EFFECT OF PHOSPHATE, ASCORBIC ACID AND α-TOCOPHEROL WITH THE CONTINUOUS NON-VACUUM OR VACUUM TUMBLING PROCESS ON LIPID OXIDATION OF PRECOOKED ROAST BEEF

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Background

Lipids can be oxidized by enzymatic and nonenzymatic reactions and there are many mechanisms to explain these complex reactions in meat. However, autoxidation is a continuous free-radical chain reaction and is the most important mechanism of lipid oxidation in meat (Pearson *et al*., 1983).
Synergistic antioxidants are the compounds used to improve the function of primary antioxidant and improve lipid stability in food. The functions of synergists are to regenerate the primary antioxidants, to react with oxygen (oxygen scavengers), and to chelate prooxidants (chelators) such as iron and copper (Rajalakshmi and Narasimhan, 1996). Phosphate chelates irons which act as catalysts for lipid oxidation. The antioxidative ability of vitamin E is that it acts as a free radical scavenger and a singlet oxygen quencher (Yang and Min, 1993). Ascorbic acid stabilizes lipid oxidation is due to its functions as an oxygen scavenger (Jadhav *et al*., 1996), and it is used to regenerate activity of primary antioxidants and to inactivate prooxidants (Bauernfient and Pinkert, 1970).
There are two major types of tumbling that includes vacuum and non-vacuum processing. According to tumbling schedules, Ockerman *et al*. (1978) indicated that continuous tumbling is a constant mechanical action during a short period of time from 1 to 3 hours; however, intermittent tumbling is where the tumbler works for 10-15 minutes followed by a rest period each hour for an 18-24 hours period.

Objectives

The objective of this experiment was to test if continuous vacuum or non-vacuum tumbling decreases lipid oxidation of precooked roast beef under a short tumbling period (3 hour of tumbling) after injection.

Materials and methods

Raw beef bottom rounds, which were approximately 7 days post-mortem, were purchased from a local supermarket in Columbus, Ohio. The beef round primal cuts were trimmed of visible fat and connective tissue. The water-soluble antioxidants, such as sodium tripolyphosphate and ascorbic acid, were dissolved in distilled water. The α-tocopherol, a fat soluble antioxidant, was dissolved in propylene glycol. All beef bottom rounds were cut into uniform roasts (8 x 8 x 8 dimensions). The tumbling was a continous schedule` for 3 hrs. A non-vacuum tumbler and a vacuum (Hobart, Model HVM 30, Troy, Ohio) of 15 in (381mm) Hg were drawn and the tumbler was rotated at 12 rpm in a 4°C cooler.
Moisture content (Oven Dry Method; Ockerman, 1985) was measured in a drying oven at 100°C for 18 hours. A Corning pH meter (Model 7) measured the pH values of the samples. A modified extraction of the TBARS method was used to analyze lipid oxidation (Pensel, 1990). The shear values of cooked roast beef were evaluated using a 2.54 cm core by the Warner-Bratzler (G.K. Electric Mfg. Co., Kansas) instrument (Ockerman, 1985). Total iron was followed the ferrozine assay from Stookey, 1970 and Clark *et al*, 1997. Total pigment test was measured by the modified method from Ockerman (1985). Heme iron was calculated by the modified technique of Clark et al. (1997); the iron content is calculated with the factor of 0.0882 μg/μg hematin (Merck, 1989).

Heme iron (ppm; μg/g) = total pigment (ppm; μg/g) x 0.0882
Nonheme iron of sample = Total iron content – Heme iron content

Total aerobic, psychrotrophic, and thermophilic bacteria tests were utilized to detect contamination of various bacteria in precooked roast beef. Total aerobic plate count was evaluated using aerobic plate count (APC; Difco Laboratory, Detroit, MI) agar at an incubation temperature of 25°C for 4 days (Speck, 1984). Psychrotrophic bacteria were tested using APC agar at 4°C for 10 days and also "thermophiles" were determined on APC agar at 35°C for 48 hours. The number of bacteria was converted to $\log_{10}$ colony forming units per gram ($\log_{10}$CFU/g).

The control treatment was a non-injected roast beef.
PAT (phosphate, ascorbic acid and tocopherol) was a roast beef injected (based on cooked meat weight) with sodium tripolyphosphate (0.5%), ascorbic acid (550ppm) and α-tocopherol (200ppm).
PATT(phosphate, ascorbic acid, tocopherol and nonvacuum tumbling) was a 3 hr non-vacuum tumbled roast beef injected (based on cooked meat weight) with sodium tripolyphosphate (0.5%), ascorbic acid (550ppm) and α-tocopherol (200ppm).
PATV (phosphate, ascorbic acid, tocopherol and vacuum tumbling) was a 3 hr-vacuum tumbled roast beef injected (based on cooked meat weight) with sodium tripolyphosphate (0.5%), ascorbic acid (550ppm) and α-tocopherol (200ppm).

Results and discussion

There was a significant difference due to treatment for yield. The non-injected (control) roast beef had significantly lower cooking yield than injected treatments probably due to no added phosphate in the control; however, injected roast beef with or without tumbling had the same cooking yield (Table 1). There was no significant difference between the vacuum tumbled roast beef and the non-vacuum tumbled samples. Basically, nontumbling, continuous non-vacuum, or vacuum tumbling (3 hr) with three antioxidants (tocopherol, ascorbic acid and sodium tripolyphosphate) increased cooking yield, but there was a non-significant difference when non-vacuum was compared with vacuum tumbling.
There was no significant difference of psychrotrophs, mesophile or thermophile among treatments (Table 1). For cooked roast beef, the numbers for total plate counts were relative low.
For moisture, there was no significant treatment-time interaction for the roast beef samples. The control, noninjected treatment, had significantly lower moisture due to non-liquid injection compared to other treatments that all had the same values (Table 2). Increase in water-holding capacity with phosphate is due to the unfolding of the three dimensional protein network by the high ionic strength that causes the muscle to swell and the protein to solublize and to retain water before heating (Torley *et al*., 2000). During refrigerated storage, the moisture content was decreased significantly over time as would be expected.
For TBARS, there was a significant interaction due to treatment and storage time. The control (non-injected roast beef) had significantly higher TBARS value than other treatments at all measurement days (Table 3). During refrigerated storage, samples with three antioxidants maintained stable lipid oxidation up to day 14. However, the control significantly increased its TBARS value at day 14 compared to day 0. There was no significant difference of TBARS values among non-tumbled, non-vacuum tumbled and vacuum tumbled samples. Vacuum is used to retard oxygen that attacks muscle but did not significantly decrease lipid oxidation in this study. The reason could be it only prevents oxygen that contacts the surface of whole muscle while tumbling. Also, vacuum tumbling could cause more disruption of the cell membrane of muscle compared to non-vacuum tumbling.
For pH, there was no significant two-way interaction (treatment x storage time). The control had significantly lower pH value compared to other treatments (Table 2). It appears that the 0.5% sodium tripolyphosphate increased pH values in roast beef (Table 2). The antioxidative functions of alkaline phosphates are to increase the pH and ionic strength and tie up some prooxidants (Trout and Schmidt, 1984). There was no significant difference between non-tumbled, non-vacuum and vacuum tumbling treatments in pH values. There was no consistent change in pH values during the storage period
For shear values, there was no significant treatment x storage day interaction. The control and non-tumbled treatments had significantly higher shear values (tougher) when compared to non-vacuum and vacuum tumbled samples (Table 2). The increased tenderness is a primary function of the tumbling process along with increasing uniformity (Krause *et al*., 1978). The tumbling process did increase tenderness of precooked roast beef during 14-day refrigerated storage. The shear values of all samples had significantly ($p<0.05$) higher values at day 14 than day 0.
There was no significant treatment x storage day interaction and main effects (treatment and time) of total iron (Table 2). For heme iron, there was a treatment-time interaction for roast beef. There was no significant difference of heme iron among treatments at day 0 (Table 4). The vacuum tumbled treatment had the lowest heme iron at day 2, but it was the same as the control. There was no significant difference of heme iron among treatments at day 7 and 14. However, there was no treatment x storage day interaction for nonheme iron. The nonheme iron contents of the control had a significantly higher value than that of non-vacuum tumbled roast beef (Table 2). At day 7 and 14, nonheme iron content significantly increased comparing to those at 0, 2 and 4. According to this result, nonheme iron content was increased during storage.

Conclusions

There was no significant difference among non-tumbled, non-vacuum tumbled and vacuum tumbled samples for lipid oxidation. The vacuum tumbling only prevented oxygen from coming in contact with the surface of whole muscle; therefore, it was not significant in decreasing lipid oxidation compared to non-vacuum tumbling.

References

Bauernfeind, J.C. and Pinkert, D.M. 1970. Food processing with added ascorbic acid. Advances in Food Research 18:219-315.

Clark, E.M., Mahoney, A.W., and Carpenter, C.E. 1997. Heme and total iron in ready-to-eat chicken. J. Agric. Food Chem. 45: 124-126.

Jadhav, S.J., Nimbalkar, S.S., Kulkarni, A.D., and Madhavi, D.l. 1996. Lipid oxidation in biological and food. In"Food Antioxidants" ed. by Madhavi, D.L., Deshpande, S.S., and Salunkhe, D.K. Marcel Dekker, Inc., New York.

Krause, R.J., Ockerman, H.W., Krol, B., Moerman, P.C., and Plimpton, R.F. 1978. Influence of tumbling, tumbling time, trim and sodium tripolyphosphate on quality and yield of cured hams. J. Food Sci. 43:853-855.

Merck, Index, An encyclopedia of chemicals, drugs, and biologicals. 1989. 11th ed., Merck and Company: Rahway, NJ.

Ockerman, H.W. 1985. Quality control of Post-Mortem Muscle Tissue. Dept. of Animal Sciences, The Ohio State University, Columbus, OH.

Ockerman, H.W., Plimpton, R.F., Cahill, V.R., and Parrett, N.A. 1978. Influence of short term tumbling, salt and phosphate on cured canned pork. J. Food Sci. 43:878-881.

Pearson, A. M., Gray, J. I., Wolzak, A. M., and Horenstein, N. A. 1983. Safety implications of oxidized lipids in muscle foods. Food Technol. 37, 121-129.

Pensel, N.A. 1990. Influence of experimental conditions on porcine muscle and its effect on oxidation. A thesis, The Ohio State University, Columbus, OH.

Rajalakshmi, D. and Narasimhan, S. 1996. Food antioxidants; sources and methods of evaluation. In “Food antioxidants: technological, toxicological, and health perspectives. Ed. by Madhavi, D.L., Deshpande, S.S., and Salunkhe, D.K. Marcel Dekker, Inc., NY.

Speck, M.L. 1984. “Compendium of methods for the microbiological examination of foods” 2nd edition by American Health Association Inc., Washington, D.C.

Stookey, L.L. 1970. Ferrozine- a new spectrophotometric reagent for iron. Anal. Chem. 42: 779-781.

Torley, P.J., Arcy, B.R., and Trout, G.R. 2000. The effect of ionic strength, polyphosphates type, pH, cooking temperature and preblending on the functional properties of normal and pale, soft, exudative (PSE) pork. Meat Sci. 55:451-462.

Trout, G.R. and Schmidt, G.R. 1984. The effect of phosphate type and concentration, salt level and method of preparation on binding in beef rolls. J. Food Sci. 49: 687-694.

Yang, W.T. and Min, D.B. 1993. Chemistry of singlet oxygen oxidation of foods, *In Lipids in Food Flavors, Ho, C. and Hartman, T.G. edited*. 15-29.

Table 1 Effect of phosphate, ascorbic acid and tocopherol with noninjected, nontumbled, continuous non-vacuum or vacuum tumbling on yield, psychrophile, mesophile and thermophile of roast beef

	Treatments			
	T1 Control	T2 PAT%	T3 PATT	T4 PATV
Yield %[1]	59.52[B] (1.10)	63.46[A] (1.74)	64.98[A] (0.97)	64.22[A] (1.79)
TPC7[2] (log_{10}CFU/g)	1.7 (0.2)	0.9 (1.2)	1.5 (1.0)	1.7 (1.1)
TPC25[2] (log_{10}CFU/g)	1.9 (0.4)	0.9 (1.1)	1.1 (0.8)	1.9 (0.3)
TPC35[2] (log_{10}CFU/g)	1.5 (1.0)	0.9 (1.1)	2.1 (0.3)	1.7 (1.1)

Treatments:
Control= non-injected roast beef
PAT= roast beef injected with sodium tripolyphosphate (0.5%), ascorbic acid (550ppm) and α-tocopherol (200ppm)
PATT= 3 hr-nonvacuum tumbled roast beef injected with sodium tripolyphosphate (0.5%), ascorbic acid (550ppm) and α-tocopherol (200ppm)
PATV= 3 hr-vacuum tumbled roast beef injected with sodium tripolyphosphate (0.5%), ascorbic acid (550ppm) and α-tocopherol (200ppm)
[1] Yield= cooked/fresh meat at day 0
[2] Total plate counts was incubated at 7°C for psychrotrophile, 25°C for mesophile and 35°C for thermophile at day 14, expressed as log_{10} CFU/g.
[AB] Means with different uppercase superscripts within the same row are significantly different ($p<0.05$)

Table 2 Main effect of moisture, pH values, shear values, total iron and nonheme iron of roast beef with different treatments during refrigerated storage

Main effect / Treatment	Moisture	pH	Shear values (Kg)	Total iron (μg/g)	Nonheme iron (μg/g)
T1: Control	51.80[B]	5.77[B]	4.74[A]	52.23	26.50[A]
T2: PAT	53.38[A]	5.92[A]	4.57[A]	49.46	22.48[AB]
T3: PATT	54.76[A]	5.97[A]	3.70[B]	48.46	21.86[B]
T4: PATV	53.66[A]	5.96[A]	3.57[B]	50.48	24.26[AB]
Time					
0	56.01[a]	5.96[a]	3.54[b]	50.37	21.73[b]
2	55.19[ab]	5.87[b]	3.85[b]	49.55	20.05[b]
4	54.09[b]	5.91[ab]	4.14[ab]	48.62	22.04[b]
7	52.12[c]	5.87[b]	4.19[ab]	50.06	27.44[a]
14	49.68[d]	5.92[ab]	5.02[a]	52.19	27.67[a]

[AB] Means with different uppercase superscripts within a column, within main effect of treatment are significantly different ($p<0.05$)
[abcd] Means with different lowercase superscripts within a column, within main effect of time are significantly different ($p<0.05$)

Table 3 Means and standard deviations of TBARS values (mg of malonaldehyde /kg of muscle) of roast beef with different treatments during refrigerated storage

	Storage Days				
Treatments	0	2	4	7	14
T1: Control	0.35^{C}	0.38^{C}	0.71^{B}	0.94^{A}	1.00^{A}
	(0.05)	(0.05)	(0.05)	(0.30)	(0.10)
T2: PAT	0.19^{D}	0.22^{D}	0.21^{D}	0.24^{D}	0.20^{D}
	(0.06)	(0.05)	(0.06)	(0.06)	(0.04)
T3: PATT	0.20^{D}	0.16^{D}	0.17^{D}	0.22^{D}	0.25^{D}
	(0.07)	(0.06)	(0.04)	(0.03)	(0.03)
T4: PATV	0.22^{D}	0.20^{D}	0.20^{D}	0.24^{D}	0.21^{D}
	(0.06)	(0.05)	(0.04)	(0.05)	(0.04)

^{ABCD} All means with different uppercase superscripts are significantly different ($p<0.05$)

Table 4 Means and standard deviations of heme iron (μg/g) of roast beef with different treatments during refrigerated storage

	Storage Days				
Treatments	0	2	4	7	14
T1: Control	29.39^{ABCD}	29.54^{ABCD}	24.74^{DEFG}	21.74^{G}	23.24^{FG}
	(2.73)	(2.04)	(3.44)	(3.88)	(2.26)
T2: PAT	29.39^{ABCD}	31.94^{A}	29.84^{ABC}	21.07^{G}	22.64^{FG}
	(4.52)	(1.33)	(1.02)	(2.63)	(1.86)
T3: PATT	27.44^{ABCDEF}	31.64^{AB}	24.14^{EFG}	24.29^{EFG}	25.49^{CDEFG}
	(4.88)	(3.41)	(2.37)	(4.55)	(2.42)
T4: PATV	28.34^{ABCDE}	24.89^{CDEFG}	27.59^{ABCDEF}	23.39^{EFG}	26.91^{BCDEF}
	(2.99)	(3.55)	(1.77)	(2.02)	(1.87)

^{ABCDEFG} All means with different uppercase superscripts are significantly different ($p<0.05$)