IMPACT OF ENCAPSULATED POLYPHOSPHATES ON LIPID OXIDATION INHIBITION DURING THE STORAGE OF COOKED GROUND MEAT

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Abstract – The effect of encapsulated (e) polyphosphates (PP; sodium tripolyphosphate, STP; sodium hexametaphosphate, HMP; sodium pyrophosphate, SPP) on lipid oxidation inhibition during storage (0, 1, 7 d) of ground meat (chicken, beef) was evaluated. The research included five work packages (WP). WP1 demonstrated that PP can be protected from phosphatases by encapsulation in order to accomplish more effective lipid oxidation inhibition ($p<0.05$). STP and SPP with or without encapsulation were more effective polyphosphate types for inhibiting lipid oxidation in both meat species ($p<0.05$). The greater coating level (50%) did not have a further impact on advancing the lipid oxidation inhibition compared to 30%. WP2 indicated that more effective ($p<0.05$) lipid oxidation inhibition can be accomplished by the use of PP encapsulated with a higher temperature release point (68 vs 60 °C). WP3 suggested that the efficiency of ePP on lipid oxidation inhibition can be enhanced by lowering end-point cooking temperature (EPCT, $p<0.05$). WP4 revealed that increasing levels of added ePP resulted in lower lipid oxidation ($p<0.05$). Furthermore, WP5 showed that increasing levels of added eSTP or eSPP at 0.5% added total PP upto 0.2% in beef and 0.4% in chicken resulted in lower lipid oxidation development for both PP types ($p<0.05$).

Key Words – Encapsulated polyphosphate, ground meat, lipid oxidation.

I. INTRODUCTION

The oxidative degradation is recognized as a primary cause of quality deterioration in meat products and this process results in discoloration, drip losses, off-odor and off-flavor developments, loss of nutrient value, and the production of toxic compounds [1]. Deterioration in RTE products associated with oxidation is enhanced during storage. Phosphates also have very strong antioxidant effects against lipid oxidation 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]. The use of encapsulation has proven to be successful in the food industry to protect the encapsulated materials from moisture, heat or other extreme conditions to enhance their stability and maintain functionality. Encapsulation technology can also be applied to polyphosphates to protect them from phosphatases. It is important to find an optimized conditions such as encapsulation thickness, encapsulation melting release point, heating rate, end-point cooking temperatures and percentage of added encapsulated polyphosphates to satisfy quality and economic goals pertinent to the meat processors.

II. MATERIALS AND METHODS

Fresh skinless, boneless broiler chicken breast meat and beef were obtained from a local slaughterhouse. The meat was ground. All treatments contained 1.0% sodium chloride and 10% added distilled water. According to each work package, ground meat was formulated to contain different type of ePP, different coating levels (30 % or 50 %;), two different melting release points of encapsulation (68 vs 60 °C), and various amounts of ePP (0.1, 0.2, 0.3, 0.4, 0.5%). The three PP used (sodium tripolyphosphate, STP; sodium hexametaphosphate, HMP; sodium pyrophosphate, SPP). Encapsulation was accomplished by using

different hydrogenated vegetable oils to achieve the desired melting release point.

Table 1. Coding for phosphate treatments evaluated.

Coding	Explanations
C	Control, no phosphate
u	unencapsulated
e	encapsulated
STP	Sodium tripolyphosphate
HMP	Sodium hexametaphosphate
SPP	Sodium pyrophosphate
30	30% Coating level
50	50% Coating level
60	60 °C Melting point temperature
68	68 °C Melting point temperature
0.1	0.1 % Added encapsulated phosphate level
0.2	0.2 % Added encapsulated phosphate level
0.3	0.3 % Added encapsulated phosphate level
0.4	0.4 % Added encapsulated phosphate level
0.5	0.5 % Added encapsulated phosphate level

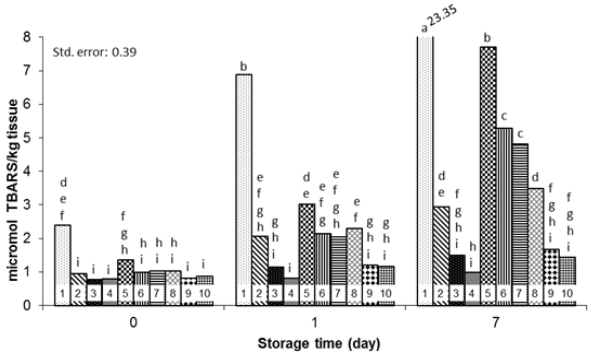
Ground meat samples from each species were cooked in capped plastic centrifuge tubes (50 mL). Approximately 45 g ground meat was placed into each tube and heat processed in a water bath. Samples were cooked to 74 °C (WP3 tested three different cooking endpoint temperatures). Cooked samples were stored in tubes (0, 1, 7 days) at 4 °C. Samples were subjected to pH, cooking loss, soluble orthophosphates, TBARS and lipid hydroperoxides (LPO) analysis.

III. RESULTS AND DISCUSSION

WP1:Effect of encapsulation on protecting PP from hydrolysis

Results of first work package (Figure 1) illustrated that encapsulation enhanced the oxidative stability of cooked samples during storage ($p<0.05$). The highest oxidative stability was accomplished in the samples with eSTP or eSPP ($p<0.05$) followed by uSTP or uSPP. However, there were no differences between 30% and 50% coating levels as far as TBARS were concerned. The highest TBARS were determined in control ($p<0.05$). The slightly higher TBARS were obtained from chicken samples that underwent slow heating rate, dissimilar to beef, where heating rate did not affect TBARS. Furthermore, the lowest LPO formation was also determined in chicken and beef samples produced with eSTP or eSPP ($p<0.05$). However, higher coating level (50%) had no extra impact on inhibition of LPO compared to the inhibition level accomplished with 30% encapsulation.

Fig. 1. Pooled mean results for TBARS associated with cooked ground chicken and ground beef.



Phosphate treatment of numbered bars; 1: C, 2: uSTP, 3: eSTP-30, 4: eSTP-50, 5: uHMP, 6: eHMP-30, 7: eHMP-50, 8: uSPP, 9: eSPP-30, 10: eSPP-50. Bars with no matching letters are different ($p<0.05$).

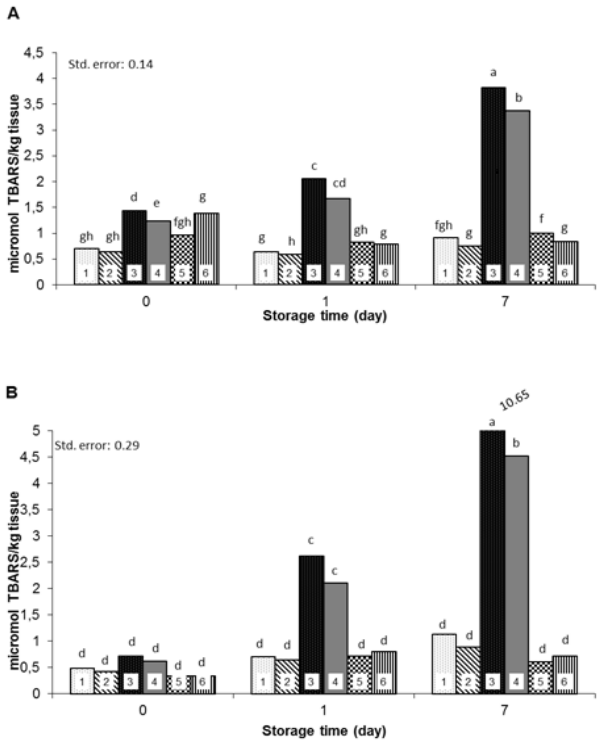
WP2:Effect of the temperature release point (MT) of the PP from ePP

WP2 (Figure 2) showed that the TBARS increased during storage in all beef and chicken samples regardless of phosphate type, heating rate (HR), or MT ($p<0.05$). Regardless of MT or HR, the lowest ($p<0.05$) TBARS were determined in the samples with eSTP or eSPP in beef and chicken. The highest ($p<0.05$) TBARS were obtained in samples with eHMP in both meat species. Regardless of the phosphate incorporated or HR, the use of ePP with the higher MT (68 °C) resulted in lower ($p<0.05$) TBARS compared with ePP with the lower MT (60 °C) in beef and chicken. This was probably because higher melting points of encapsulation might have provided more time for further thermal inactivation of phosphatases during cooking, leading to more effective protection of PP from phosphatase activity. Thus, phosphates could contribute more to lipid oxidation inhibition. However, there was no effect of HR on TBARS of beef and chicken samples.

There was a gradual increase in LPO during 7 days of storage ($p<0.05$) in all beef and chicken samples. Regardless of MT or HR, ground beef with eSTP resulted in the lowest ($p<0.05$) LPO

followed by eSPP. This result was dissimilar to chicken, where eSTP or eSPP inhibited LPO at the same level. The highest ($p<0.05$) LPO were obtained in samples with eHMP in both meat species. Differences in the antioxidant effect of PP used in this study might be the result of their sequestering capacity of various metal ions. Although, STP can be used to sequester many ions, this phosphate can effectively sequester heavy metals, such as copper and iron. On the other hand, HMP was reported to be the best sequestering agents for calcium and magnesium (Ellinger, 1972). In addition, regardless of phosphate incorporated or HR, the higher MT (68 °C) resulted in lower ($p<0.05$) LPO compared with the lower MT (60 °C) in chicken. This was dissimilar to beef, where there was no observable effect of differences in MT on LPO. Contrary to the TBARS results, the use of a fast HR resulted in higher ($p<0.05$) LPO in beef and chicken samples.

Fig. 2. Pooled mean results for TBARS associated with cooked ground chicken and ground beef.



A: Beef samples, B: Chicken samples. Phosphate treatment of numbered bars; 1: eSTP-60, 2: eSTP-68, 3: eHMP-60, 4: eHMP-68, 5: eSPP-60, 6: eSPP-68. Bars with no matching letters between phosphate treatments are different ($p<0.05$).

WP3:Effects of different heating rates and endpoint temperatures on the efficiency of ePP

WP3 illustrated that the lowest ($p<0.05$) TBARS were determined in the samples with eSTP or eSPP in both meat species. The highest ($p<0.05$) TBARS were obtained in samples with HMP. The use of encapsulated form of each PP resulted in lower TBARS compared with unencapsulated counterparts ($p<0.05$). Furthermore, increasing EPCT resulted in lower ($p<0.05$) TBARS in beef samples.

The changes in LPO of cooked ground chicken and beef during storage at 4°C showed that There was a gradual increase in LPO in all samples during 7 days storage ($p<0.05$) in both beef and chicken samples. The formulation of ground beef with STP or SPP resulted in the lowest ($p<0.05$) LPO, dissimilar to chicken, where the lowest ($p<0.05$) LPO were obtained by use of STP followed by SPP. The highest ($p<0.05$) LPO were obtained in samples with HMP in both meat species. It was found that the use of encapsulated form of each polyphosphate resulted in lower LPO compared with unencapsulated counterparts ($p<0.05$) in beef and chicken samples. On the contrary to TBARS results, increasing EPCT resulted in the higher ($p<0.05$) LPO in both ground beef and chicken samples.

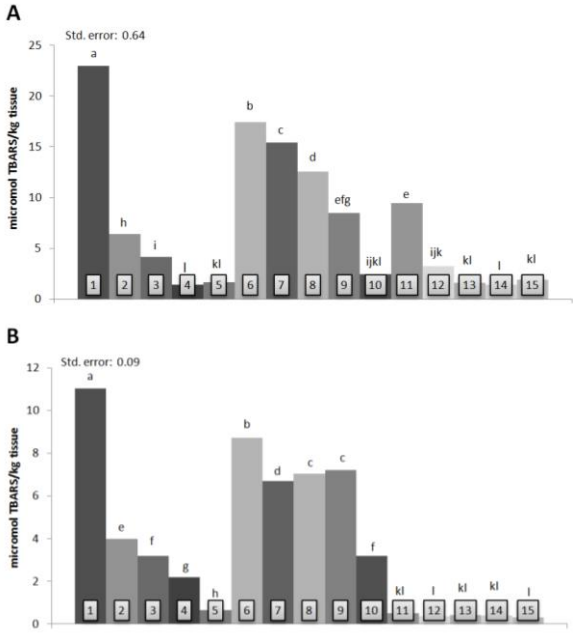
WP4:Determine the minimum functional amount of ePP

Results of WP4 (Figure 3) revealed that regardless of level of added encapsulated phosphate, the lowest ($p<0.05$) TBARS were determined in the samples formulated with eSPP in both ground beef and ground chicken followed by eSTP. On the other hand, the highest ($p<0.05$) TBARS were obtained in samples with eHMP in both meat species. Regardless of PP incorporated, increasing the level of added encapsulated phosphate generally resulted in lower ($p<0.05$) TBARS values in both beef and chicken samples

Regardless of added encapsulated polyphosphate levels, the formulation of ground beef and ground chicken with eSPP resulted in the lowest ($p<0.05$) LPO followed by eSTP. On the other hand, the highest ($p<0.05$) LPO values were obtained in

samples with eHMP in both meat species. In addition, regardless of phosphate incorporated, increasing added ePP level resulted in lower ($p<0.05$) LPO in ground beef and chicken.

Fig. 3. Pooled mean results for TBARS in cooked ground chicken and beef at the end of storage.



A: Beef samples, B: Chicken samples. Phosphate treatment of numbered bars; 1:eSTP-0.1, 2:eSTP-0.2, 3:eSTP-0.3, 4:eSTP-0.4, 5:eSTP-0.5, 6:eHMP-0.1, 7:eHMP-0.2, 8:eHMP-0.3, 9:eHMP-0.4, 10:eHMP-0.5, 11:eSPP-0.1, 12:eSPP-0.2, 13:eSPP-0.3, 14:eSPP-0.4, 15:eSPP-0.5. Bars with no matching letters are different ($p<0.05$).

WP5: Effectiveness of various blends of un-encapsulated and encapsulated PP

Results of last work package showed that the lower ($p<0.05$) TBARS were determined in the samples with SPP in both ground beef and chicken compared to STP regardless of levels of added ePP at 0.5% added total PP. Furthermore, regardless of PP incorporated, increasing levels of added ePP at 0.5% added total PP upto 0.2% in beef and 0.4% in chicken resulted in lower ($p<0.05$) TBARS in beef and chicken samples. This was probably because that increasing the amount of ePP added to a meat system provide an increase in the amount of active phosphate (the amount of pure phosphate added to the meat), leading to have more effective lipid oxidation inhibition.

The changes in LPO of cooked ground chicken and beef during storage at 4°C showed that the formulation of ground beef and chicken with SPP resulted in the lower ($p<0.05$) LPO compared to STP regardless of levels of added ePP at 0.5% added total PP. This was most likely due to differences in the antioxidant capacity of tested polyphosphates. In addition, regardless of polyphosphate incorporated, it was determined that increasing levels of added encapsulated polyphosphates at 0.5% added total polyphosphates generally resulted in lower ($p<0.05$) LPO values in ground chicken. This effect was also observed in beef samples upto 0.2% level of added encapsulated polyphosphates at 0.5% added total polyphosphates ($p<0.05$).

IV. CONCLUSION

Research results revealed that the use of encapsulated polyphosphates can be an effective strategy to inhibit lipid oxidation in ready to eat meat products. Optimum conditions for polyphosphate type, coating level, heating rate, endpoint cooking temperature, the temperature release point of the PP from EPP and level of added encapsulated polyphosphates determined in this research may contribute more to further limit the development of lipid oxidation during storage in ready to eat meat products.

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