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Reduction in lipid oxidation by incorporation of encapsulated sodium tripolyphosphate in ground turkey

Marsha L. Sickler [a,b], James R. Claus [a,b,*], Norman G. Marriott [a,b], William N. Eigel [a,b], Hengjian Wang [a,b]

[a] Department of Animal Sciences, University of Wisconsin-Madison, Meat Science and Muscle Biology Laboratory, 1805 Linden Drive, Madison, WI 53706, USA
[b] Department of Food Science, Virginia Tech, Blacksburg, VA 24061, USA

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ABSTRACT

Ground turkey, with 1% NaCl, was incorporated with no sodium tripolyphosphate (control, nSTP), unencapsulated STP (uSTP; 0.3% or 0.5%), encapsulated STP (eSTP; 0.3% or 0.5% active, phosphate basis), or a blend (0.3% uSTP plus 0.2% eSTP). Encapsulate (hydrogenated vegetable oil) was designed to melt at 74 °C. Treatments were stored (4, 24 h at 3 °C) before being cooked to two different endpoints (EPT; 74, 79 °C) followed by post-cooked storage (0, 5, 10 days). An improvement of 77% (0.3% eSTP) and 80% (0.5% eSTP) in the reduction of TBARS was found in comparison to corresponding uSTP. The blend produced a 62% improvement compared to uSTP (0.5%) while maintaining cook yield. CIE a* values were highest at both EPT and post-cooked storage times beyond 0 day for eSTP. Meat manufacturing procedures that entail a delayed thermal processing step will benefit by an improvement in lipid oxidation control through the use of encapsulated phosphates.

1. Introduction

Health conscious consumers prefer to have meals which contain a higher percentage of unsaturated fatty acids than saturated fatty acids. Unfortunately, these unsaturated fatty acids are highly susceptible to lipid oxidation (Dugan, 1987). For every additional double bond in an unsaturated fatty acid, the oxidation rate increases by a factor of two (Moerck & Ball, 1974). Poultry meat contains a relatively high amount of unsaturated fatty acids, thus, being highly oxidative in comparison with other meats (Dawson & Gartner, 1983). Therefore, a means to reduce the level of lipid oxidation is extremely beneficial to the food industry.

Natural antioxidants, synthetic antioxidants, and chelators are used to aid in controlling oxidation. Although these contribute to controlling lipid oxidation, Dziezak (1990) indicated that phosphates are predominately used in the meat industry. Phosphates have the capability to chelate free metals (Tims & Watts, 1958), increase pH (Miller, David, Seideman, Ramsey, & Rolan, 1986), reduce phosphatase activity (McComb, Bowers, & Posen, 1979), and increase water-holding capacity (Claus, Colby, & Flick, 1994). Phosphates are known to reduce oxidation and the amount added influences effectiveness. Ang and Young (1989) found that 0.5% STP was more beneficial in the reduction of oxidation in broiler breast patties than 0.2% STP. However, hydrolysis of polyphosphates occurs before thermal processing which alters phosphate functionality (Sutton, 1973) and shortens chain length. Sofos (1986) reported that the best sequestering agents are long-chain polyphosphates. About 80% of added polyphosphate is lost by the time meat is cooked due phosphatase activity (Decker & Mei, 1996). Given an incorporation level of 0.5% (legal limit) suggests that only 0.10% polyphosphate (meat weight basis) remains after cooking. Furthermore Li, Bowers, Craig, and Perng (1993) demonstrated that 100% of STP was lost after one day of incorporation in raw turkey. Decker and Mei (1996) found that an improvement in controlling oxidation during storage was achieved if after cooking sodium tripolyphosphate was added. Unfortunately, the addition of phosphates after cooking is not feasible for the meat industry due to food safety issues and inefficiency in production.

Non-meat ingredients can be encapsulated (coated) with a hydrogenated vegetable oil. Encapsulation of selected phosphates known for their strong antioxidative properties could be potentially beneficial by protecting the phosphates from the phosphatases during raw meat storage and the initial stages of cooking (Sickler, 2000). This protection could provide time for some of the heat sensitive phosphatases to be inactivated prior to the release of the phosphate. Phosphatase activity can be greatly reduced by thermal processing (Kuda, Tsuda, & Yano, 2004). Sickler, Claus, Marriott, Eigel, and Wang (2013) incorporated encapsulated phosphates into ground beef but cooked the patties immediately. Results demonstrated limited improvement in lipid oxidation associated with encapsulation. However, extended contact time of encapsulated phosphates in raw meat has not been published. Therefore, the objective of this research was to determine the effect of various levels of encapsulated and unencapsulated phosphates (0.3%, and

* Corresponding author at: Department of Animal Sciences, University of Wisconsin-Madison, Meat Science and Muscle Biology Laboratory, 1805 Linden Drive, Madison, WI 53706, U.S.A. Tel.: +1 608 262 0875; fax: +1 608 265 3110.
E-mail address: clausjr@ansci.wisc.edu (J.R. Claus).

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0.5%, active phosphate basis) on the development of lipid oxidation during storage (0, 5, 10 days), cooking loss, color, and pH. The significance of storage time before cooking (4, 24 h) and endpoint temperature (74, 79 °C) was determined.

2. Materials and methods

2.1. Phosphate encapsulation

Sodium tripolyphosphate (STP) was provided by Rhodia Co. (Cranbury, NJ). STP was encapsulated by Balchem Inc. (Slate Hill, NY). Phosphate was encapsulated with hydrogenated vegetable oil designed to release the phosphate once the temperature reaches 74 °C. The encapsulated ingredients were composed of 51.1-g active phosphate and 48.9-g encapsulating oil. The amount of pure phosphate added to the meat is referred to as active.

2.2. Formulation and processing

Fresh, boneless, skinless tom turkey breast muscles (*pectoralis major*) were obtained from a Virginia producer immediately following slaughter and stored at a temperature of 3 °C. After 24 h, the turkey breasts were cut into strips and coarse ground (Model 4532, Hobart Manufacturing Co., Troy, OH) through a 12.7-mm plate and then a 4.8-mm plate. The turkey was mixed for one minute in a bowl mixer with a dough hook attachment (Model A-200, Hobart Manufacturing Co., Troy, OH) between grinding. All treatments consisted of 1% NaCl (meat weight basis), 400 g of ground turkey, and one of the following: no STP (control, nSTP), unencapsulated STP (uSTP; 0.3% or 0.5%), encapsulated STP (eSTP; 0.3% or 0.5% active), or a blend of unencapsulated (0.3%) and encapsulated (0.2% active) phosphate. Samples were mixed for 2 min with the ingredients at speed 1 using a hand mixer (Model KHM3WH-1, Kitchen Aid, St. Joseph, MI). The turkey was then stored in an unsealed bag (20.3 × 35.6 cm, Product code 90053, Cryovac Division W.R. Grace & Co., Duncan, SC) at a temperature of 3 °C in the dark. Storage time between the addition of the phosphates and cooking was 4 or 24 h.

The samples were cooked via sous vide method using a custom built circulating water bath (Virginia Polytechnic Institute and State University). Two sets of the six treatments (three centrifuge tubes per treatment) were cooked to an end point temperature of 74 °C or 79 °C. Each tube (50-mL 28 × 15 mm polypropylene tubes with screw plug seal, #05-539-9, Fisher Scientific, Pittsburgh, PA) contained a 45-g sample. The internal temperature was measured by four samples containing thermocouples attached to a datalogger (Model 5100, Electronic Controls Design, Milwaukie, OR). The thermocouples were placed in four tubes, which were distributed randomly throughout the other samples. The thermocouple wire was placed at the center of the sample. The cooked samples were ground at speed 2 through a 4.8-mm plate (Model K45SS Kitchen Aid™ Classic Mixer, Kitchen Aid Inc., St. Joseph, MI) after cooking loss was determined. The cooked, ground turkey samples were then stored at 3 °C in the dark until analyzed on days 0, 5, and 10.

2.3. pH

The pH of the cooked ground turkey was measured (Model 340, pH meter, Corning Inc., Corning, NY) by placing 5 g of meat into a beaker and homogenizing at a speed of 40% (Virtishear 225318, The Virtis Company Inc., Gardiner, NY) for 1 min with 50-mL distilled water. The pH was measured for cooked ground turkey on 0, 5, and 10 days.

2.4. Cooking loss

The cooking loss was determined by the equation: Cooking loss = (wt of raw turkey − wt of cooked turkey)/(wt of raw turkey) ∗ 100. The cooked weight was determined after the turkey was cooled to approximately 25 °C. The cooked turkey (meat plug) was removed from the centrifuge tube and patted dry with paper towels in order to absorb excess exudate.

2.5. Thiobarbituric acid reactive substances (TBARS) determination

TBARS determination (modification of Spanier & Traylor, 1991) on a 5-g sample in triplicate was homogenized in a 250-mL beaker with 40 mL of distilled water, 0.1 mL of 10% sodium dodecyl sulfate (SDS), and 10 mL of solution III (0.05-g propylgallate and 0.10-g ethylenediaminetetraacetic acid, EDTA, dissolved 500-mL distilled water). A Macro Ultrafine generator (Virtishear 225318, The Virtis Company Inc., Gardiner, NY) at a speed setting of 40% for one minute was used for homogenization. The homogenate volume was increased to 100 mL with distilled water and rehomogenized. All homogenates were maintained in an ice slush. A mixture of 0.8 mL of homogenate with 3.2 mL of solution I (0.375% TBA, 0.506% SDS, and 11.7% of 80% acetic acid for a final volume of 100 mL, diluted with distilled water) with a final pH of 3.4 was placed into a centrifuge tube. Spanier and Traylor (1991) used 0.4 mL of homogenate and 1.6 mL of solution I. These volumes were doubled to scale up to the available equipment. The centrifuge tube was placed into a 95 °C water bath (Model 10-L, Fisher Scientific, Pittsburgh, PA) for 60 min. Samples were shaken every 15 min throughout heating. The tubes were then cooled in tap water to room temperature. After cooling, 1 mL (modified from 0.5 mL, Spanier & Traylor, 1991) of 4 °C distilled water and 5 mL (modified from 2.5 mL, Spanier & Traylor, 1991) of solution II (1:15 ratio of pyridine to n-butanol) was added to the centrifuge tube and vortexed (Model G560, Vortex Genie 2, Scientific Industries Inc., Bohemia, NY) at maximum speed for 10 s. The samples were centrifuged (Model PR-2, International Portable Refrigerated Centrifuge, International Equipment Company, Boston, MA) at room temperature (25 °C) at 2180 ×*g* for 15 min. The organic layer, located at the top of the tube, was then pipetted into a cuvette. Absorbance of the sample was measured at 532 nm (Model Spectronic 21D, Milton Roy Company, Rochester, NY).

A standard curve was obtained by pipetting 1 mL of 5-mM tetramethoxypropane (TMP) into a test tube with 9-mL distilled water. Five standards of 0, 0.5, 1.0, 1.5, and 2.0 mL of 0.05-mM standard TMP solutions were made. The standards were treated as samples above with the absence of homogenization.

2.6. Instrumental color determination

The samples were analyzed for CIE L*a*b* readings immediately after cooking loss was determined by using a chroma meter (Model CR-200; 8 mm diameter measuring area, observer angle 0°, illuminant C; Minolta Corp., Osaka, Japan). Once cooking loss was determined,

Table 1
Means[1] for various physical and chemical traits in cooked ground turkey breast.

Treatments[2]	Cooking loss (%)	pH	TBARS (mg/kg)	CIE values		
				L*	a*	b*
Control	16.8^{a}	6.09^{c}	12.50^{a}	76.5^{a}	1.50^{b}	16.1^{a}
Unencap STP, 0.3%	15.3^{ab}	6.25^{b}	11.73^{a}	75.3^{ab}	1.75^{b}	16.1^{a}
Unencap STP, 0.5%	13.3^{b}	6.32^{a}	9.66^{b}	74.7^{b}	1.97^{b}	15.9^{a}
Encap STP, 0.3%	15.8^{ab}	6.27^{b}	2.61^{cd}	75.4^{ab}	3.37^{a}	15.6^{a}
Encap STP, 0.5%	14.6^{b}	6.33^{a}	1.97^{d}	74.6^{b}	3.66^{a}	15.6^{a}
Unencap, 0.3% & Encap, 0.2%	13.6^{b}	6.34^{a}	3.62^{c}	74.1^{b}	3.38^{a}	15.8^{a}
Standard Error	0.49	0.01	0.37	0.39	0.16	0.25

[1]Means were pooled over pre-storage time (4 h, 24 h), endpoint temperature (74 °C, 79 °C), and post-storage (0, 5, 10 days).
[2]Percentage of phosphate represents amount of pure phosphate added to product on a meat weight basis.
$^{a–d}$ Means bearing unlike superscripts within each trait are different ($P < 0.05$).