# EFFECTS OF DIFFERENT END-POINT COOKING TEMPERATURES ON THE EFFICIENCY OF ENCAPSULATED PHOSPHATES ON LIPID OXIDATION INHIBITION IN GROUND MEAT

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**Abstract – Effects of 0.5% encapsulated (e) phosphates (sodium tripolyphosphate, STP; sodium hexametaphosphate, HMP; sodium pyrophosphate, SPP) on lipid oxidation during storage (0, 1, 7 d) of ground meat (chicken, beef) after being cooked to three end-point cooking temperatures (EPCT; 71, 74, 77 °C) were evaluated. The use of STP or eSTP resulted in lower ($p<0.05$) cooking loss (CL) compared to encapsulated or unencapsulated forms of HMP and SPP. Increasing EPCT led to a significant increase in CL ($p<0.05$). Both STP and eSTP increased pH, whereas SPP and eSPP decreased pH ($p<0.05$). The higher orthophosphate (OP) was obtained with STP or SPP compared to their encapsulated counterparts ($p<0.05$). The lowest OP was determined in samples with HMP or eHMP ($p<0.05$). A 77 °C EPCT resulted in lower OP in chicken compared to 74 and 71°C ($p<0.05$), dissimilar to beef, where EPCT did not affect OP. In encapsulated or unencapsulated form, using STP and SPP enhanced reduction in TBARS and lipid hydroperoxides (LPO) compared with HMP ($p<0.05$). Regardless of the phosphate type, more effective lipid oxidation inhibition was achieved by the use of encapsulated forms ($p<0.05$). Increasing EPCT resulted in lower TBARS in beef and higher LPO values in both beef and chicken samples ($p<0.05$).**

**Key Words – Encapsulated phosphate, end-point cooking temperature, lipid oxidation.**

## I. INTRODUCTION

Lipid oxidation is a primary cause of quality deterioration that negatively influences acceptability of ready-to-eat-meat (RTE) products. Oxidation results in discoloration, drip losses, off-odor and off-flavor developments, texture defects, loss of nutrient value, and the production of toxic compounds [1]. Deterioration in RTE products associated with oxidation is strongly enhanced during storage leading to the loss of marketing and consumer acceptance of these products. Phosphates have very strong antioxidant effects against oxidation of lipids in cooked meat products during storage by binding metal ions that act as catalysts for oxidation. However, the ability to inhibit lipid oxidation by added phosphates in cooked meat products is reduced by phosphatases, which are typically found in red meat and poultry [2]. Even though phosphatase activity is greatly reduced by cooking, most of the added phosphates are lost by the time meat is cooked due to phosphatase activity in meat systems [3]. It was previously proven that encapsulation technology can also be applied to polyphosphates to protect them from phosphatases in order to accomplish more effective lipid oxidation inhibition in muscle foods [4]. However, the effect of end-point cooking temperature on the effectiveness of antioxidant properties of phosphates was not addressed in this studiy. It is important to find the appropriate end-point cooking temperature to further optimize the antioxidant potential of the encapsulated polyphosphates in the storage of cooked ground muscle foods.

## II. MATERIALS AND METHODS

Fresh skinless, boneless broiler chicken breast meat (*Musculus superficiolis*) and beef (*Musculus longissimus dorsi*) cattle were obtained from a local slaughterhouse for each of two replications on separate production days. The meat was ground. All treatments contained 1.0% sodium chloride and 10% added distilled water (meat weight basis). Ground meat was formulated to contain 0.5% encapsulated phosphate (phosphate weight basis) with 30% coating level and 68 °C melting release points of encapsulation in the hydrogenated

vegetable oil. The three phosphates used (STP; HMP; SPP) were obtained from a commercial supplier. Encapsulation was accomplished by a commercial coating company (Coating Place Inc., Verona, WI, U.S.A). A commercially available hydrogenated vegetable oil was selected to achieve the desired melting release point.

Ground meat samples from each species were cooked in capped plastic centrifuge tubes (50 mL) eight hours after the phosphate was added. Approximately 45 g of ground meat was placed into each tube and heat processed in a water bath. After the tubes had been loaded, the water bath setting was changed to 85 °C. Samples were cooked to three end-point temperatures (71, 74 and 77 °C). Cooked samples were stored in tubes (0, 1, 7 days) in refrigeration (4 °C) after decanting of the cookout liquid. Samples were subjected to pH, cooking loss, soluble orthophosphates, TBARS and lipid hydroperoxides analysis.

## III. RESULTS AND DISCUSSION

### *pH*

The results of pH analysis illustrated that samples formulated with eSTP (5.94 ± 0.006 in beef, 6.22 ± 0.005 in chicken, mean ± std error) or STP (5.92 in beef, 6.22 in chicken) had higher and eSPP (5.60 in beef, 5.83 in chicken) or SPP (5.63 in beef, 5.93 in chicken) had lower pH values compared to eHMP (5.83 in beef, 6.05 in chicken) or HMP (5.83 in beef, 6.06 in chicken) groups, respectively, in both beef and chicken samples ($p< 0.05$). As a relative benchmark, pH of control group (no encapsulated phosphate) was 5.84 ± 0.007 for ground beef and 6.08 ± 0.009 for ground chicken. The use of encapsulated form of STP resulted in higher pH compared to unencapsulated counterparts ($p< 0.05$) in beef samples, hovewer this was not a case in chicken samples. On the other hand, a higher ($p< 0.05$) pH values were determined in the samples containing SPP compared with eSPP in both meat species. Encapsulation did not create any differences for final pH values of the samples formulated with HMP in neither beef nor chicken.

### *Cooking Loss*

The results showed that the highest ($p<0.05$) CL was observed in beef samples manufactured with SPP (22.14) or eSPP (20.90) followed by those produced with HMP (20.61) or eHMP (20.53) or eSTP (13.32 ± 0.17). This might be due to a greater loss of the water holding capacity of the muscle proteins at decreased pH by sodium pyrophosphate. Among three phosphates studied, the use of STP resulted in the lowest ($p<0.05$) CL values in ground beef samples (12.35 ± 0.17). As far as chicken samples are concerned, while the use of SPP (11.25) or eSPP (11.06) resulted in the highest CL, the use of STP (6.20) or eSTP (5.98 ± 0.12) resulted in the lowest ($p<0.05$) CL values. Apart from phosphate treatments, CL of control group was 20.59 ± 0.28 for beef and 11.60 ± 1.13 for chicken. The results also indicated that increasing EPCT in the samples led to a significant increase ($p<0.05$) in CL of beef (17.00 at 71°C, 17.68 at 74 °C; 20.24 at 77 °C; std error, 0.12) and chicken (5.56 at 71 °C, 8.87 at 74 °C; 12.89 at 77 °C; std error, 0.08) samples. The differences in CL between different EPCT observed in our study could be due to a difference in cooking times required to reach each EPTC.

### *Soluble Orthophosphates*

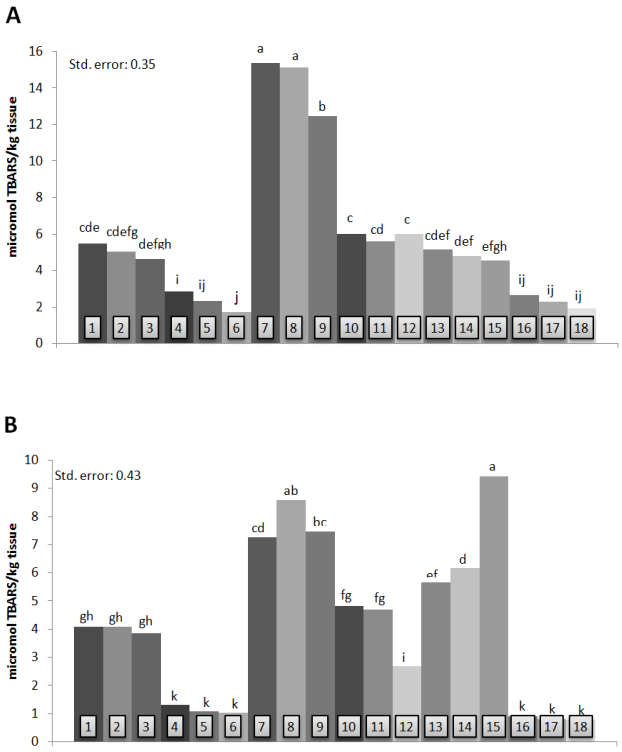
The results indicated that OP content of all cooked ground beef and ground chicken samples was generally quite stable during the 7 d storage period The highest ($p<0.05$) OP level was determined in the samples formulated with STP (3968.3) in ground beef followed by those produced with SPP (3803.21) or eSTP (3630.29) or eSPP (3418.42) or HMP (2774.34) or eHMP (2739.93; std error, 54.84). In case of chicken samples, the use of SPP (6820.87) or STP (6817.71) resulted in the highest ($p<0.05$) OP level followed by eSTP (6083.96) or eSPP (5719.63) or HMP (4575.43) or eHMP (4514.48; std error, 84.14). Encapsulated form of STP or SPP had lower ($p<0.05$) OP level in both meat species compared with unencapsulated counterparts. This result showing that STP and SPP were protected from phosphatase activity by encapsulation. On the other hand, OP level was the same in the samples produced with HMP or eHMP in both meat species. The results indicated that HMP was not as susceptable to hydrolysis as STP

and SPP. The lowest ($p<0.05$) OP level was determined in samples with HMP or eHMP in both meat species. OP levels on the same products manufactured without phosphate added (control group) were 2245.5± 21.86 for beef and 4092.1 ± 43.41 for chicken. In the present study, higher OP content in samples containing encapsulated or unencapsulated forms of STP compared to that of SPP or HMP seemed to be results of increased pH by STP. Results from the present study indicated that the use of 77 °C EPCT resulted in lower ($p<0.05$) OP in chicken samples (5921.13 at 71 °C, 5757.15 at 74 °C, 5587.76 at 77 °C; std error, 59.50) compared with 71 or 74 °C EPCT.

*TBARS*

Results of TBARS analysis (Figure 1) illustrated that the TBARS values increased gradually during storage period in all cooked ground beef (2.56 0 d; 2.70 1 d; 5.77 7d; std error, 0.08) and ground chicken (0.48 0 d; 1.55 1 d; 4.15 7d; std error, 0.10) samples ($p<0.05$). The lowest ($p<0.05$) TBARS values were determined in the samples formulated with eSTP or eSPP in both ground beef (2.28, 2.46, respectively; std error, 0.12) and ground chicken (0.83, 0.48, respectively; std error, 0.14). On the other hand, the highest ($p<0.05$) TBARS were obtained in samples with HMP in both meat species (7.12 ± 0.12 in beef, 3.94 ± 0.14 in chicken). Futhermore, TBARS values of control group were 13.60 ± 1.56 for beef and 5.41 ± 0.75 for chicken. Therefore, the use of eSTP or eSPP over eHMP could be a better approach for controling lipid oxidation in cooked ground beef storage. It was found that the use of encapsulated form of each phosphate resulted in lower TBARS formation compared with unencapsulated counterparts ($p<0.05$). Furthermore, the study results indicated that increasing EPCT resulted in lower ($p<0.05$) TBARS values in beef samples (4.02 at 71 °C, 3.75 at 74 °C, 3.26 at 77 °C; std error, 0.08). This was probably because higher EPCT might provide more time for further thermal inactivation of phosphatases during cooking, leading to have more effective protection of phosphates from phosphatase activity.

Figure 1. Pooled mean results for TBARS values of cooked ground chicken and beef at the end of storage.



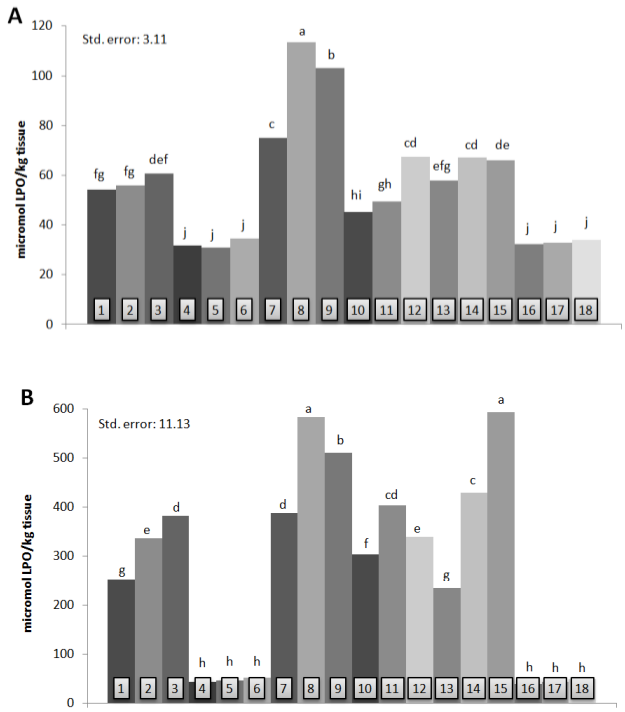

A: Beef samples, B: Chicken samples. Phosphate treatment of numbered bars; 1:uSTP-71, 2:uSTP-74, 3:uSTP-77, 4:eSTP-71, 5:eSTP-74, 6:eSTP-77, 7:uHMP-71, 8:uHMP-74 9:uHMP-77, 10:eHMP-71, 11:eHMP-74, 12:eHMP-77, 13:uSPP-71, 14:uSPP-74, 15:uSPP-77, 16:eSPP-71, 17:eSPP-74, 18:eSPP-77. Bars with no matching letters between phosphate treatments are different ($p<0.05$).

*Lipid Hydroperoxides*

The changes in LPO of cooked ground chicken and ground beef during storage at 4°C are shown in Figure 2. There was a gradual increase in LPO in all samples during 7 days storage period ($p<0.05$) in both ground beef (25.41 0 d; 28.65 1 d; 56.35 7d; std error, 0.73) and ground chicken (20.35 0 d; 75.86 1 d; 279.05 7d; std error, 2.62) samples. The formulation of ground beef with STP or SPP resulted in the lowest ($p<0.05$) LPO values (37.18, 38.38, std error, 1.04), dissimilar to chicken, where the lowest ($p<0.05$) LPO values were obtained by use of STP (142.49) followed by SPP (191.56, std error, 3.71). On the other hand, the highest ($p<0.05$) LPO values were obtained in

samples with HMP in both meat species (51.34 ± 1.04 in beef, 223.19 ± 3.71 in chicken). Futhermore, LPO values of control group were 82.48 ± 11.33 for beef and 300.90 ± 43.41 for chicken. It was found that the use of encapsulated form of each phosphate resulted in lower LPO formation compared with unencapsulated counterparts ($p<0.05$) in ground beef (eHMP; 37.09, eSTP; 26.96, eSPP; 29.89, std error, 1.04) and ground chicken samples (eHMP; 132.80, eSTP; 32.99, eSPP; 27.48, std error, 3.71). Furthermore, on the contrary to TBARS results, increasing EPCT resulted in the higher ($p<0.05$) LPO values in both ground beef samples (33.21 at 71 °C, 37.34 at 74 °C, 39.86 at 77 °C; std error, 0.73) and ground chicken (95.50 at 71 °C, 138.28 at 74 °C, 141.48 at 77 °C; std error, 2.62).

Figure 2. Pooled mean results for LPO values of cooked ground chicken and beef at the end of storage.




A: Beef samples, B: Chicken samples. Phosphate treatment of numbered bars; 1:uSTP-71, 2:uSTP-74, 3:uSTP-77, 4:eSTP-71, 5:eSTP-74, 6:eSTP-77, 7:uHMP-71, 8:uHMP-74 9:uHMP-77, 10:eHMP-71, 11:eHMP-74, 12:eHMP-77, 13:uSPP-71, 14:uSPP-74, 15:uSPP-77, 16:eSPP-71, 17:eSPP-74, 18:eSPP-77. Bars with no matching letters between phosphate treatments are different ($p<0.05$).

## IV. CONCLUSION

This study proved that better oxidation inhibition in cooked ground beef and ground chicken during storage can be achieved by STP and SPP compared with HMP. Antioxidant effect of STP or SPP can be significantly enhanced with encapsulated forms of these phosphates. The use of higher EPCT led to a significant decrease in TBARS of ground beef and an increase in LPO values of both ground beef and ground chicken compared with lower EPCT.

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