A FINAL REPORT TO THE

CALIFORNIA PRUNE BOARD

EVALUATION OF PLUM/PRUNE INGREDIENTS AS A COMPONENT OF MEAT PRODUCTS

PART II

EVALUATION OF HAM AND ROAST BEEF PRODUCTS CONTAINING FRESH PLUM JUICE CONCENTRATE, DRIED PLUM JUICE CONCENTRATE, OR SPRAY DRIED PLUM POWDER

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EXECUTIVE SUMMARY

Boneless Roasts

Boneless top round beef roasts (*Semimembranosus, Adductor*) were injected at 20% above raw weight with a brine containing fresh plum juice concentrate (FP), dried plum juice concentrate (DP) and spray dried plum powder (PP) at levels of 2.5 and 5.0%. Roasts were cooked in a commercial, climate-controlled smokehouse to an internal temperature of 145°F (62.8°C), chilled and one-half of each roast vacuum packaged whole while the other half was sliced and stored under refrigeration (<38°F) for 70 days. Evaluations were performed to determine cook loss (yield), sliced vacuum package purge, Allo-Kramer shear force (tenderness), trained sensory profile panel for aromas, flavors, off-aromas/flavors, and texture, lipid oxidation (2-thiobarbituric acid, TBA), proximate analysis, colorimeter color space values and sensory panel color.

The most significant observation was that all plum treatments reduced lipid oxidation, as measured by TBA values, which could potentially minimize warmed-over flavor (WOF) in precooked beef products. Both FP levels and 2.5% DP did not affect cooking losses, but the inclusion of 5.0% DP or PP increased the percentage of cook loss in roast beef. Cooked, vacuum purge tended to be less for the plum treated samples. The roasts with plum treatments, except 5.0% PP, were slightly darker (as determined by colorimeter), but incorporation of the reddish colored DP increased redness slightly while the light pink colored FP decreased redness. Sensory panel evaluation of color with the natural eye noted only that the 2.5% FP treatment was slightly less red than the other treatments. PP inclusion caused a "brownish hue" to the meat surface. Plum treatments had minimal effects on tenderness. As expected, sensory scores indicated a barely detectable plum/prune aroma for FP and DP treated roasts, but not for PP. Inclusion of 5.0% levels of FP and DP tended to increase sweetness slightly likely due to the additional sugars in the plum materials. **Overall, these results indicate that FP or DP could be successfully incorporated into brine-injected beef roasts at a level of 2.5% with the potential benefit of reducing lipid oxidation and preventing warmed-over flavor (WOF).** Use of PP (spray dried powder) at any level is not recommended.

Hams

Fresh, boneless inside ham muscles (*Semimembranosus, Adductor*) were injected at 20% above raw weight with a brine containing fresh plum juice concentrate (FP), dried plum juice concentrate (DP) and spray dried plum powder (PP) at levels of 2.5 and 5.0%. Hams were cooked in a commercial, climate-controlled smokehouse to an internal temperature of 160°F (71.1°C), chilled and one-half of each ham vacuum packaged whole while the other half was sliced and stored under refrigeration (<38°F) for 70 days. The same evaluations as were performed on the roasts were used to evaluate injected hams.

The plum ingredients did not have the same affect on the hams as were noted for the beef roasts. There were no differences in lipid oxidation as determined by TBA values. This might be anticipated since hams contain sodium erythorbate (a salt of asborbic acid, Vitamin C) and sodium nitrite, each of which has antioxidant properties. Unexpectedly, all plum ingredients increased cook loss (decreased yield) when compared to the control. Vacuum package purge and sliced vacuum package purge were not affected by the plum ingredients. Hams with DP were slightly darker and redder when measured by coloimeter while subjective panel scores indicated that 5.0% DP enhanced redness while 5.0% PP decreased redness. Incorporation of DP from 2.5

to 5.0% increased the amount of brown off-color in the ham slices. Sensory profile scores noted that salty taste decreased with the inclusion of a 5.0% level of plum ingredients. Based on these results, inclusion of plum ingredients in cured ham is not recommended due to reductions in product yield, limited benefit in antioxidant properties and possible reduction in consumer acceptability due to a slight “off” color (brown) in the cured boneless ham.

Further research with brine injected products using fresh plum concentrate, depigmented plum concentrates and/or plum extracts is warranted due to their potential contributions as antioxidants/antimicrobials and flavor enhancers.

INTRODUCTION

Plum-derived food ingredients have been reported to function as antioxidants, antimicrobials, fat replacers, humectants, and flavorants while controlling costs in meat and poultry products. Dried plum puree contains 7.55% fiber, about 15% naturally occurring sorbitol and between 1 to 2% naturally occurring malic acid. Its fiber (half of which is pectin) helps to retain moisture, while malic acid enhances flavor and sorbitol acts as a natural humectant. Moreover, neochlorogenic and chlorogenic acids (phenolic compounds) have been reported to be the main contributors of its antioxidant properties (Donovan et al., 1998). Dried plum puree has been approved for use in the school lunch program by the USDA. Pre-cooked and frozen hamburgers containing 3 to 5% of the puree have been shown to retain more moisture (after re-heating) and were rated by students to be equal or better than hamburger products from major fast food chains (Decker, 1999). In that study, moisture retention was improved 15.8% in precooked patties reheated to 215.6ºF (102ºC) and held warm for up to 4 hours. Opportunities also exist for replacing a portion of the fat component in beef patties (Nunes, 1999). Frankfurters prepared with 3.5 to 5% dried plum puree have been reported to have 4 to 8% more moisture than all-beef frankfurters and also retain more moisture (23.7 to 47.1%) when reheated (PruneTec, 1998). When a consumer sensory panel of 175 participants evaluated frankfurters with dried plum puree, 79% rated the puree franks the same as or better than franks they had recently purchased. Overall flavor was mentioned as the most desired attribute of the franks with dried plum.

Recent work at the Agricultural Research Service’s Jean Mayer Human Nutrition Research Center on Aging at Tufts University in Boston, MA, has suggested that foods with a high ORAC (Oxygen Radical Absorbance Capacity) value (Cao et al., 1995) may reduce disease risks due to aging. Their research has shown that dried plums or prunes have the highest ORAC value (5,770) of a group of 22 fruits and vegetables (Table 1) studied (McBride, 1999; Cao et al., 1996; Wang et al., 1996). This antioxidant potential also may be useful in retarding lipid oxidation in meat products such as fresh ground beef or precooked pork sausage that may contain up to 50% fat along with substantial amounts of endogenous (iron) and added (salt) prooxidants, respectively.

ORAC values of Fruits and Vegetables with Antioxidant Potential

	ORAC Value*/100g
Fruits	
Dried Plums……………………………..	5,770
Raisins……………………………….…..	2,830
Blueberries………………………………	2,400
Blackberries……………………………....	2,036
Strawberries……………………………....	1,540
Raspberries………………………………	1,220
Plums…………………………………….	949
Oranges………………………………….	750
Red Grapes…………………………….....	739
Cherries………………………………….	670
Kiwi Fruit………………………………..	602
Grapefruit, Pink……………………….....	483
Vegetables	
Kale…………………………………….....	1770
Spinach…………………………………..…	1260
Brussels Sprouts…………………………	980
Broccoli Flowers………………………....	890
Beets……………………………………..…	840
Red Bell Pepper………………………….	710
Onion…………………………………..…	450
Corn……………………………………....	400
Eggplant………………………………….	390

*ORAC (Oxygen Radical Absorbance Capacity) measures a food's ability to subdue oxygen free radicals by comparing its absorption of peroxyl or hydroxyl radicals to that of Trolox, a water-soluble vitamin E analog.

Source: USDA Human Nutrition Research Center on Aging Tufts University, Boston.

Animal fats have predominant amounts of C16 and C18 saturated fatty acids, medium amounts of unsaturated fatty acids and small amounts of odd-numbered acids, but the proportions of these fatty acids vary with species, genetics, and diet. In general, fats become less saturated in the following species ranking lamb and beef (more saturated)> pork> poultry> fish (less saturated). The relative proportions or profile of fatty acids in representatives of these different species are shown in the following table

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Fatty Acid Composition of Meat Tissues from Porcine, Bovine, Poultry and Fish Species (composite of boneless meat tissues).

Fat Component	Bovine	Porcine	Poultry	Fish
Saturated Fatty Acids (%)				
Lauric,C_{12}	0.050	0.050	0.010	0.009
Myristic, C_{14}	0.740	0.440	0.020	0.011
Palmitic, C_{16}	5.780	7.650	0.530	0.156
Stearic, C_{18}	2.930	4.200	0.220	0.051
Total	9.500	12.340	0.780	0.227
Unsaturated Fatty Acids (%)				
Palmitoleic, $C_{16:1}$	1.150	0.990	0.120	0.025
Oleic, $C_{18:1}$	9.120	14.660	0.760	0.108
Linoleic, $C_{18:2}$	0.620	3.300	0.550	0.008
Linolenic, $C_{18:3}$	0.240	0.290	0.020	0.012
Arachidonic acid, $C_{20:4}$	0.050	0.110	0.080	0.028
Eicopentaenoic acid (EPA), $C_{20:5}$	0.010	_	0.010	0.037
Docosahexaenoic acid (DHA), $C_{22:6}$	_	_	0.030	0.181
Total	11.190	19.350	1.570	0.399

Source: USDA Nutrient Database for Standard Reference, Release 13 (1999).

Lipid oxidation is a major cause of deterioration in the quality of stored meat and meat products, and can be accelerated by several factors such as increasing degree of unsaturation, higher levels of polyunsaturated fatty acids, oxygen, heat, UV light, metal ions, oxidation of meat/heme pigments, and oxidative enzymes. Lipid oxidation results when double bonds in unsaturated (particularly the polyunsaturated) fatty acids react with molecular oxygen via a series of free radical chain reactions to produce breakdown products such as short chain acids, aldehydes and ketones (Fennema, 1996). Some of these compounds contribute to “warmed-over flavor” (WOF) in pre-cooked sausages. Whole-muscle ham is less susceptible to lipid oxidation and WOF development because of its lower fat content (in comparison to fresh pork sausage), and the presence of alkaline phosphates (metal ion chelator), spices (with antioxidant properties), sodium nitrite (highly antioxidative) and sodium erythorbate (salt of vitamin C, potentially antioxidative). Similarly, roast beef is relatively low in fat content and contains alkaline phosphate in the brine, which retards lipid and pigment (myoglobin) oxidation in raw uncooked meat (Tims and Watts, 1958).

Lipid oxidation not only produces rancid flavors in foods but also can decrease their nutritional quality and safety by the formation of secondary products after cooking and processing. Oxidative rancidity development in meat is distinguished between "normal oxidation", the oxidation of the triacyglycerol fraction, and rapid oxidation (mainly the oxidation of phospholipids) responsible for WOF development. In some non-meat foods, normal oxidation occurs during long-term storage, while the development of WOF takes place after cooking, and varies at different stages of lipid oxidation. Rancidity due to lipid oxidation also occurs readily in uncooked meat when muscle membranes are disrupted by mechanical manipulation and processing. Lipid oxidation in meat is also associated with deterioration of desirable beef flavor by formation of other flavors described as cardboardy or painty (Frankel, 1998). Precooked, uncured meat products are more susceptible to lipid oxidation and WOF development because fewer materials with antioxidant properties are added as ingredients. Therefore, additives that exhibit antioxidant properties and retard WOF would be desirable to enhance their flavor shelf-life.

Antioxidants such as butylated hydroxy anisole (BHA) and butylated hydroxy toluene (BHT) or their combination may be incorporated into uncured, ground or sausage products (fresh pork sausage, brown and serve sausages, fresh Italian sausages, pre-grilled beef patties, pizza toppings, meat balls and meat fillings), but are not typically used in brine pumped products. The Code of Federal Regulations (USDA, 1999) allows use of up to 0.01% (based on the product fat content) of a single antioxidant (BHA or BHT), or 0.02% if the two are used in combination. The maximum product fat content for fresh ground sausage is 50%, 35% for fresh Italian sausage and 30% for most other sausages. Thus, sausage products (especially precooked pork sausage) have the greatest potential for oxidative rancidity due to their high fat content, fairly high level of salt and higher amounts of polyunsaturated fatty acids in comparison to the more saturated fat in ground beef.

Rationale and Justification

Oxidative rancidity is not a significant problem in cured products due to the incorporation of sodium nitrite and sodium erythorbate which retard lipid oxidation. However, roast beef is an uncured, lean product with a high oxidation potential due to its high levels of endogenous prooxidant (iron) and membrane phospholipids. Thus, the inclusion of plum ingredients may reduce or retard lipid oxidation. Other important issues to be addressed include product functionality (juiciness and moisture retention), flavor enhancement and humectant properties that may be contributed by the plum ingredients. Based on the objectives specified in the Request for Proposal issued by the California Dried Plum Board, this study evaluated two levels (2.5 and 5.0%) of fresh plum juice concentrate (FP), dried plum juice concentrate (DP), and spray dried plum powder (PP) incorporated into beef top round roasts and cured inside ham muscles (20% brine pump).

Objectives

The overall objectives of this study were to evaluate the properties of fresh or dried plum juice concentrate and spray dried plum powder in whole-muscle, precooked meat products to:

1) Determine the functional, sensory and humectant properties of different levels of plum juice concentrate products (fresh, dried, and spray dried) in brine-injected hams and roast beef over a 10 week refrigerated storage period.
2) Quantify costs and economic benefits of plum juice concentrate ingredients in whole-muscle pre-cooked meat products.

TREATMENT VARIABLES

1. Seven fresh plum/dried plum treatments (all samples coded) -
   CTL FP 2.5% FP 5.0% DP 2.5% DP 5.0% PP 2.5 % PP 5.0%
2. Six storage treatments – 0, 2, 4, 6, 8, 10 weeks
3. Four roasts and hams per treatment combination -treatments x 6 storage times x 4 roast or hams/treatment = 168 roast or hams (total of 336)

MATERIALS AND METHODS

Beef Roast and Ham Raw Materials

Fresh, boneless, select, top rounds (*Semimembranosus, Adductor*) weighing 25 to 30 pounds (11.3 to 13.6 kg) were purchased from Ruffino Meats & Food Service in College Station, Texas. Fresh, trimmed, boneless, inside ham muscles (*Semimembranosus, Adductor*) weighing 2 to 4 pounds (0.9 to 1.8 kg) were acquired from International Trading Company in Houston, Texas. Whole, boneless top rounds were trimmed of excess fat and connective tissue and then split into equal halves to form roasts weighing 4 to 8 pounds (1.8 to 3.6 kg). Inside ham muscles had been previously trimmed and were ready for injection on arrival.

Injection

A total of 24 roasts or hams per treatment were injected with a brine solution (20% by weight or raw product). One set of roasts and hams without plum ingredient served as the control. The concentration of brine ingredients in the treated samples was the same as the control except that the fresh plum/dried plum ingredients were incorporated at either 2.5 or 5.0% on a cooked weight basis assuming a 15% cook loss. Prior to injection, roasts or hams were randomly assigned to 6 storage times within treatment according to the following scheme.

Roast or Ham Allocation by Treatment and Storage Time

	0 Weeks	2 Weeks	4 Weeks	6 Weeks	8 Weeks	10 Weeks	Total
Control	4	4	4	4	4	4	24
Plum Juice Con. 2.5 %	4	4	4	4	4	4	24
Plum Juice Con. 5.0 %	4	4	4	4	4	4	24
Dried Plum Juice Con. 2.5%	4	4	4	4	4	4	24
Dried Plum Juice Con. 5.0%	4	4	4	4	4	4	24
Spray Dried Plum Powder 2.5%	4	4	4	4	4	4	24
Spray Dried Plum Powder 5.0%	4	4	4	4	4	4	24
					Total Roast or Hams		168

Roast or hams were weighed just prior to injection to obtain a raw weight, then injected with a commercial brine injector (Inject Star, Model BI-72, Brookfield, CT) set at a 20% pump level. A formulation example is given in the following table.

Ingredients as Percentage of the Injected Product and Brine (20% Pump)

	Roast Beef		Ham Insides		
	Roast (%)	Brine (%)	Ham (%)	Brine (%)	
Salt (Culinox 999)	1.7	8.67	2.5	12.75	Morton Salt
Dextrose	0.9	4.59	0.9	4.59	
Phosphate (Brifisol 512)	0.35	1.78	0.35	1.78	B.K. Giulini Corp.
Potassium Lactate (Purasal®P HiPure 60)	3.0	15.3	3.0	15.3	Purac America
Plum/Dried Plum Conc.	2.5	12.75	2.5	12.75	
	5.0	25.5	5.0	25.5	
Sodium Nitrite (Quickcure)	—	—	0.19	0.1	
Sodium Erythorbate	—	—	0.49	0.25	
Water (Remainder)					

The brine formulation was adjusted to account for the level of plum ingredient using water as the replacement. Ingredients were added to the brine using a high speed mixer to ensure complete incorporation. Phosphate was the first ingredient added, due to its insolubility, followed by salt, then dextrose or plum material, potassium lactate, and for ham brines sodium nitrite and erythorbate. The control roasts and hams were injected with the same formulation without any plum additive. Following injection, the roasts and hams were allowed to drain to remove excess brine, then re-weighed, and pumped weights were recorded to determine the percent pump. After brine injection, roasts or hams within each treatment and injection level were vacuum tumbled for 1 hour to aid brine distribution. Following tumbling, product weights were recorded, the roasts and hams were vacuum-packaged in Cryovac® 12 in x 24 in (30.48 cm x 60.96 cm) cook-in bags (Type CN530, Product # 97725, Std. Gauge, Simpsonville, SC), re-weighed, and packaged weights were recorded.

Cooking/Chilling

Prior to cooking, roasts and hams were stored overnight in a cooler maintained at <38°F (3.3°C) to allow for color development and brine equalization. Then, the products were randomly placed on separate smoke house truck racks and a thermocouple was placed in the geometric center of a sample roast and/or ham to ensure an internal endpoint temperature of 145°F (62.8°C) for roasts and 160°F (71.1°C) for hams. Roasts and hams then were processed in separate climate controlled smokehouses (Alkar, Model 1000, DEC International Inc., Lodi, WI) using the following cooking schedule.

Smokehouse Processing Schedule

Roast Beef		Ham	
Time	**Dry Bulb**	**Time**	**Dry Bulb**
1 hrs	140°F	1 hrs	140°F
1 hrs	150°F	2 hrs	155°F
1 hrs	155°F	1 hrs	170°F
1 hrs	160°F	2-4 hrs	185°F
2-4 hrs	165°F		

Roasts and hams were processed in cook-in bags at a wet bulb setting of 0°F (-17.8°C). During cooking, roasts and hams were continuously monitored with a digital thermometer. Upon completion of the cooking cycle, the roasts and hams were cooled to <100°F (37.7°C) by showering with cold water and immediately placed in a cooler maintained at <38°F (3.3°C) for chilling according to Federal Register 1999 (Appendix B) guidelines.

Post-Cooking Processing

Chilled roasts and hams were weighed prior to opening the cook-in bags to obtain cooked, packaged weights. Individual roasts and hams were then removed from the package, drained thoroughly, and cooked meat weights and empty package weights were recorded to calculate cook loss. Cook loss was calculated as follows:

$$\text{Percent Cook Loss} = \frac{\text{Purge Weight}}{\text{Cooked Ham Weight} + \text{Purge Weight}} \times 100$$

Roasts and hams assigned to storage treatments (2, 4, 6, 8, and 10 weeks) were vacuum-packaged in Cryovac® 13 in x 26 in (33.02 cm x 66.04 cm) bags (Type BH620T, Product # 9D640, Std Gauge, Simpsonville, SC) and stored in a cooler maintained at <38°F (3.3°C) for the duration of the storage treatment period. At the end of the designated storage period, roasts and hams were split in half, sliced, and samples were taken for sliced vacuum-package purge, Allo-Kramer shear force, descriptive attribute sensory panel evaluation, color space (L*, a*, and b*) value analysis, lipid oxidation assay, and proximate analysis. From one half, two 0.28 in. (0.7 cm) thick slices were removed for sensory panel evaluation and Allo-Kramer shear force determination. From the second half, 0.1875 in. (0.48 cm) thick slices were removed to obtain a one-pound (0.45 kg) sample for vacuum-package purge assessment followed by a 0.28 in. (0.7 cm) thick slice for lipid oxidation and color analysis. All sample slices were vacuum-packaged in Cryovac® 7 in x 12 in (17.78 cm x 30.48 cm) bags (Type B540, Product # 90184, STD Gauge, Simpsonville, SC) and stored at <38°F (3.3°C) until analyses could be performed the following day. For roasts and hams assigned to the 0 week storage period, an additional 0.28 in. (0.7 cm) thick slice was removed from one half, vacuum-packaged, and frozen for proximate analysis.

Sliced Vacuum-Package Purge at 21-days Post Storage

At the end of the designated storage period, a one-pound (0.45 kg) sample of 0.125 in (0.3127 cm) slices from each roast or ham were vacuum-packaged and stored for 21 days at <38°F (3.3°C). After three weeks, each package was weighed to obtain a total package weight. Slices were then removed from the package, patted dry with a towel, and reweighed. Purge was calculated as total package weight minus package and sample weights. Percent vacuum-package purge was determined using the following formula:

$$\text{Percent Vacuum Package Purge} = \frac{\text{Purge Weight}}{\text{Sample Weight} + \text{Purge Weight}} \times 100$$

Allo-Kramer Shear Force Determination

Allo-Kramer shear force was performed using an Instron Universal Testing Machine (Model 1011, Instron Corporation, Houston, TX). A standardized specimen size (2 x 5 cm^2) was cut, weighed and placed in an Allo-Kramer shear cell attached to a load cell (500 kg) with a standard load range setting of 100 kg. Kilograms of shear force were recorded and divided by the sample weight to determine the shear force in kilograms per gram of sample.

Sensory Evaluations

A highly trained descriptive attribute sensory panel was used to evaluate cooked roast beef and ham samples for flavor, mouth feel, basic tastes, aftertastes, and texture. This panel was selected and trained according to procedures of Cross et al. (1978) and Meilgaard et al. (1987). Training prior to testing was conducted by presenting reference samples to the panel to characterize the basic attributes of cooked boneless roast beef and ham with the various fresh plum/dried plum ingredients at 0, 2.5% and 5.0% levels of addition. Roast beef samples were evaluated for flavor (beef/brothy, beef fat, grainy/cowy, soured, cardboard, painty, fishy, livery, chemical taste, serum bloody, and fresh plum/dried plum); basic tastes (salt, sour, bitter, and sweet); mouth feel (astringent, metallic, and chemical burn); and texture (springiness, juiciness, hardness, cohesiveness, and denseness) characteristics. Ham samples were evaluated for flavor (cooked pork brothy, cured lean, cured fat, soured, cardboard, painty, fishy, mature animal, chemical taste, canned meat, and fresh plum/dried plum); basic tastes (salt, sour, bitter, and sweet); mouth feel (astringent, metallic, and chemical burn); aftertaste (cured lean); and texture (springiness, juiciness, hardness, cohesiveness, and denseness) characteristics. All samples were scored using the 16 point Spectrum Universal intensity scale (Meilgaard et al., 1987) where 0 = absence of an attribute and 15 = extremely intense. Panelists evaluated 14 samples (7 samples per session, 2 sessions per day) with roast beef samples being presented during the first session due to the higher percentage of salt in the ham samples. One of four 0.28 in. (0.7 cm) thick slices was selected at random from each of the seven fresh plum/dried plum treatments, randomly ordered, cut into 1 in. (2.54 cm) squares, and presented to the trained sensory panel for evaluation.

In addition to flavor and texture, the trained sensory panelists also evaluated roast and ham samples for color. One of three remaining slices from each treatment was selected at random and displayed for subjective evaluation of color intensity, greyness, off-color, and iridescence. Panelists scored roast and ham slices for overall color using an 8-point descriptive scale (1 = grey; 8 = dark reddish pink). Using a 6-point descriptive scale panelists also scored percent surface discoloration (grey and/or brown) (1 = no surface grey color 0%, no surface brown color 0%; 6 = total surface grey color 100%, total surface brown color 100%) and iridescence (1= none 0%; 6 = very strong 100%). All samples were evaluated under standard room fluorescent lighting (Econ-o-watt F40CW/RS/EW, 34W, Philips Electronics North America, New York, NY). After color evaluation by the trained sensory panel, roast and ham slices were measured for L* (lightness), a* (redness), and b* (yellowness) color space values using a Minolta colorimeter (Model CR200, Minolta

Corporation, New Jersey). In addition to trained sensory panel samples, objective color space measurements (L*, a*, b*) were also obtained on roast and ham slices collected for lipid oxidation.

2-Thiobarbituric Acid Analysis

Lipid oxidation was determined by the thiobarbituric acid test (TBA) of Tarladgis et al. (1960) as modified by Rhee (1978). Slices from roasts and hams were homogenized in a food processor (Robot Coupe S.A., Model R6, Bagnolet, France) to create a uniform sample. Meat samples (10 g) were blended with 15 ml of distilled water and 5 ml of an antioxidant solution with 0.5% propyl gallate and 0.5% ethylenediamine tetraacetic acid. Blended samples (30 g) were combined with an additional 77.5 ml of distilled water and 2.5 ml of 4 N HCl in a Kjeldahl flask. The acidified sample was distilled and 50 ml of distillate collected. Following distillation, 5 ml of distillate was added to 5 ml of 0.02 M TBA reagent then heated in boiling water for 35 min to fully develop the color reaction. Absorbance was measured at 540 nm using an UV-visible spectrophotometer (Varian Instruments, Model Cary 300 Bio, Sugarland, TX). Results were reported as mg of malonaldehyde (MDA) per kilogram of meat and defined as TBA values.

Proximate Analysis

Percent moisture, fat, and protein were determined using AOAC (2000) methods. Slices from roasts and hams assigned to each treatment at the 0 week storage period were homogenized in a food processor (Robot Coupe S.A., Model R6, Bagnolet, France) before sampling. Percent moisture and fat were determined using the convection air-dry oven and soxhlet ether extraction methods, respectively (AOAC, 2000). Two-gram samples were placed in pre-weighed, previously dried paper thimbles and the thimble plus sample weights recorded. Samples were dried overnight at 100°C, cooled to room temperature in a desiccator, and the dried thimble plus sample weights collected. 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 16 hours, the thimbles dried overnight to remove excess ether, 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 nitrogen analyzer which vaporized samples of ~ 0.5 gram to release total nitrogen. Percent crude protein was calculated as 6.25 times the percent nitrogen.

Statistical Analysis

Roast and ham treatments were analyzed separately using the PROC GLM procedure of the Statistical Analysis System (SAS, 1995) to perform an Analysis of Variance and determine the least square means for each variable. The main effects for the model were level of ingredients (fresh plum, dried plum, plum powder) at 0, 2.5% or 5.0% of the cooked weight and storage time (0, 2, 4, 6, 8, or 10 weeks). Main effect means were compared to one another using the PDIFF option of SAS. Significance was established at $P < 0.05$. Least square means with different superscripts will be different from one another statistically. Results for the boneless beef roasts are presented in Tables 1.1 – 1.7 while results for the boneless hams are presented in Tables 2.1 – 2.7.

RESULTS AND DISCUSSION

Physical and Chemical Evaluation of Precooked Roast Beef with Plum Ingredients

Results for percent cook loss, vacuum-package purge, objective color, lipid oxidation, and tenderness of boneless, precooked, roast beef are presented in Table 1.1. Cook loss, when compared to the control, was not different ($P>0.05$) for roasts containing fresh plum juice concentrate (FP) at 2.5% and 5.0% or dried plum juice concentrate (DP) at 2.5%. However, roasts containing DP at 5.0% or spray dried plum powder (PP) at 2.5% and 5.0% had a slightly higher ($P<0.05$) percent cook loss. With an increasing level of plum material, percent cook loss increased ($P<0.05$) for roasts injected with DP and PP. The percent cook loss for roast beef injected with 2.5% DP and 5% FP tended to be less than the 2.5% FP treatment. Overall, percent cook loss of the 2.5% and 5% FP and 2.5% DP treatments would be comparable to conventionally processed beef roast.

Most refrigerated vacuum-packaged storage of whole roasts showed little or no change in percent vacuum purge loss. However, roasts injected with 2.5% DP had slightly higher ($P<0.05$) percentages of vacuum-package purge, but those with 5.0% PP were slightly lower ($P<0.05$). After 10 weeks, only the roasts with 5% PP had less purge, but also had less moisture than the control roasts. Because this particular plum treatment had the highest percent cook loss and lowest percent moisture, may explain the low 10 week purge loss value during vacuum-package storage. With greater cook loss, one would expect the vacuum-package purge during refrigerated storage to be less.

Meat product color is a significant determinate in consumer acceptance. Thus, objective color measurements were performed on boneless roast beef slices to note variations caused by the addition of plum ingredients. Injection of plum ingredients into roast beef cuts resulted in slightly darker ($P<0.05$) samples, with the exception of 5.0% PP treatment which was equivalent to the control for L* color space values. Increasing the level of FP or DP to 5.0% also decreased L* color space values or in effect made the samples slightly darker than the 2.5%

level or the control. Samples injected with FP were less red (P<0.05) while roasts with DP increased (P<0.05) in redness. The differences are noted by the respective a* color space values in Table 1.1 as compared to the control. PP was not different from the control for redness values. The a* color space values indicate that the addition 2.5 or 5.0% FP could decrease redness while inclusion of 2.5 or 5.0% DP should increase redness of boneless beef roast cuts. In addition to changes in redness, FP and DP decreased (P<0.05) yellowness or b* color space values in roast beef samples. Samples injected with PP were similar to the control for b* color space values.

Warmed-over flavor and tenderness are two important sensory factors affecting consumer acceptance of meat products. Warmed-over flavor is the result of lipid oxidation during storage of meat products. The 2-Thiobarbituric acid test (TBA) gives some indication of the magnitude of oxidation in meat tissues during refrigerated or frozen storage. As shown in Table 1.1, the addition of plum ingredients decreased (P<0.05) TBA values over storage when compared to the control. For roasts containing plum ingredients, increasing the level of ingredient tended to decrease TBA values, although not significantly (P>0.05). Only small differences in tenderness were observed as a result of the addition of plum ingredients. The 2.5% FP treatment was slightly less tender, based on Allo-Kramer shear force value, but the level of difference would not likely be detected by consumers. Other elements can affect tenderness, such as fat composition, percent moisture, muscle fiber orientation, degree of doneness, age of the animal, degree and type of connective tissue, and other external factors such as diet and genetics. **Overall, the inclusion of plum ingredients significantly reduced lipid oxidation and the potential for warmed-over flavor development in beef roasts, with a minimal effect on tenderness.**

With changes in percent cook loss, changes in percent moisture, fat, and protein would be expected (Table 1.2). Small changes in percent moisture were noted that were reflective of the cooking losses. For example, 5.0% DP and both PP treatments had significant cooking losses (Table 1.1) and also were lower (P<0.05) in percent moisture (Table 1.2) as compared to the control. Conversely, roast beef samples containing PP had a higher (P<0.05) percentage of fat and protein as compared to control samples due to the moisture loss. FP at 2.5 and 5.0% and 2.5% DP treatments had small declines in fat content. Percent protein among the FP and DP treatments was variable and likely reflected the dilution effect of the plum ingredients (i.e. 5.0% FP and 2.5% DP) retained or loss of these ingredients (2.5% FP and both PP).

Effects of Refrigerated, Vacuum-Package Storage

Changes in percent vacuum-package purge, percent sliced vacuum-package purge, objective color, lipid oxidation, and tenderness for boneless roast beef during 10 weeks of refrigerated vacuum-package storage are shown in Table 1.3. Percent cook loss did not change due to storage. However, the percentage of purge increased ($P<0.05$) after 2 to 4 weeks but remained relatively constant through 8 to 10 weeks. After 21 days, percent sliced vacuum-package purge post storage declined ($P<0.05$) as storage progressed from 0 to 6 weeks. Compared to week 0, weeks 8 and 10 sliced purge were less.

Objective color space values during refrigerated vacuum-package storage were variable since all treatments were pooled over storage. However, in general, a* color space values for redness decreased ($P<0.05$) over the 10 week storage period. Changes in lipid oxidation would be expected with extended refrigerated storage of precooked roast beef. Overall, a slight increase ($P<0.05$) in TBA values was noted from 0 to 10 weeks indicating that a slight amount of lipid oxidation occurred during storage. As shown in Table 1.1, however, all plum ingredient treatments reduced lipid oxidation. Allo-Kramer shear values for precooked roast beef declined over 8 weeks, but at week 10 it was not different from the control.

Sensory Profile Evaluation of Precooked Roast Beef with Plum Ingredients

Descriptive attribute sensory panel scores revealed only marginally detectable differences for the plum/prune aromatic and sweetness taste between roast beef samples injected with plum ingredients and the control roasts (Table 1.4). Plum/prune aromatic, although barely detected, was higher ($P<0.05$) in roasts containing both FP and DP as compared to the control, and tended to be higher in the 5.0% level as compared to the 2.5% level. Samples injected with PP were similar to the control for plum/prune aroma intensity. Sweetness taste was similar ($P>0.05$) between the control and all roast beef samples injected with plum ingredients. Increasing the level of plum material from 2.5% to 5.0% tended to increase sweetness of precooked roast beef but not significantly except for the DP.

In addition to the objective color measurements, human or subjective color observations were made as an indicator of consumer acceptability. The addition of plum ingredients to roast beef was found to slightly decrease ($P<0.05$) the redness color scores of only the 2.5% FP treatment (Table 1.5). Other roast beef samples did not ($P>0.05$) differ in red color, surface grey color, off-color (surface browning), or iridescence. Roasts injected with 2.5% PP had slightly higher ($P<0.05$) color scores than samples containing FP. Thus, injection of plum ingredients into beef had minimal affects on sensory color and appearance attributes.

Effects of Refrigerated Vacuum-Package Storage

With changes reported for purge loss, lipid oxidation, and tenderness during refrigerated vacuum-package storage, changes in flavor and texture profile might be expected (Table 1.6). Beefy/brothy and beef fat aromatics increased ($P<0.05$) through week 4 of storage, but then declined ($P<0.05$) by week 8. Other aromatics were only marginally detected. Mouth feel differences were detectable, but of such low magnitude that they would not likely affect consumer perception of the product. Saltiness was the dominant taste and was lower ($P<0.05$) for the first two weeks in storage. Sour and bitter taste scores intensified ($P<0.05$) after 4 weeks of refrigerated storage, but these were again barely detectable. After 2 weeks of refrigerated vacuum-package storage, springiness and juiciness scores increased ($P<0.05$) with little to no change reported with subsequent storage. The largest effects due to storage on sensory panel scores were noted for an increase in the beef/brothy aromatic and springiness after 2 weeks storage. Other changes were minimal. Subjective color scores of roast beef slices over the storage period were somewhat inconclusive with no definitive trends (Table 1.7).

Physical and Chemical Evaluation of Precooked Ham with Plum Ingredients

The injection of plum ingredients into boneless, cured ham muscles affected percent cook loss, objective color, and tenderness (Tabel 2.1). Incorporation of plum ingredients into precooked cured hams increased ($P<0.05$) the percentage of cook loss from 2 to 7% for all treatments and levels when compared to control hams. FP tended to increase percent cook loss with increasing level of plum ingredient while notable increases ($P<0.05$) were observed as DP and PP were increased from 2.5 to 5.0%. Even with changes in percent cook loss, the addition of various plum ingredients had no affect on vacuum-package purge nor sliced vacuum-package purge.

Cured hams traditionally have a bright pink reddish color. The addition of FP which is also pink, did not affect objective L* (lightness) color space values. However, DP, which is slightly darker red, reduced ($P<0.05$) L* (lightness) color space values or darkened ham slice color as compared to the control. PP did not affect lightness. However, incorporation of PP lightened ($P<0.05$) color values with increasing levels of the ingredient. All a* (redness) color space values were higher ($P<0.05$) for plum treatments and for higher injection levels as compared to control hams. Hams injected with DP had the greatest increase ($P<0.05$) in a* (redness) color space values but moved the color scale away from the traditional reddish pink color of cured pork. Hams containing DP or PP increased ($P<0.05$) in redness slightly, as level of material increased from 2.5 to 5.0%. Yellowness as measured by b* color space value was unaffected ($P>0.05$) by the incorporation of plum material. These results may indicate potential difficulties with consumer acceptance of the redder colored product produced with injection of DP, while FP may yield quite acceptable color.

As with beef roasts, lipid oxidation and tenderness were determined on precooked cured ham samples. Unlike the roast beef, ham is typically cured with the addition of sodium nitrite. The main purposes for the addition of sodium nitrite are to control *Clostridium botulinum* and to produce a reddish pink color. The presence of sodium nitrite also enhances flavor and inhibits lipid and pigment oxidation, thus it would be expected to have antioxidant properties and reduce TBA values as might the addition of plum ingredients. As expected, TBA values of hams injected with plum ingredients at 2.5% and 5.0% were similar ($P>0.05$) to TBA values for the control. Allo-Kramer shear force values of ham samples increased only as the level of plum ingredient was increased ($P<0.05$) from 2.5 to 5.0%. Similar to the roast beef samples, the higher percentage of moisture loss during cooking tended to increase in Allo-Kramer shear force values or reduce tenderness.

Values for percent moisture, fat, and protein for precooked ham are presented in Table 2.2. Ham samples containing 5.0% DP and PP were lower ($P<0.05$) in moisture content, while samples containing 2.5% DP were higher ($P<0.05$) as compared to the control. Since the percent cook loss was significantly higher ($P<0.05$) for the 5.0% DP and PP samples, lower percentages of moisture would be expected. With lower percentages of moisture, percent fat would normally be expected to be higher; however, percent fat was more variable possibly due to the solids retained during cooking. Different levels of solids retention would cause variations in the individual components of the proximate analysis. Ham injected with FP at 5.0% and DP at 2.5% or 5.0% had higher ($P<0.05$) levels of protein as compared to the control. Changes in percent fat and percent protein were small and likely varied in response to retained solids.

Effects of Refrigerated Vacuum-Package Storage

With increased refrigerated storage, differences were observed in percent vacuum-package purge, percent sliced vacuum-package purge, objective color, lipid oxidation, and tenderness (Table 2.3). No differences (P>0.05) were noted in cook loss for vacuum-package hams refrigerated from 0 to 10 weeks while percent vacuum-package purge increased (P<0.05) as storage progressed. After 21 days, sliced vacuum-package purge ham slices were not different except at week 6.

Objective color values during refrigerated vacuum-package storage did not change dramatically. After 6 and 10 weeks of refrigerated storage, L* (lightness) color space values increased (P<0.05) slightly while a* (redness) and b* (yellowness) color space values decreased at weeks 4 and 10.

TBA values fluctuated only slightly (up and down) over the 10 week period of refrigerated vacuum-package storage. Little to no change was observed for Allo-Kramer shear force values except at week 10 when ham samples became tougher (P<0.05).

Sensory Profile Evaluation of Precooked Ham with Plum Ingredients

Sensory panel scores revealed detectable differences between ham samples injected with plum ingredients and controls in intensity of plum/prune aromatic, salty, sour, and sweetness tastes (Table 2.4). In general, the plum/prune aromatic was at the threshold for detection in samples with plum ingredients, and increased (P<0.05) only slightly as the level of DP and PP increased from 2.5 to 5.0%. The plum/prune aromatic intensity in hams injected with 2.5% FP was not (P>0.05) different from that of the control. Salt was the dominant taste, but was less (P<0.05) in hams with a 5.0% level of plum ingredient. Sensory scores for sour taste of hams injected with plum material were not different from the control except that 5.0% PP was deemed slightly (P<0.05) less sour. Similar to plum/prune aromatic flavor, sweet taste increased (P<0.05) in hams with 5.0% material. Overall, the inclusion of 5.0% plum ingredients increased the plum/prune flavor note and sweetness taste, but decreased saltiness.

Although objective color measurements were made, human or subjective color observations are often used as an indicator of consumer acceptability. The addition of plum ingredients to ham was found to affect subjective color, off-color, and iridescence scores (Table 2.5). Compared to control hams, color intensity scores were similar (P>0.05) across plum treatments and levels of injection with the exception of hams containing 2.5% PP which were lighter (P<0.05) in color. Subjective color scores for redness were variable; 5.0% DP tended to enhance redness while 5.0% PP decreased (P<0.05) redness when compared to the 2.5% levels. Only the 2.5% PP was more (P<0.05) reddish pink than any of the other treatments or levels. DP ham samples had slightly higher (P<0.05) off-color (brown) scores as compared to all other samples, regardless of level. Increasing the level of DP from 2.5 to 5.0% also increased (P<0.05) scores for brown off-color. Iridescence scores were low overall, but ham samples containing 2.5% FP, 2.5% DP, and 5.0% PP had slightly more (P<0.05) iridescence than the control. In general, some variations in color (redness) intensity were noted, but not of sufficient magnitude to be different from the control (except for PP 2.5%). Off-color was most notable for the DP treatment and some slight increase in iridescence was observed with low levels of FP and DP and a high level of PP. These results indicate that the addition of DP to cured boneless hams may reduce consumer acceptability based on color.

Effects of Refrigerated Vacuum-Package Storage

With changes reported for moisture loss, lipid oxidation, and tenderness during refrigerated vacuum-package storage, changes in flavor and texture profile would be expected (Table 2.6). Initially cooked pork was the dominant aromatic, but by the second week, cured lean was highest. After two weeks of storage, cooked pork, chemical taste, and canned meat scores decreased (P<0.05) in intensity while cured fat and plum/prune increased (P<0.05). Sweet, and to some extent sour taste scores, increased (P<0.05) over time, but salt remained the overall dominant taste throughout storage. A stepwise increase (P<0.05) and decrease (P<0.05) was observed for cured fat and canned meat aromatic scores, respectively, during the first 4 weeks of refrigerated storage, but no further changes occurred through 8 weeks storage. No consistent pattern was observed in texture scores over the storage period and slight differences were observed on different test days. It appears that refrigerated storage of vacuum-packaged ham primarily causes a decline in cooked pork aroma and a corresponding increase in cured lean aroma. Evaluation of color intensity, grey color, off-color, and iridescence by the sensory panel noted changes in ham slices as a result of storage (Table 2.7). The most consistent observation was that ham slices tended to develop a slight (P<0.05) amount of iridescence by 8 weeks of storage.

SUMMARY AND CONCLUSIONS

Beef Roasts with Plum Ingredients

Fresh plum juice concentrate (FP), dried plum juice concentrate (DP), and spray dried plum powder (PP) were injected into top round beef roasts (*Semimembranosus, Adductor*) at levels of 2.5 and 5.0%, respectively. DP at 5.0% and PP at 2.5% and 5.0% increased the percentage of cook loss in roast beef but the other treatments were not different from the control. Cooked vacuum-package purge tended to be less in plum treated samples, but few differences were noted for sliced vacuum-package purge at 21-days post storage. All plum treatments, except 5.0% PP, caused the roast beef cuts to be slightly darker, while FP reduced redness slightly and DP increased redness when measured by Minolta colorimeter. Sensory panel evaluation of sliced roast beef noted only that the 2.5% FP was less red than the other treatments. **The most significant observation was that all plum treatments reduced lipid oxidation as measured by 2-thiobarbituric acid values (TBA) which could potentially minimize warmed-over flavor (WOF) in precooked roasts.** Plum treatments also had minimal effects on the tenderness of beef roasts as measured by Allo-Kramer shear. Sensory panel scores indicated a slight plum/prune aroma for FP and DP treated samples but not the PP. Inclusion of 5.0% FP and DP also increased sweetness slightly. **Overall, these results indicate that FP or DP could be incorporated into a brine-injected cooked roast beef product at a level of 2.5% without detrimental effects and with the potential benefit of reducing lipid oxidation and warmed-over flavor.** Use of PP (spray dried powder) at any level is not recommended due to reduced product yield.

Hams with Plum Ingredients

Fresh plum juice concentrate (FP), dried plum juice concentrate (DP), and spray dried plum powder (PP) were injected into boneless hams (*Semimembranosus, Adductor*) at levels of 2.5 and 5.0%, respectively. All plum ingredient treatments increased the percentage of cook loss in brine-injected cured hams, but did not affect the vacuum-package purge or the sliced vacuum-package purge at 21-days post storage. Hams with DP were slightly darker causing an off-color (brown) that may affect consumer acceptance. All treatments increased redness when measured by Minolta colorimeter, but the DP color was much more intense and atypical of cured ham. TBA values were not affected by any treatment and inclusion of 5.0% of each plum ingredient increased Allo-Kramer shear values (decreased tenderness). Salty taste was reduced and sweet taste increased by the inclusion of 5.0% plum ingredients. Based on these results, the inclusion of plum ingredients in cured ham is not recommended due to reductions in product yield and no perceived benefit in antioxidant properties. Further research with brine-injected products using de-pigmented fresh plum concentrate, dried plum concentrate, or plum extracts is warranted due to their potential contributions as antioxidants and/or antimicrobials.

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Table 1.1 Least squares means for percent cook loss, vacuum-package purge, sliced vacuum-package purge at 21-days post storage, L* a* b* color space values, TBA values, and Allo-Kramer shear force values of boneless roast beef.

	Percent Cook Loss[1]	Percent Vacuum-package Purge[1]	Percent Sliced Vacuum-package Purge at 21-days Post Storage[1]	Color Space Values			TBA (mg malonaldehyde/kg)[1]	Allo-Kramer Shear Force Value (kg/g sample)[1]
				L*[1]	a*[1]	b*[1]		
Control	16.60[ab]	3.04[b]	2.63[b]	54.49[c]	10.20[b]	12.22[cd]	0.621[c]	6.74[abc]
Fresh Plum Juice 2.5 %	18.18[bc]	2.50[ab]	2.48[b]	52.49[b]	9.46[a]	11.31[ab]	0.264[ab]	7.80[d]
Fresh Plum Juice 5.0 %	16.76[ab]	2.62[ab]	2.65[b]	50.76[a]	9.42[a]	11.09[ab]	0.163[a]	7.36[cd]
Dried Plum Juice 2.5 %	15.21[a]	3.96[c]	2.39[b]	52.72[b]	12.23[c]	10.93[ab]	0.389[b]	6.41[a]
Dried Plum Juice 5.0 %	19.46[c]	2.95[b]	2.89[b]	50.49[a]	11.79[c]	10.68[a]	0.306[ab]	7.20[bcd]
Spray Dried Plum Powder 2.5 %	19.80[c]	2.50[ab]	2.68[b]	52.71[b]	10.18[b]	12.48[d]	0.396[b]	6.69[ab]
Spray Dried Plum Powder 5.0 %	27.73[d]	2.16[a]	1.70[a]	53.62[bc]	10.32[b]	11.63[bc]	0.327[ab]	7.31[bcd]

[1] Std Error LSMean (%) Cook Loss = 0.689, VP Puge = (C, FP2.5, FP5.0, DP5.0, PP2.5, PP5.0 = 0.273; DP2.5 = 0.280), VP Purge 21 Day = (C, DP2.5, DP5.0, PP5.0 = 0.210; FP2.5, FP5.0, PP2.5 = 0.214), L* = (C, FP2.5, FP5.0, DP5.0, PP2.5, PP5.0 = 0.432; DP2.5 = 0.442), a* = (C, FP2.5, FP5.0, DP5.0, PP2.5, PP5.0 = 0.211; DP2.5 = 0.216), b* = (C, FP2.5, FP5.0, DP5.0, PP2.5, PP5.0 = 0.288; DP2.5 = 0.294), TBA = (C, FP2.5, FP5.0, DP5.0, PP2.5, PP5.0 = 0.0607; DP2.5 = 0.0620), Allo-Kramer = (C, FP2.5, FP5.0, DP5.0, PP2.5, PP5.0 = 0.236; DP2.5 = 0.241).

[abcd] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 2.1 Least squares means for percent cook loss, vacuum-package purge, sliced vacuum-package purge at 21-days post storage , L* a* b* color space values, TBA values, and Allo-Kramer shear force values of cured, boneless ham.

	Percent Cook Loss[1]	Percent Vacuum-package Purge[1]	Percent Sliced Vacuum-package Purge at 21-days Post Storage[1]	Color Space Values L*[1]	Color Space Values a*[1]	Color Space Values b*[1]	TBA (mg malonaldehyde/kg)[1]	Allo-Kramer Shear Force Value (kg/g sample)[1]
Control	10.58[a]	2.78	2.82	61.92[cd]	4.72[a]	12.39	0.116	4.50[ab]
Fresh Plum Juice 2.5 %	12.63[b]	2.53	2.72	61.64[cd]	6.95[c]	12.99	0.142	4.33[a]
Fresh Plum Juice 5.0 %	13.73[bc]	2.37	2.93	60.13[abc]	7.34[c]	12.69	0.114	5.25[c]
Dried Plum Juice 2.5 %	12.98[b]	2.79	3.23	59.84[ab]	10.20[d]	11.94	0.109	4.75[b]
Dried Plum Juice 5.0 %	14.79[c]	2.47	3.03	58.45[a]	11.20[e]	12.66	0.118	5.19[c]
Spray Dried Plum Powder 2.5 %	12.94[b]	2.68	2.74	61.36[bc]	5.80[b]	12.32	0.115	4.66[b]
Spray Dried Plum Powder 5.0 %	17.74[d]	2.52	2.68	63.43[d]	6.97[c]	12.62	0.140	5.20[c]

[1] Std Error LSMean (%) Cook Loss = 0.609, VP Puge = 0.159, VP Purge 21 = (C, FP5.0, DP2.5 DP5.0= 0.207; FP2.5, PP2.5, PP5.0 = 0.203), L* = 0.643, a* = 0.348, b* = 0.248, TBA = 0.0162 (C = 0.1652), Allo-Kramer = 0.114.

[abcd] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 1.3 Least squares means for percent cook loss, vacuum-package purge, sliced vacuum-package purge at 21-days post storage , L* a* b* color space values, TBA values, and Allo-Kramer shear force values of boneless roast beef.

	Percent Cook Loss[1]	Percent Vacuum-package Purge[1]	Percent Sliced Vacuum-package Purge at 21-days Post Storage[1]	Color Space Values L*[1]	a*[1]	b*[1]	TBA (mg malonaldehyde/kg)[1]	Allo-Kramer Shear Force Value (kg/g sample)[1]
Week 0	19.80		3.31[d]	52.29[bc]	11.38[c]	11.22[b]	0.202[a]	7.68[c]
Week 2	18.70	1.91[a]	2.79[cd]	53.10[c]	10.65[b]	11.89[b]	0.287[ab]	7.35[bc]
Week 4	20.29	3.27[c]	2.52[bc]	51.81[ab]	10.41[b]	10.41[a]	0.305[ab]	6.69[a]
Week 6	19.18	2.52[ab]	1.75[a]	55.30[d]	9.61[a]	11.91[b]	0.513[c]	6.88[ab]
Week 8	18.27	3.16[bc]	2.33[bc]	50.92[a]	11.33[c]	13.31[c]	0.394[bc]	6.65[a]
Week 10	18.40	3.23[c]	2.24[ab]	51.39[ab]	9.71[a]	10.12[a]	0.414[bc]	7.18[abc]

[1] Std Error LSMean (%) Cook Loss = 0.638, VP Puge = (Week 2, 4, 6, 10= 0.231; Week 8 = 0.235), VP Purge 21-day (Week 0 = 0.202; Week 2, 4, 6, 10 = 0.194; Week 8 = 0.198), L* = (Week 2, 4, 6, 10= 0.400; Week 8 = 0.408), a* = (Week 2, 4, 6, 10= 0.196; Week 8 = 0.199), b* = (Week 2, 4, 6, 10= 0.267; Week 8 = 0.271), TBA = (Week 2, 4, 6, 10= 0.0562; Week 8 = 0.0572), Allo-Kramer = (Week 2, 4, 6, 10= 0.218; Week 8 = 0.222).

[abcd] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 2.3 Least squares means for percent cook loss, vacuum-package purge, sliced vacuum-package purge at 21-days post storage , L* a* b* color space values, TBA values, and Allo-Kramer shear force values of cured, boneless ham.

	Percent Cook Loss[1]	Percent Vacuum-package Purge[1]	Percent Sliced Vacuum-package Purge at 21-days Post Storage[1]	Color Space Values			TBA (mg malonaldehyde/kg)[1]	Allo-Kramer Shear Force Value (kg/g sample)[1]
				L*[1]	a*[1]	b*[1]		
Week 0	14.25		2.89^{bc}	60.30^{ab}	8.03^{b}	13.10^{c}	0.105^{bc}	4.93^{bc}
Week 2	13.34	2.12^{a}	3.35^{c}	61.62^{bc}	7.92^{b}	13.08^{c}	0.024^{a}	4.68^{ab}
Week 4	13.12	2.46^{ab}	3.12^{c}	58.84^{a}	6.84^{a}	12.06^{b}	0.078^{b}	4.51^{a}
Week 6	13.58	2.75^{bc}	2.34^{a}	62.92^{c}	7.90^{b}	13.07^{c}	0.168^{d}	4.65^{ab}
Week 8	13.57	2.73^{bc}	3.15^{c}	60.15^{ab}	8.19^{b}	13.13^{c}	0.126^{c}	5.01^{cd}
Week 10	13.91	2.91^{c}	2.42^{ab}	61.98^{c}	6.69^{a}	10.65^{a}	0.232^{e}	5.25^{d}

[1] Std Error LSMean (%) Cook Loss = 0.564, VP Puge = 0.134, VP Purge 21 = (Week 0 = 0.195; Week 2, 8, 10 = 0.188; Week 4, 6 = 0.191), L* = 0.595, a* = 0.322, b* = 0.230, TBA = 0.0150 (Week 10 = 0.0152), Allo-Kramer = 0.106.

[abcd] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 1.4 Least squares means of descriptive attribute sensory panel scores for aromatics[1], feeling factors[1], basic tastes[1], and textures[2] of boneless roast beef.

	Control	Fresh Plum Juice 2.5 %	Fresh Plum Juice 5.0 %	Dried Plum Juice 2.5 %	Dried Plum Juice 5.0 %	Spray Dried Plum Powder 2.5 %	Spray Dried Plum Powder 5.0 %
Aromatics							
Beef/Brothy[3]	5.7	5.6	5.4	5.4	5.6	5.6	5.7
Beef Fat[3]	1.7	1.6	1.7	1.7	1.7	1.5	1.4
Chemical Taste[3]	0.8	0.8	0.9	0.8	0.8	0.8	1.0
Serum/Bloody[3]	0.1	0.1	0.1	0.0	0.1	0.1	0.1
Plum/Prune[3]	0.5[a]	1.5[bc]	2.6[d]	1.5[bc]	2.2[cd]	0.8[ab]	1.0[ab]
Mouth Feels							
Astringent[3]	2.3	2.5	2.6	2.4	2.3	2.4	2.4
Metallic[3]	2.0	2.1	2.2	1.9	2.0	1.9	2.0
Chemical Burn[3]	0.7	0.9	1.1	0.9	0.8	0.9	0.8
Basic Tastes							
Salt[3]	6.5	7.0	6.8	7.4	6.5	7.5	6.5
Sour[3]	2.3	2.2	2.5	2.4	2.3	2.0	2.2
Bitter[3]	1.8	1.6	1.9	1.9	1.6	1.7	1.7
Sweet[3]	1.5[ab]	1.5[ab]	1.8[b]	1.3[a]	1.9[b]	1.3[a]	1.5[ab]
Textures							
Springiness[3]	4.7	4.9	5.0	4.9	4.8	5.1	4.8
Juiciness[3]	4.7	4.8	4.6	4.5	4.6	5.1	4.6
Hardness[3]	5.5	5.7	5.1	5.5	5.7	5.4	5.4
Cohesiveness[3]	6.3	6.1	5.9	6.2	6.5	6.0	6.1
Denseness[3]	6.8	6.6	6.4	6.8	6.7	6.9	6.6

[1] Based on a 16-point intensity scale (0 = absence of flavor; 15 = extremely intense flavor).
[2] Based on a 15-point intensity scale (1 = not springy, dry, soft, crumbles, airy; 15 = very springy, juicy, hard, defined particle size, dense).
[3] Std Error LSMean Beef/Brothy = 0.26, Beef Fat = 0.12, Chemical Taste = 0.20, Serum/Bloody = 0.08, Plum/Prune = 0.26, Astringent = 0.12, Metallic = 0.10, Chemical Burn = 0.16, Salt = 0.35, Sour = 0.15, Bitter = 0.16, Sweet = 0.17, Springiness = 0.20, Juiciness = 0.21, Hardness = 0.21, Cohesiveness = 0.18, Denseness = 0.26.
[abcd] Means in the same row with different superscript letters are different ($P < 0.05$).

Table 2.4 Least squares means of descriptive attribute sensory panel scores for aromatics[1], feeling factors[1], basic tastes[1], and textures[2] of cured, boneless ham.

	Control	Fresh Plum Juice 2.5 %	Fresh Plum Juice 5.0 %	Dried Plum Juice 2.5 %	Dried Plum Juice 5.0 %	Spray Dried Plum Powder 2.5 %	Spray Dried Plum Powder 5.0 %
Aromatics							
Cooked Pork[3]	1.3	1.2	1.3	1.2	1.3		

Table 1.2 Least squares means for percent moisture, fat, and protein of boneless roast beef.

	Percent Moisture[1]	Percent Fat[1]	Percent Protein[1]	Percent
Control	68.24[d]	1.93[c]	25.13[c]	95.30
Fresh Plum Juice 2.5 %	68.15[d]	1.22[a]	26.96[e]	96.33
Fresh Plum Juice 5.0 %	67.37[bc]	1.46[b]	24.49[b]	93.32
Dried Plum Juice 2.5 %	68.70[e]	1.22[a]	24.07[a]	93.99
Dried Plum Juice 5.0 %	67.05[b]	1.81[c]	25.36[cd]	94.22
Spray Dried Plum Powder 2.5 %	67.56[c]	2.25[e]	25.58[d]	95.39
Spray Dried Plum Powder 5.0 %	64.85[a]	2.13[d]	27.82[f]	94.80

[1] Std Error LSMean (%) Moisture = 0.123, (%) Fat = 0.035, (%) Protein = 0.116.
[abcdef] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 2.2 Least squares means for percent moisture, fat, and protein of cured, boneless ham.

	Percent Moisture[1]	Percent Fat[1]	Percent Protein[1]	Percent
Control	70.29[c]	2.26[d]	23.82[b]	96.37
Fresh Plum Juice 2.5 %	70.62[cd]	2.57[e]	22.75[a]	95.94
Fresh Plum Juice 5.0 %	70.30[c]	0.77[a]	24.73[d]	95.80
Dried Plum Juice 2.5 %	70.84[d]	1.04[b]	24.20[c]	96.08
Dried Plum Juice 5.0 %	68.17[a]	1.47[c]	25.43[e]	95.07
Spray Dried Plum Powder 2.5 %	69.81[b]	1.09[b]	24.03[bc]	94.93
Spray Dried Plum Powder 5.0 %	68.23[a]	3.03[f]	25.39[e]	97.23

[1] Std Error LSMean (%) Moisture = 0.123, (%) Fat = 0.027, (%) Protein = 0.101.
[abcdef] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 1.5 Least squares means of descriptive attribute sensory panel scores for color[1], grey color[2], off color[3], and iridescence[4] of boneless roast beef slices.

	Color[5]	Grey Color[5]	Off Color[5]	Iridescence[5]
Control	5.8[bc]	1.9	1.7	2.5
Fresh Plum Juice 2.5 %	4.9[a]	2.6	1.6	2.3
Fresh Plum Juice 5.0 %	5.2[ab]	1.9	1.8	2.5
Dried Plum Juice 2.5 %	5.5[abc]	1.8	1.5	2.5
Dried Plum Juice 5.0 %	5.4[abc]	2.0	1.8	2.7
Spray Dried Plum Powder 2.5 %	6.0[c]	1.8	1.5	2.1
Spray Dried Plum Powder 5.0 %	5.2[ab]	2.0	1.6	2.4

[1] Based on a 8-point intensity scale (1 = grey; 8 = dark reddish pink).
[2] Based on a 6-point intensity scale (1 = no surface grey color 0%; 6 = total surface grey color 100%).
[3] Based on a 6-point intensity scale (1= no surface brown color 0%; 6 = total surface brown color 100%).
[4] Based on a 6-point intensity scale (1= none 0%; 6 = very strong 100%).
[5] Std Error LSMean Color = 0.25, Grey = 0.25, Off Color = 0.22, Iridescence = 0.22.
[abc] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 2.5 Least squares means of descriptive attribute sensory panel scores for color[1], grey color[2], off color[3], and iridescence[4] of cured, boneless ham slices.

	Color[5]	Grey Color[5]	Off Color[5]	Iridescence[5]
Control	4.4[abc]	1.3	1.5[a]	1.5[a]
Fresh Plum Juice 2.5 %	4.8[cd]	1.1	1.5[a]	2.1[bc]
Fresh Plum Juice 5.0 %	4.8[cd]	1.1	1.4[a]	1.4[a]
Dried Plum Juice 2.5 %	4.0[a]	1.6	3.0[b]	2.2[bc]
Dried Plum Juice 5.0 %	4.7[bcd]	1.4	3.9[c]	1.8[ab]
Spray Dried Plum Powder 2.5 %	5.1[d]	1.1	1.5[a]	1.5[a]
Spray Dried Plum Powder 5.0 %	4.2[ab]	1.3	1.7[a]	2.3[c]

[1] Based on a 8-point intensity scale (1 = grey; 8 = dark reddish pink).
[2] Based on a 6-point intensity scale (1 = no surface grey color 0%; 6 = total surface grey color 100%).
[3] Based on a 6-point intensity scale (1= no surface brown color 0%; 6 = total surface brown color 100%).
[4] Based on a 6-point intensity scale (1= none 0%; 6 = very strong 100%).
[5] Std Error LSMean Color = 0.19, Grey = 0.20, Off Color = 0.17, Iridescence = 0.18.
[abcd] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 1.6 Least squares means of descriptive attribute sensory panel scores for aromatics[1], feeling factors[1], basic tastes[1], and textures[2] of boneless roast beef.

	Week 0	Week 2	Week 4	Week 6	Week 8
Aromatics					
Beef/Brothy[3]	3.6[a]	6.3[c]	7.0[d]	6.5[cd]	4.6[b]
Beef Fat[3]	0.4[a]	1.6[b]	2.2[d]	1.9[c]	1.9[c]
Chemical Taste[3]	0.9[ab]	0.9[ab]	1.1[b]	0.4[a]	1.1[b]
Serum/Bloody[3]	0.4[c]	0.0[a]	0.1[b]	0.0[a]	0.0[a]
Plum/Prune[3]	1.4[ab]	1.5[bc]	1.5[abc]	0.9[a]	2.0[c]
Mouth Feels					
Astringent[3]	2.2[a]	2.3[ab]	2.7[c]	2.4[ab]	2.5[bc]
Metallic[3]	1.9[a]	2.0[ab]	2.0[ab]	1.9[a]	2.2[b]
Chemical Burn[3]	0.7[b]	0.5[ab]	1.3[c]	0.3[a]	1.7[d]
Basic Tastes					
Salt[3]	6.1[a]	6.2[a]	7.0[b]	7.9[b]	7.2[b]
Sour[3]	1.9[a]	2.1[ab]	2.5[c]	2.3[bc]	2.5[c]
Bitter[3]	1.3[a]	1.6[a]	2.1[b]	1.6[a]	2.0[b]
Sweet[3]	1.3[ab]	1.3[a]	1.7[bc]	1.5[ab]	1.9[c]
Textures					
Springiness[3]	3.1[a]	4.9[b]	5.1[bc]	5.5[cd]	5.8[d]
Juiciness[3]	4.1[a]	4.8[b]	5.1[b]	4.7[b]	4.7[b]
Hardness[3]	5.4	5.8	5.3	5.4	5.4
Cohesiveness[3]	5.9[a]	6.5[b]	6.3[ab]	6.0[a]	6.2[ab]
Denseness[3]	6.6[a]	6.6[a]	6.1[a]	6.6[a]	7.4[b]

[1] Based on a 16-point intensity scale (0 = absence of flavor; 15 = extremely intense flavor).
[2] Based on a 15-point intensity scale (1 = not springy, dry, soft, crumbles, airy; 15 = very springy, juicy, hard, defined particle size, dense).
[3] Std Error LSMean Beef/Brothy, Beef Fat, Chemical Taste, Serum/Bloody, Plum/Prune, Astringent, Metallic, Chemical Burn, Salt, Sour, Bitter, Sweet, Springiness, Juiciness, Hardness, Cohesiveness, Denseness = (Week 0, 2, 6, 8 = 0.21, 0.10, 0.17, 0.06, 0.21, 0.10, 0.08, 0.13, 0.29, 0.13, 0.14, 0.14, 0.17, 0.18, 0.18, 0.15, 0.21; Week 4 = 0.24, 0.11, 0.19, 0.07, 0.24, 0.11, 0.09, 0.15, 0.32, 0.14, 0.15, 0.15, 0.19, 0.20, 0.20, 0.16, 0.24).
[abcd] Means in the same row with different superscript letters are different ($P < 0.05$).

Table 2.6 Least squares means of descriptive attribute sensory panel scores for aromatics[1], feeling factors[1], basic tastes[1], and textures[2] of cured, boneless ham.

	Week 0	Week 2	Week 4	Week 6	Week 8
Aromatics					
Cooked Pork[3]	4.9[b]	0.4[a]	0.3[a]	0.3[a]	0.2[a]
Cured Lean[3]	3.2[b]	7.7[b]	7.5[b]	7.6[b]	7.4[b]
Cured Fat[3]	0.7[a]	1.2[b]	2.1[c]	1.9[c]	1.9[c]
Chemical Taste[3]	0.7[c]	0.1[ab]	0.2[ab]	0.0[a]	0.3[b]
Canned Meat[3]	1.5[c]	0.6[b]	0.2[a]	0.1[a]	0.3[ab]
Prune/Plum[3]	0.4[a]	0.8[abc]	0.9[bc]	0.5[ab]	1.1[c]
Mouth Feels					
Astringent[3]	2.2	2.1	2.5	2.2	2.4
Metallic[3]	1.7	1.8	1.8	1.6	1.9
Chemical Burn[3]	0.5[bc]	0.3[ab]	0.7[c]	0.1[a]	0.4[abc]
Basic Tastes					
Salt[3]	6.5	7.0	7.1	6.9	7.0
Sour[3]	1.6[a]	1.7[ab]	2.0[bc]	1.6[a]	2.0[c]
Bitter[3]	1.3[a]	1.3[a]	1.8[b]	1.4[a]	1.4[a]
Sweet[3]	1.1[a]	1.7[b]	1.7[b]	1.7[b]	1.9[b]
Cured Meat[3]	1.3[a]	2.3[b]	2.6[b]	2.4[b]	2.7[b]
Textures					
Springiness[3]	4.6[a]	5.5[bc]	5.0[ab]	5.6[cd]	6.0[d]
Juiciness[3]	4.3[a]	4.2[a]	4.9[b]	5.1[b]	4.1[a]
Hardness[3]	5.4[bc]	5.5[c]	5.4[bc]	5.1[ab]	4.8[a]
Cohesiveness[3]	6.1[bc]	6.3[cd]	6.5[d]	5.7[b]	5.3[a]
Denseness[3]	6.8[b]	6.7[b]	6.1[a]	6.0[a]	7.2[b]

[1] Based on a 16-point intensity scale (0 = absence of flavor; 15 = extremely intense flavor).
[2] Based on a 15-point intensity scale (1 = not springy, dry, soft, crumbles, airy; 15 = very springy, juicy, hard, defined particle size, dense).
[3] Std Error LSMean Cooked Pork, Cured Lean, Cured Fat, Chemical Taste, Canned Meat , Plum/Prune, Astringent, Metallic, Chemical Burn, Salt, Sour, Bitter, Sweet, Cured Meat, Springiness, Juiciness, Hardness, Cohesiveness, Denseness = (Week 0, 2, 6, 8 = 0.12, 0.17, 0.10, 0.08, 0.11, 0.16, 0.10, 0.09, 0.11, 0.21, 0.11, 0.12, 0.11, 0.14, 0.18 0.16, 0.14, 0.14; Week 4 = 0.14,0.19, 0.11, 0.09, 0.13, 0.18, 0.11, 0.10, 0.13, 0.23, 0.12, 0.14, 0.12, 0.16, 0.20, 0.18, 0.15, 0.15).
[abcd] Means in the same row with different superscript letters are different ($P < 0.05$).

Table 1.7 Least squares means of descriptive attribute sensory panel scores for color[1], grey color[2], off color[3], and iridescence[4] of boneless roast beef.

	Color[5]	Grey Color[5]	Off Color[5]	Iridescence[5]
Week 0	4.5[a]	2.5[c]	1.1[a]	2.8
Week 2	5.8[b]	1.3[a]	1.4[bc]	2.6
Week 4	5.6[b]	2.3[bc]	1.9[ab]	2.5
Week 6	5.6[b]	1.7[ab]	1.4[ab]	2.5
Week 8	5.3[b]	1.9[abc]	2.1[c]	2.0
Week 10	5.7[b]	2.5[c]	1.9[bc]	2.2

[1] Based on a 8-point intensity scale (1 = grey; 8 = dark reddish pink).
[2] Based on a 6-point intensity scale (1 = no surface grey color 0%; 6 = total surface grey color 100%).
[3] Based on a 6-point intensity scale (1= no surface brown color 0%; 6 = total surface brown color 100%).
[4] Based on a 6-point intensity scale (1= none 0%; 6 = very strong 100%).
[5] Std Error LSMean Color, Grey, Off Color, Iridescence = (Week 0, 2, 6, 8 = 0.22, 0.22, 0.19, 0.19; Week 4 = 0.24, 0.22, 0.22, 0.21; Week 10 = 0.28, 0.28, 0.25, 0.24.
[abc] Means in the same column with different superscript letters are different ($P < 0.05$).

Table 2.7 Least squares means of descriptive attribute sensory panel scores for color[1], grey color[2], off color[3], and iridescence[4] of cured, boneless ham.

	Color[5]	Grey Color[5]	Off Color[5]	Iridescence[5]
Week 0	4.5^{ab}	1.2^{b}	2.0	1.6^{ab}
Week 2	4.9^{b}	0.6^{a}	1.7	1.3^{a}
Week 4	4.8^{b}	1.2^{b}	2.4	2.2^{cd}
Week 6	4.8^{b}	1.4^{bc}	2.0	1.7^{bc}
Week 8	4.1^{a}	1.5^{bc}	2.3	2.2^{d}
Week 10	4.4^{ab}	1.9^{c}	1.9	1.9^{bcd}

[1] Based on a 8-point intensity scale (1 = grey; 8 = dark reddish pink).
[2] Based on a 6-point intensity scale (1 = no surface grey color 0%; 6 = total surface grey color 100%).
[3] Based on a 6-point intensity scale (1= no surface brown color 0%; 6 = total surface brown color 100%).
[4] Based on a 6-point intensity scale (1= none 0%; 6 = very strong 100%).
[5] Std Error LSMean Color, Grey, Off Color, Iridescence = (Week 0, 2, 6, 8 = 0.17, 0.18, 0.15, 0.16; Week 4 = 0.18, 0.20, 0.17, 0.18; Week 10 = 0.21, 0.23, 0.19, 0.21.
[abcd] Means in the same column with different superscript letters are different ($P < 0.05$).