IMPACT OF ADDED ENCAPSULATED PHOSPHATE LEVEL ON THE RATE OF LIPID OXIDATION INHIBITION DURING THE STORAGE OF COOKED GROUND MEAT

B. Kılıç[1], A. Şimşek[1], J.R. Claus[2], E. Atılgan[1], D. Bilecen[1]

[1] Suleyman Demirel University, Faculty of Engineering, Department of Food Engineering, 32260, Isparta, Turkey

[2]University of Wisconsin-Madison, Meat Science and Muscle Biology Building, 1805 Linden Drive, Madison, WI 53706, U.S.A.

Abstract – The effect of level (0.1, 0.2, 0.3, 0.4, 0.5%) of added encapsulated (e) phosphate (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 use of eSTP and eSPP resulted in lower and higher cooking loss (CL) compared to eHMP, respectively ($p<0.05$). Increasing encapsulated phosphate level (PL) enhanced the impact of phosphates on CL in both beef and chicken samples ($p<0.05$). Encapsulated STP increased pH, whereas eSPP decreased pH ($p<0.05$). pH was not affected by PL. The highest orthophosphate (OP) was obtained with eSTP, followed by eSPP and eHMP ($p<0.05$). The level of OP determined in both beef and chicken samples increased ($p<0.05$) during storage. Increasing PL caused an increase in OP ($p<0.05$). The highest reduction rate in the formation of TBARS and LPO for both meat species were obtained with eSPP, followed by eSTP and eHMP ($p<0.05$). Increasing PL resulted in lower TBARS and LPO ($p<0.05$).

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

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, 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 also 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 added encapsulated polyphosphates level on the effectiveness of antioxidant properties of phosphates was not addressed in this studiy. It is important to determine minimum level of added encapsulated polyphosphates for desired lipid oxidation inhibition to meet the concerns of the meat industry about increased production costs and negative impact on the nutritional composition of the meat products as a result of increasing the amount of added hydrogenated vegetable oils used for the encapsulation material.

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 various amounts of encapsulated phosphate (0.1, 0.2, 0.3, 0.4, 0.5%, phosphate weight basis) with 30 % coating level (phosphate weight basis) 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. The starting temperature of the water in the water bath was either 60 °C. After the tubes had been loaded, the water bath setting was changed to 85 °C. A cooking endpoint temperature was determined by inserting thermocouples into the geometric center of extra sample tubes. Samples were cooked to 74 °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.

Table 1. Coding for phosphate treatments evaluated.

Phosphate treatmen	Phosphate type	Added encapsulated phosphate level (%)
eSTP-0.1	STP	0.1
eSTP-0.2	STP	0.2
eSTP-0.3	STP	0.3
eSTP-0.4	STP	0.4
eSTP-0.5	STP	0.5
eHMP-0.1	HMP	0.1
eHMP-0.2	HMP	0.2
eHMP-0.3	HMP	0.3
eHMP-0.4	HMP	0.4
eHMP-0.5	HMP	0.5
eSPP-0.1	SPP	0.1
eSPP-0.2	SPP	0.2
eSPP-0.3	SPP	0.3
eSPP-0.4	SPP	0.4
eSPP-0.5	SPP	0.5

STP: Sodium tripolyphosphate, HMP: Sodium hexametaphosphate, SPP: Sodium pyrophosphate

III. RESULTS AND DISCUSSION

pH

Results of pH analysis illustrated that samples formulated with eSTP (5.75 ± 0.005 in beef, 6.30 ± 0.005 in chicken, mean ± std error) and eSPP (5.49 ± 0.005 in beef, 5.99 ± 0.005 in chicken) had higher and lower pH values compared to eHMP (5.62 ± 0.005 in beef, 6.18 ± 0.005 in chicken) groups, respectively, in both beef and chicken samples ($p< 0.05$). In general, the initial pH of meat increased in both beef (5.57 0 d; 5.65 1d; 5.63 7d; std error, 0.005) and chicken (6.13 0 d; 6.17 1d; 6.16 7d; std error, 0.005) samples during storage time ($p<0.05$). In this study, level of added encapsulated phosphate was not a significant factor for controlling pH changes in beef samples, however, increasing level of added encapsulated phosphate resulted in gradual decrease in pH (0.1: 6.17, 0.2: 6.16, 0.3: 6.15, 0.4: 6.14, 0.5: 6.14; std error, 0.006) of chicken samples ($p<0.05$). Hovewer, pH values among different level of added encapsulated phosphate in chicken samples varied less than 0.04 units which would not likely be of practrical significance.

Cooking Loss

The results showed that the highest ($p<0.05$) CL was observed in samples manufactured with eSPP (24.90 ± 0.18 in beef, 14.99 ± 0.33 in chicken) or eHMP (24.76 ± 0.18 in beef, 14.76 ± 0.33 in chicken). Among three phosphates studied, the use of eSTP resulted in the lowest ($p<0.05$) CL values in both ground beef samples (22.69 ± 0.18) and ground chicken (11.62 ± 0.33). Apart from phosphate treatments, CL of control group was 19.57 ± 0.22 for beef and 9.64 ± 0.93 for chicken. In general, increasing level of added encapsulated phosphate was a factor affecting CL ($p<0.05$).

Soluble Orthophosphates

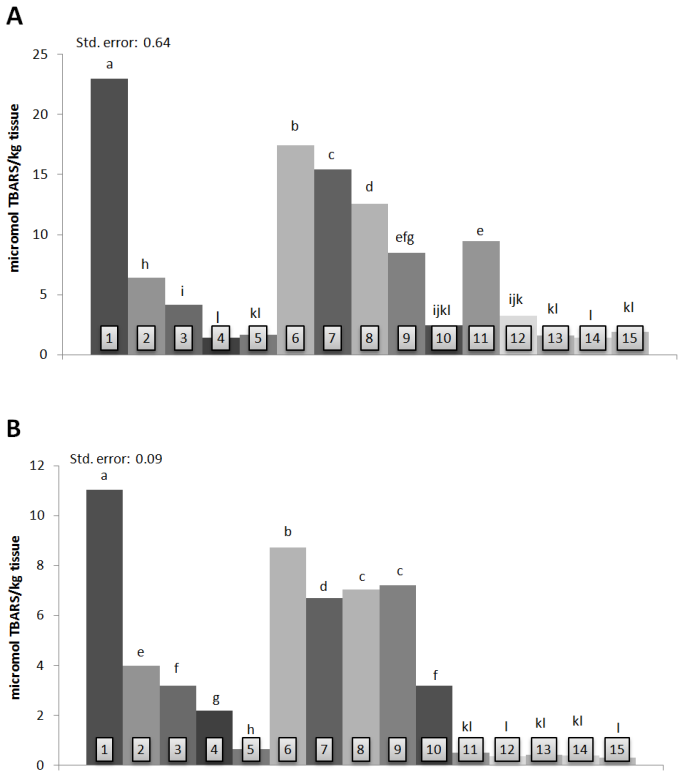
Results indicated that OP content of all samples was generally increased ($p<0.05$) in both ground beef (2996.5 0 d; 2878.6 1 d; 3291.2 7d; std error, 76.7) and ground chicken (5102.2 0 d; 5227.6 1 d; 5337.6 7d; std error, 66.3) during the 7 d storage period. The highest ($p<0.05$) OP level was determined in the samples formulated with eSTP in both ground beef (3677.6± 76.7) and ground chicken (6153.0 ± 66.3). 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 eHMP in both meat

species (2609.1 ± 76.7 in beef, 4602.9 ± 66.3 in chicken). Both beef and chicken samples produced with eSPP had OP values falling between eSTP and eHMP groups (2879.5 ± 76.7 in beef, 4911.6 ± 66.3 in chicken). As a relative benchmark, OP levels on the same products manufactured without phosphate added (control group) were 2171.6 ± 18.20 for beef and 3413.1 ± 29.10 for chicken. Results from the present study indicated that the higher PL resulted in higher ($p<0.05$) OP in beef (0.1: 2665.9, 0.2: 2955.2, 0.3: 3089.0, 0.4: 3202.3, 0.5: 3364.8; std error, 99.0) and chicken (0.1: 4780.9, 0.2: 4984.3, 0.3: 5237.6, 0.4: 5398.9, 0.5: 5710.7; std error, 85.6) samples. This result was anticipated as it was expected more OP level in the samples containing more added phosphate in the formulation.

TBARS

Results of TBARS analysis (Figure 1) illustrated that the TBARS values increased gradually during storage period in all cooked ground beef (1.61 0 d; 3.32 1 d; 7.36 7d; std error, 0.16) and ground chicken (0.43 0 d; 1.00 1 d; 3.73 7d; std error, 0.024) samples regardless of phosphate type or level of added encapsulated phosphate ($p<0.05$). Regardless of level of added encapsulated phosphate, the lowest ($p<0.05$) TBARS values were determined in the samples formulated with eSPP in both ground beef (2.26; std error, 0.16) and ground chicken (0.41; std error, 0.024) followed by eSTP (4.17 ± 0.16 in beef, 1.99 ± 0.024 in chicken). On the other hand, the highest ($p<0.05$) TBARS were obtained in samples with eHMP in both meat species (5.85 ± 0.16 in beef, 2.76 ± 0.024 in chicken). Furthermore, regardless of phosphate incorporated, the study results indicated that increasing the level of added encapsulated phosphate generaly resulted in lower ($p<0.05$) TBARS values in both beef (0.1: 8.31, 0.2: 4.52, 0.3: 3.51, 0.4: 2.37, 0.5: 1.77; std error, 0.21) and chicken samples (0.1: 2.19, 0.2: 1.77, 0.3: 1.62, 0.4: 1.56, 0.5: 0.75; std error, 0.031).

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



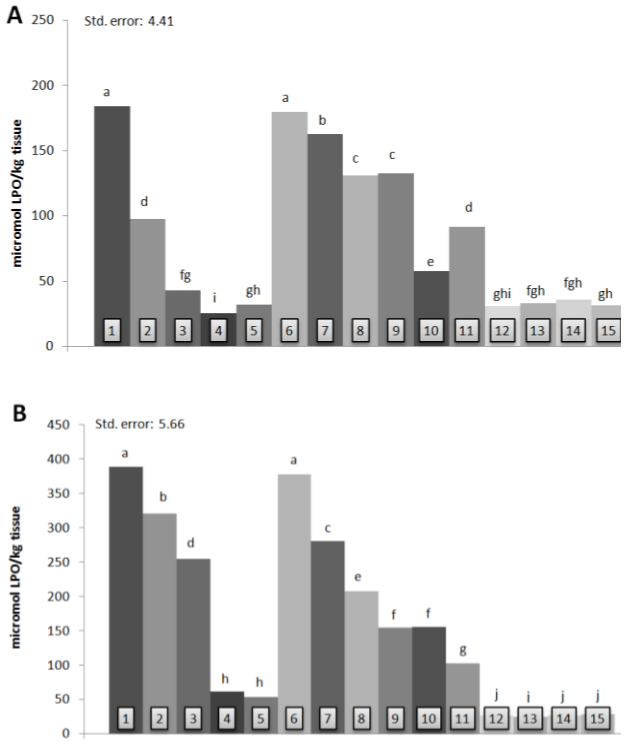
A: Beef samples, B: Chicken samples. Phosphate treatment of numbered bars; 1:eSTP-0.1, 2:eSTP-0.2, 3:eSTP-0.3, 4:eSTP-0.4, 5:eSTP-0.5, 6:eHMP-0.1, 7:eHMP-0.2, 8:eHMP-0.3, 9:eHMP-0.4, 10:eHMP-0.5, 11:eSPP-0.1, 12:eSPP-0.2, 13:eSPP-0.3, 14:eSPP-0.4, 15:eSPP-0.5. Bars with no matching letters between phosphate 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 (23.29 0 d; 35.08 1 d; 84.55 7d; std error, 1.14) and ground chicken (24.07 0 d; 31.69 1 d; 164.53 7d; std error, 1.46) samples. Regardless of added encapsulated phosphate levels, the formulation of ground beef and ground chicken with eSPP resulted in the lowest ($p<0.05$) LPO values (33.95 in beef, 30.95 in chicken) followed by eSTP (43.92 ± 1.14 in beef, 90.83 ± 1.46 in chicken). On the other hand,

the highest ($p<0.05$) LPO values were obtained in samples with eHMP in both meat species (65.04 ± 1.14 in beef, 98.51 ± 1.46 in chicken). In addition, regardless of phosphate incorporated, it was determined that increasing added encapsulated phosphate level generally resulted in lower ($p<0.05$) LPO values in ground beef (0.1: 74.51, 0.2: 51.37, 0.3: 42.21, 0.4: 39.24, 0.5: 30.86; std error, 1.47) and ground chicken (0.1: 119.57, 0.2: 89.47, 0.3: 71.78, 0.4: 43.87, 0.5: 42.46; std error, 1.89).

Figure 2. Pooled mean results for lipid hydroperoxide values associated with cooked ground chicken and ground 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 between phosphate treatments are different ($p<0.05$).

IV. CONCLUSION

Regarding the results of TBARS and LPO, this study proved that better oxidation inhibition in cooked ground beef and ground chicken during storage can be achieved by eSTP and eSPP and antioxidant effect of eSTP or eSPP can be enhanced with increasing added encapsulated phosphate level.

ACKNOWLEDGEMENTS

Appreciation is expressed to The Scientific and Technological Research Council of Turkey (TUBITAK) for providing financial support for this work (Project no: 111O261).

REFERENCES

1. Morrissey, P.A., Sheehy, P.J.A., Galvin, K., Kerry, J.P., & Buckley, D.J. (1998). Lipid stability in meat and meat products. Meat Science 49: 73-86.
2. Jones, D.R., Fletcher, D.L., & Lyon, C.E. (2002). Variations in levels of acid phosphatase present in chicken whole leg meat. Poultry Science 81: 1567–1570.
3. Davis, C.E., & Townsend, W.E. (1994). Rapid fluorometric analysis of acid phosphatase activity in cooked poultry meat. Journal of Food Protection 57 (12): 1094–1097.
4. Kılıç, B., Şimşek, A., Claus, J.R. & Atılgan, E., Encapsulated phosphates reduce lipid oxidation in both ground chicken and ground beef during raw and cooked meat storage with some influence on color, pH, and cooking loss, Meat Science 97 (1): 93-103.