EVALUATION OF SODIUM CHLORIDE AND POLYPHOSPHATES EFFECTS ON WATER HOLDING CAPACITY OF MEAT BATTER DURING PROCESSING

Ya-Min Deng, Jun-Hua Shao*, Tong Sun, Na Jia, Deng-Yong Liu, Li Song

College of Food Science and Technology, Bohai University; Food Safety Key Lab of Liaoning Province; National & Local Joint Engineering Research Center of Storage, Jinzhou, Liaoning, 121013, PR China

Abstract –The objective of this study was to evaluate the influence of sodium chloride and polyphosphates (STP、SPP、SHMP, 1∶1∶1), in established addition amount of solely with sodium chloride (S), solely with polyphosphates (P), joint of sodium chloride and polyphosphates (PS) and the control without any salt (C) on meat emulsion processing properties. The cooking loss, textural property, color change and relaxometry were determined and correlations between the indicators were analyzed. An increase ($P < 0.05$) of water retention was found when a combination of sodium chloride and polyphosphates was used when compared with samples with only sodium chloride or polyphosphates. Elastic and compact texture was observed in the two treatment with sodium chloride PS and S, but not in the group with polyphosphates. And the light value (L*) had a significant positive correlation with the cooking loss. By estimating of the relaxation data, certain correlation of the water mobility and distribution with the macro-quality was found. It was revealed that sodium chloride had evidently affected the processing properties, particularly with the polyphosphates, but the polyphosphates could not equally substitute the role of sodium chloride.

Key Words –Cooking loss, texture, LF-NMR.

I. INTRODUCTION

Finely emulsified meat products have a complex structure and consist of numerous components that are held together by a variety of attractive forces[1]. In preparation of meat batters, salt is added to lean meat and comminuted mainly to extract the salt-soluble protein components. Sodium chloride, as the common type of salt, contributes to the flavor, texture and improves the processability, plays an essential role in meat processing[2-4]. But excessively intake of sodium chloride may has been related with the major risk factors of cardiovascular disease, much work to reduce the salt usage in meat products is actively being done[5-7]. More basic knowledge concerning the reduction of salt on the functional and technological properties should be emphasized. Food additives, especially polyphosphates, are generally added into fresh retail cuts as well as further processed products to improve water holding capacity (WHC) and tenderness by meat industries. Xu *et.al*[8] reported that polyphosphates have tenderizing effects on the muscle more or less when used alone. Xiong[9] also found phosphate types specially influenced the dynamics of brine penetration into muscle fibril, the presence of pyrophosphate and tripolyphosphate greatly facilitated ($P < 0.05$) brine penetration, throughout the 30min marination period. In contrast, hexametaphosphate promoted water pickup only for the first 5 min. In this study, we choose the three components as a whole to analysis, aiming to explore their synergy effects.

A thorough understanding of the mechanisms that cause the changes in water retention and protein solubility that accompany treatment with sodium chloride and polyphosphates is necessary. It requires a detailed knowledge of the structural changes that occur, including the sites of changes in water content and of protein solubilisation[10]. LF-NMR has been successfully employed to assess pork quality, particularly as a tool for fast nondestructive analysis of WHC in industry, mainly provides specific information about water-protein interactions within meat[11]. By multi-exponential fitting analysis, different water components may be identified as that tightly associated with macromolecules, within highly organized protein structures, located outside the myofibrillar network[12-13]. The relaxation time acts as an indicator for water mobility, while the

area under curve can indicate the amount of water with the component. It has been proved useful to improve the understanding of the interaction between the different salt condition and major quality characteristic[14]. However, investigations just use NaCl and polyphosphate without any other additives were not that much. Therefore, further studies of the effect of sodium chloride and polyphosphates on water distribution caused only by salt addition were needed, to establish relationship between the micro-structure change and the macro-quality characteristics.

The goal of this work was to use Low- Field NMR relaxometry to differentiate water holding capacity in the four groups dealt with NaCl and polyphosphate in different way, combining the results of color determination and textural properties to evaluate the overall effects of the two additives

II. MATERIALS AND METHODS

Preparation of meat batters

Four different types of meat batters were formulated: control meat batter (C), conducted with only 250 g ice water (1:1); meat batter with sodium chloride (S), containing 50 g NaCl and 250 g water; the third meat batter with polyphosphates (P), manufactured with 6.25 g prepared polyphosphate and 250 g water; and finally the dealt with both the same amount of sodium chloride, polyphosphates and water (PS).

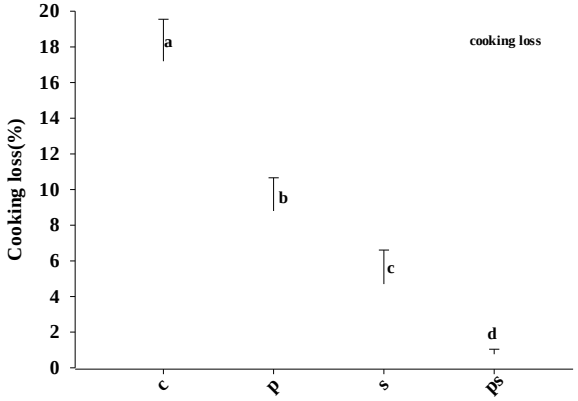
The manufacturing process was as described below: meat was put into the prepared chilled bowl chopper (Stephan UMC-5C, Germany), then sodium chloride and complex phosphate were directly added into the meat according to formulation, and the mixture were chopped at the high speed setting (3000 r/min) for 1 min under vacuum condition. Finally, release the vacuum condition and add the ice water, the whole meat batter was again chopped for 4 min under the condition stated before. Final temperature of the meat batter did not exceed 16 °C in all cases. Parts of each batter were vacuum-packed to remove trapped air. Approximately 35 g samples were stuffed into 50 mL polypropylene tubes, then hermetically sealed. The plastic containers were centrifuged (Model Allegra 64R, Beckman, Coulter, USA) at 500 g (4 °C) setting for 5 min to remove any remaining air bubbles. Then the centrifuged samples were stored in a chiller at 4 °C until analyzed.

III. RESULTS AND DISCUSSION

Cooking loss

The ability of protein matrix to bind water by heating reflects the meat emulsion stability, which is an indicator of functional property of meat in an emulsion system[15]. It determines the final cooking yield and also the sensory index and other features that constitute the products quality.

Fig.1 Effects of sodium chloride and polyphosphates on four treatments cooking loss



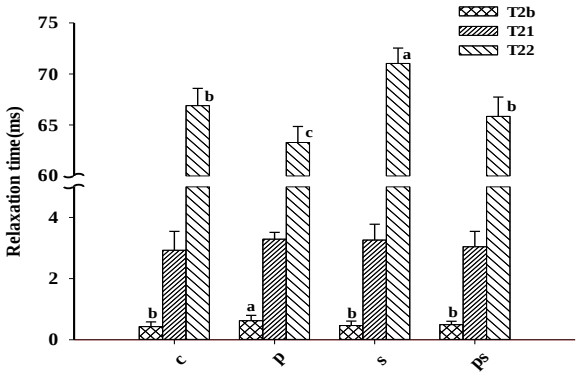
[a-d]Means related to cooking loss(above a bar) with different letters differ significantly (P < 0.05). Error bars show the standard error. The treatments C-the control without any salt; P-the polyphosphate; S-the sodium chloride; PS-the polyphosphate and sodium chloride.

As expected, sodium chloride and polyphosphate had significantly ($P < 0.05$) affected the stability of meat emulsions. The results (Fig.1) showed that there were significant differences ($P < 0.05$) among the four formulated meat batters. Contrast with the control (17.20%), other three meat batters with salt either NaCl or polyphosphates, all decreased prominently. Moreover, the type of salt also had significant effects on the cooking loss, as seen the sodium chloride group (4.70%) was significantly lower than the polyphosphates treat (8.80%), and the PS in which polyphosphate and sodium chloride may play a role of interaction exhibited the lowest cooking loss (0.76%). The observation in this study were also demonstrated by Johnsen *et al*[16], who showed the addition of

salt led to a significant increase in WHC, and the combined effect of salt and phosphates was even more pronounced. For the polyphosphates which were believed to raise the pH slightly and selectively bind to the proteins and increase solubilization and water holding capacity[17], when added as the only salt in our study, could reduce the cooking loss to certain degree. But the total effect of polyphosphate and sodium chloride were 10% more higher than the polyphosphate alone effect, providing the evidence that polyphosphate can partially but not absolutely substitute for NaCl[18]. The results exhibited a significant negative correlation (R=-0.919, P <0.01) between the cooking loss and salt content, this also suggested that with the increasing salt content , the cooking loss decreased[19-20], the salt addition had great influence on the products WHC.

LF-NMR spin–spin relaxation (T_2) measurements

Fig.2 Effects of sodium chloride and polyphosphates on four treatments relaxation time



[a-b]Means related to relaxation time (above a bar) with different letters differ significantly (P < 0.05). Error bars show the standard error. The treatments C-the control without any salt; P-the polyphosphate; S-the sodium chloride; PS-the polyphosphate and sodium chloride.

As Fig.2 showed, the water that tightly bound to macromolecules (T_{21}) was not observed to have significant difference in the four treatments. It has been suggested, the bound water to macromolecules (T_{2b} ,T_{21})[21] is independent of any mechanical stress and micro- or macro-structural changes in the meat matrix. However, in our findings, T_{2b} was significantly higher (P < 0.05) in the meat emulsion with addition of polyphosphate (P) than the other three groups, indicating the tightly-bind water under this treatment was relatively weaker to be restricted. And we inferred that the poor textural properties in the treatment adding only polyphosphate might be caused by this differ. While T_{22} of this treatment was significantly lower than all others, suggesting its immobilized water was the most intensively trapped by proteins. For the treatment with only polyphosphate, the lower cooking loss obtained most probably due to the strong capacity about the interaction between meat proteins with the immobilized water which account for a large proportion of all the water in different form. Li *et al*[12] also found that relaxation time T_{22} correlated positively with pressing loss, indicating the importance of intra-myofibrillar water for water-holding capacity of meat. In case of the control sample C, with higher T_{22}, might have less intra-myofibrillar space due to shortening and thus show higher cooking loss. As to treatment adding polyphosphate and NaCl and group with only NaCl, both have higher T_{22} and lower T_{2b} compared with polyphosphate group, meaning the mobility of immobilized water in the unheated meat emulsion were greater and absolutely, they are most probably to have poor water-holding capacity once undergoing heating or other forces. Actually they were proved to present the least cooking loss and the best textural structure.

IV. CONCLUSION

The presence of strongly water-holding capacity of polyphosphates is embodied by the combination of sodium chloride. Moreover, it has been revealed that the effect of sodium chloride can be enhanced further by the inclusion of polyphosphate. Adding phosphate alone will only get the similar or more worse texture characteristics, rough and soft, comparing the treatment without any addition of salt.

ACKNOWLEDGEMENTS

This work was supported by the National Natural Science Foundation (31301510) and project no. BA2009007.

REFERENCES

1. Gordon, A., Barbut, S., & Schmidt, G. (1992). Mechanisms of meat batter stabilization: a review. Critical Reviews in Food Science & Nutrition, 32(4), 299-332.
2. Corral, S., Salvador, A., & Flores, M. (2013). Salt reduction in slow fermented sausages affects the generation of aroma active compounds. Meat science, 93(3), 776-785.
3. Grossi, A., Søltoft-Jensen, J., Knudsen, J. C., Christensen, M., & Orlien, V. (2012). Reduction of salt in pork sausages by the addition of carrot fibre or potato starch and high pressure treatment. Meat science, 92(4), 481-489.
4. Tobin, B. D., O'Sullivan, M. G., Hamill, R. M., & Kerry, J. P. (2013). The impact of salt and fat level variation on the physiochemical properties and sensory quality of pork breakfast sausages. Meat science, 93(2), 145-152.
5. Desmond, E. (2006). Reducing salt: A challenge for the meat industry. Meat science, 74(1), 188-196.
6. Jiménez-Colmenero, F., Cofrades, S., López-López, I., Ruiz-Capillas, C., Pintado, T., & Solas, M. T. (2010). Technological and sensory characteristics of reduced/low-fat, low-salt frankfurters as affected by the addition of konjac and seaweed. Meat science, 84(3), 356-363.
7. Perisic, N., Afseth, N. K., Ofstad, R., & Kohler, A. (2011). Monitoring protein structural changes and hydration in bovine meat tissue due to salt substitutes by Fourier transform infrared (FTIR) microspectroscopy. Journal of agricultural and food chemistry, 59(18), 10052-10061.
8. Xu, S. Q., Zhou, G. H., Peng, Z. Q., Zhao, L. Y., & Yao, R. (2009). The influence of polyphosphate marination on Simmental beef shear value and ultrastructure. Journal of Muscle Foods, 20(1), 101-116.
9. Xiong, Y. L. (2005). Role of myofibrillar proteins in water-binding in brine-enhanced meats. Food Research International, 38(3), 281-287.
10. Knight, P., & Parsons, N. (1988). Action of NaCl and polyphosphates in meat processing: Responses of myofibrils to concentrated salt solutions. Meat Science, 24(4), 275-300.
11. Bertram, H. C., Kristensen, M., & Andersen, H. J. (2004). Functionality of myofibrillar proteins as affected by pH, ionic strength and heat treatment-a low-field NMR study. Meat Science, 68(2), 249-256.
12. Li, C., Liu, D., Zhou, G., Xu, X., Qi, J., Shi, P., & Xia, T. (2012). Meat quality and cooking attributes of thawed pork with different low field NMR T21. Meat science, 92(2), 79-83.
13. McDonnell, C. K., Allen, P., Duggan, E., Arimi, J. M., Casey, E., Duane, G., & Lyng, J. G. (2013). The effect of salt and fibre direction on water dynamics, distribution and mobility in pork muscle: A low field NMR study. Meat science, 95(1), 51-58.
14. Álvarez, D., & Barbut, S. (2013). Effect of inulin, β-glucan and their mixtures on emulsion stability, color and textural parameters of cooked meat batters. Meat science, 94(3), 320-327.
15. O'Flynn, C. C., Cruz-Romero, M. C., Troy, D., Mullen, A. M., & Kerry, J. P. (2014a). The application of high-pressure treatment in the reduction of salt levels in reduced-phosphate breakfast sausages. Meat science, 96(3), 1266-1274.
16. Johnsen, S. O., Jørgensen, K. B., Birkeland, S., Skipnes, D., & Skåra, T. (2009). Effects of Phosphates and Salt in Ground Raw and Cooked Farmed Cod (Gadus morhua) Muscle Studied by the Water Holding Capacity (WHC), and Supported by 31P-NMR Measurements. Journal of food science, 74(3), C211-C220.
17. Hamm, R. (1971). Interactions between phosphates and meat proteins. In Symposium: Phosphates in Food Processing, University of Guelph, Ontario, Canada.
18. Whiting, R. C. (1987). Influence of various salts and water soluble compounds on the water and fat exudation and gel strength of meat batters. Journal of Food Science, 52(5), 1130-1132.
19. Chin, K. B., Go, M. Y., & Xiong, Y. L. (2009). Konjac flour improved textural and water retention properties of transglutaminase-mediated, heat-induced porcine myofibrillar protein gel: Effect of salt level and transglutaminase incubation. Meat science, 81(3), 565-572.
20. Herrero, A. M., Carmona, P., López-López, I., & Jiménez-Colmenero, F. (2008). Raman spectroscopic evaluation of meat batter structural changes induced by thermal treatment and salt addition. Journal of agricultural and food chemistry, 56(16), 7119-7124.
21. Pearce, K. L., Rosenvold, K., Andersen, H. J., & Hopkins, D. L. (2011). Water distribution and mobility in meat during the conversion of muscle to meat and ageing and the impacts on fresh meat quality attributes-A review. Meat Science, 89(2), 111-124.