declined slightly and incrementally with 3% and 6% DP, respectively, while only 6% DPA was lower than the control. Patties with 6% DP were less hard than the other treatments. In a study by Mendoza and others (2001), reducing the fat content increased hardness and decreased springiness of ripened sausages with inulin. By comparison, the dilution of the meat block with DP or DPA in this study reduced springiness slightly while having a limited effect on hardness. Sensory hardness, unlike Allo-Kramer shear values, showed few differences with respect to the dried plum treatments.

Sensory evaluation of RR-, PR-, and PF-treated sausages across all storage periods revealed only small differences ($P < 0.05$) in flavor, feeling factors, basic tastes, mouthfeel, texture, and aftertaste attributes (data not shown). Descriptors associated with warmed-over-flavor (WOF), such as cardboard, painty, and fishy flavor/aromatics, were not affected by storage treatments. The descriptors associated with WOF were no higher than 0.3 on a 0- to 15-point scale for RR, PR, and PF patty treatments.

Although differences were observed in feeling factors, aftertastes, and texture attributes, these values were detected at very low levels in RR, PR, and PF patties (data not shown).

Consumer sensory panel. Consumer evaluations by 118 panelists of pork sausage patties (Table 9) indicated that the levels of dried plum puree treatments had no effect ($P > 0.05$) on flavor intensity, texture, or level of juiciness but did influence ($P < 0.05$) perceptions for overall like/dislike, overall flavor, and level of tenderness. Patties with 6% DP were rated as acceptable, but less preferred overall than other treatments. For flavor, patties with 3% DP or DPA and BHA/BHT were not different ($P > 0.05$) from the control. The 3% DPA and BHA/BHT treatments were considered slightly more tender than the 6% treatments. Overall, consumers appeared to like pork sausage patties with 3% DP or DPA as well as the control and BHA/BHT patties, but the addition of 6% DP or DPA appeared to decrease acceptability.

Conclusions

A significant observation in this study was that DP used at 3% or 6% levels was as effective as BHA/BHT for retarding lipid oxidation precooked (PR) or precooked frozen (PF) pork sausage. DP used at 6% was even more effective than BHA/BHT for retarding oxidative rancidity in PF pork sausage patties. All treatments increased moisture and decreased fat content of raw pork sausages, while the addition of 6% DP reduced cook yields. The results of objective color evaluations showed that the addition of DP and DPA changed the internal color attributes of raw pork sausage to a small degree by darkening the samples, slightly diluting internal redness, and increasing yellowness. Refrigerated storage of raw pork sausage for 28 d did not appear to increase lipid oxidation. However, precooking with subsequent refrigerated or frozen storage accelerated lipid oxidation. Trained panel sensory evaluations indicated that DP decreased pork and spice flavor notes incrementally, and DPA to a lesser degree. Salt and bitter tastes were higher in the control and BHA/BHT treatment, while DP and DPA patties were sweeter and seemed to mask cooked pork/brothy, cooked

Table 8 — Least squares means of descriptive attribute sensory panel scores (combined) for flavors,[e] feeling factors,[e] basic tastes,[e] mouthfeel,[e] aftertastes,[e] and textures[f] cooked pork sausage formulated with dried plum puree and stored at different conditions.

	Treatments[g]						
	Control	DP 3%	DP 6%	DPA 3%	DPA 6%	BHA/BHT	SEM
Flavors							
Cooked pork/brothy	7.59[a]	6.37[c]	5.87[d]	7.15[b]	6.56[c]	7.49[a]	0.09
Cooked pork fat	3.31[a]	3.12[b]	2.94[c]	3.27[a]	3.09[b]	3.22[a,b]	0.05
Spicy/peppery	3.92[a,b]	3.35[c]	3.20[c]	3.77[b]	3.66[b]	4.04[a]	0.08
Prune/plum	0.28[d]	2.12[b]	3.62[a]	0.80[c]	2.13[b]	0.27[d]	0.09
Sage flavor	3.08[a]	2.58[c]	2.42[c]	2.91[a,b]	2.75[b]	3.02[a]	0.06
Feeling factors							
Metallic	2.00	1.97	1.95	2.03	1.99	2.00	0.03
Astringent	2.48[a,b]	2.39[b]	2.25[c]	2.45[a,b]	2.44[a,b]	2.54[a]	0.04
Basic tastes							
Salt	5.88[a]	4.72[c]	4.29[d]	5.43[b]	4.78[c]	5.76[a]	0.11
Sour	2.10	2.23	2.24	2.19	2.16	2.09	0.05
Bitter	1.87[a,b]	1.75[b]	1.71[b]	1.84[a,b]	1.83[a,b]	1.90[a]	0.05
Sweet	1.62[d]	2.28[b]	2.72[a]	1.86[c]	2.25[b]	1.59[d]	0.06
Mouthfeel							
Pepper burn	3.08[a]	2.62[b]	2.46[b]	2.94[a]	2.94[a]	3.11[a]	0.08
Aftertastes							
Sage	2.22[a]	1.91[b,c]	1.78[c]	1.99[b]	2.03[b]	2.11[a,b]	0.06
Pepper	2.71[a]	2.35[c]	2.19[c]	2.52[b]	2.59[a,b]	2.69[a]	0.06
Salt	2.01[a]	1.39[c]	1.18[d]	1.70[b]	1.36[c,d]	1.91[a]	0.07
Sweet	0.08[b]	0.23[a,b]	0.34[a]	0.14[b]	0.23[a,b]	0.06[b]	0.04
Prune	0.07[d]	1.02[b]	1.78[a]	0.30[c]	1.07[b]	0.11[d]	0.06
Sour	0.11	0.28	0.21	0.27	0.22	0.15	0.05
Textures							
Springiness	5.69[a]	5.47[b]	5.08[c]	5.61[a,b]	5.46[b]	5.68[a]	0.06
Juiciness	4.72	4.62	4.61	4.69	4.68	4.66	0.05
Hardness	4.51[a]	4.45[a,b]	4.32[b]	4.55[a]	4.47[a]	4.59[a]	0.05
Cohesiveness	5.17	5.18	5.10	5.21	5.15	5.19	0.05
Denseness	4.63	4.53	4.47	4.59	4.55	4.64	0.05
Fracturability	3.94	3.93	3.77	4.14	3.86	3.92	0.09

[a,b,c,d]Least square means in the same row without a common superscript letter differ ($P < 0.05$).
[e]Based on the 0–15 Spectrum Universal Intensity scale (0 = absence of flavor; 15 = extremely intense flavor).
[f]Based on the 0–15 Spectrum Universal Intensity scale (0 = not springy, dry, soft, crumbly, airy, 15 = very springy, juicy, hard, defined particle size, dense).
[g]Control = no antioxidant, DP = dried plum puree; DPA = dried plum and apple puree; BHA/BHT = butylated hydroxyanisole and butylated hydroxytoluene.
[h]SEM = standard error of the mean.

Table 9 — Least squares means of consumer panel scores of cooked pork sausage formulated with dried plum puree and stored at different conditions.

	Treatments[e]						
	Control	DP 3%	DP 6%	DPA 3%	DPA 6%	BHA/BHT	SEM[f]
Overall like/dislike[d]	3.97[b,c]	3.96[b,c]	5.15[a]	3.98[b,c]	4.39[b]	3.60[c]	0.18
Flavor overall like/dislike[d]	3.84[c]	4.08[b,c]	5.12[a]	3.91[c]	4.44[b]	3.57[c]	0.18
Flavor intensity[d]	4.43	4.41	4.83	4.64	4.61	4.52	0.18
Texture overall like/dislike[d]	3.55	3.54	3.81	3.23	3.67	3.21	0.19
Level of tenderness[d]	3.55[a,b]	3.54[a,b]	3.81[a]	3.23[b]	3.67[a]	3.21[b]	0.15
Level of juiciness[d]	3.70	3.77	4.08	3.77	3.80	3.48	0.15

[a,b,c]Least square means in the same row without a common superscript letter differ ($P < 0.05$).
[d]Based on a 9-point intensity scale (1 = like extremely or extremely intense/tender/juicy; 9 = dislike extremely or extremely bland/tough/dry).
[e]Control = no antioxidant; DP = dried plum puree; DPA = dried plum and apple puree; BHA/BHT = butylated hydroxyanisole and butylated hydroxytoluene.
[f]SEM = standard error of the mean.

pork fat, spicy/peppery, and sage flavor. Intensities of flavor notes associated with WOF and lipid oxidation, such as cardboard, painty, and fishy flavor notes, were not influenced by storage treatments and were detected at very low levels in RR, PR, and PF patties. Consumer sensory evaluations indicated that pork sausage patties with 3% DP or DPA were liked as well as the control or BHA/BHT treatment. Thus, the inclusion of DP as a natural antioxidant may offer an additional natural alternative for suppressing lipid oxidation in precooked pork sausage products.

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References

Aguirrezábal MM, Mateo J, Domínguez MC, Zumalacárregui JM. 2000. The effect of paprika, garlic and salt on rancidity in dry sausages. Meat Sci 54:77–81.

Ahn J, Grün IU, Fernando LN. 2002. Antioxidant properties of natural plant extracts containing polyphenolic compounds in cooked ground beef. J Food Sci 67(4):1364–9.

[AMSA] American Meat Science Assn. 1995. Research guidelines for cookery, sensory evaluation and instrumental measurements of fresh meat. Chicago, Ill.: American Meat Science Assn., Natl. Live Stock and Meat Board.

[AOAC] Assn. Official Analytical Chemists. 2000. Official methods of analysis of AOAC Intl. 17th ed. Gaithersburg, Md.: AOAC.

Asghar A, Gray JI, Buckley DJ, Pearson AM, Booren AM. 1988. Perspectives on warmed-over flavor. Food Technol 42(6):102–8.

Cao G, Verdon CP, Wu H, Wang H, Prior RL. 1995. Automated assay of oxygen radical absorbance capacity with the COBAS FARA II. Clin Chem 41:1738–44.

Cao G, Sofic E, Prior RL. 1996. Antioxidant capacity of tea and common vegetables. J Agric Food Chem 44(11):3426–31.

Cross HR, Moen R, Stanfield MS. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol 32(7):48–54.

Formanek Z, Kerry JP, Higgins FM, Buckley DJ, Morrissey PA, Farkas J. 2001. Addition of synthetic and natural antioxidants to α-tocopheryl acetate supplemented beef patties: effects of antioxidants and packaging on lipid oxidation. Meat Sci 58:337–41.

Frankel EN. 1998. Lipid oxidation. 1st ed. Dundee, U.K.: The Oily Press Ltd., PJ Barnes and Assoc. 303 p.

Gray JI, Gomaa EA, Buckley DJ. 1996. Oxidative quality and shelf life of meats. Meat Sci 43:S111–23.

Grün IU, Ahn J, Clarke AD, Lorenzen CL. 2006. Reducing oxidation of meat. Food Technol 60(1):36–43.

Güntensperger B, Hammerli-Meier DE, Escher FE. 1998. Rosemary extract and precooking effects on lipid oxidation in heat-sterilized meat. J Food Sci 63(6): 955–7.

Harel S, Kanner J. 1985. Muscle membranal lipid peroxidation initiated by hydrogen peroxide activated metmyoglobin. J Agric Food Chem 33:1188–92.

Jiménez F. 1996. Technologies for developing low-fat meat products. Trends Food Sci Technol 7:41–8.

Johnston JE, Sepe HA, Miano CL, Brannan RG, Alderton AL. 2005. Money inhibits lipid oxidation in ready-to-eat ground beef patties. Meat Sci 70:627–31.

Kanner J. 1994. Oxidative processes in meat and meat products: quality implications. Meat Sci 36:169–89.

Lee EJ, Ahn DU. 2005. Quality characteristics of irradiated turkey breast rolls formulated with plum extract. Meat Sci 71:300–5.

Lin KW, Keeton JT. 1994. Determination of optimum particle size for low-fat, precooked ground beef patties. J. Muscle Foods 5(1):63–76.

McBride J. 1999. High-ORAC foods may slow aging. Agric Res 47(2):14–7.

McCarthy TL, Kerry JP, Kerry JF, Lynch PB, Buckley DJ. 2001. Evaluation of the antioxidant potential of food/plant extracts as compared with synthetic antioxidants and vitamin E in raw and cooked pork patties. Meat Sci 57:45–52.

Mei L, Crum AD, Decker EA. 1994. Development of lipid oxidation and inactivation of antioxidant enzymes in cooked pork and beef. J Food Lipids 1:273–83.

Meilgaard M, Civille GV, Carr BT. 1999. Sensory evaluation techniques. 3rd ed. Boca Raton, Fla.: CRC Press Inc. 387 p.

Mendoza E, García ML, Casas C, Selgas MD. 2001. Inulin as fat substitute in low fat, dry fermented sausages. Meat Sci 57:387–93.

Morrissey PA, Sheehy PJA, Galvin K, Kerry JP, Buckley DJ. 1998. Lipid stability in meat and meat products. Meat Sci 49:S73–86.

Nissen LR, Byrne DV, Bertelsen G, Skibsted LH. 2004. The antioxidative activity of plant extracts in cooked pork patties as evaluated by descriptive sensory profiling and chemical analysis. Meat Sci 68:485–95.

Pradhan AA, Rhee KS, Hernández P. 2000. Stability of catalase and its potential role in lipid oxidation in meat. Meat Sci 54:385–90.

Rhee KS. 1978. Minimization of further lipid peroxidation in the distillation 2-thiobarbituric acid test of fish and meat. J Food Sci 43(6):1776–81.

Rhee KS. 1988. Enzymic and nonenzymic catalysts of lipid oxidation in muscle foods. Food Technol 42(6):127–32.

Rhee KS, Anderson LM, Sams AR. 1996. Lipid oxidation potential of beef, chicken, and pork. J Food Sci 61(1):8–12.

Rhee KS, Ziprin YA, Calhoun MC. 2001. Antioxidative effects of cottonseed meals as evaluated in cooked meat. Meat Sci 58:117–23.

SAS Inst. 1995. SAS user's guide: statistics. Cary, N.C.: SAS Inst. Inc.

Sebranek JG, Sewalt VJH, Robbins KL, Houser TA. 2005. Comparison of a natural rosemary extract and BHA/BHT for relative antioxidant effectiveness in pork sausage. Meat Sci 69:289–96.

Stacewicz-Sapuntzakis M, Bowen PE, Hussain EA, Damayanti-Wood BI, Farnsworth NR. 2001. Chemical composition and potential health effects of prunes: a functional food? Crit Rev Food Sci Nutr 41(4):251–86.

St. Angelo AJ, Crippen KL, Dupuy HP, James C, Jr. 1990. Chemical and sensory studies of antioxidant-treated beef. J Food Sci 55(6):1501–5.

Tarladgis BG, Watts BM, Younathan MT, Dugan LR. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J Am Oil Chem Soc 37(1):44–8.

Wang H, Cao G, Prior RL. 1996. Total antioxidant capacity of fruits. J Agric Food Chem 44(3):701–5.