QUALITY CHANGES AND OXIDATION OF PORCINE LONGISSIMUS DORSI DURING FROZEN STORAGE AT DIFFERENT TEMPERATURE

Xiufang Xia [1], Baohua Kong * [1], Qian Chen [1], Yi Ding [1], Li Huang [1], Nan Pan [1]

[1] College of Food Science, Northeast Agricultural University, Harbin, Heilongjiang, China

Abstract –Changes in cutting force, thawing loss, cooking loss, redness, carbonyl content and TBARS of porcine longissimus dorsi during frozen storage at – 5 °C, – 18 °C, – 26 °C, – 35 °C and – 70 °C for 12 month were investigated. The thawing loss, cooking loss and cutting force of samples increased (P < 0.05), a*-value decreased (P < 0.05) with the extended frozen time at the same temperature. Nevertheless, cutting force increased and reached a maximum with a subsequent decrease up to the end of storage at – 5 °C and – 26 °C. Lipid and protein oxidation appeared to occur simultaneously during frozen storage, measured as the increase in carbonyl groups and TBARS (thiobarbituric acid reactive substances). The results showed that the samples stored at higher frozen temperature (–5°C) had more serious quality deterioration than that of lower frozen temperature (P<0.05). The freezing processes have a profound effect on muscle physicochemical characteristic. And at the same frozen temperature, the longer frozen time was, the more the qualities loss was. There was markedly loss in band intensity of myosin heavy chain, actin, paramyosin, troponin, and propomyosin from frozen meat within frozen storage.

Key Words –Porcine longissimus dorsi, Freezing, Quality property

I. INTRODUCTION

Frozen is one of the most important preservation methods for meat foods compared with other methods, it leads to a minimal loss of quality during long-term storage. Despite microbial spoilage being effectively terminated, quality deterioration, especially in texture, flavor and color, still take place during freezing and frozen storage due to the osmotic removal of water, myosin denaturation, mechanical damage, as well as cross-linking and aggregation of myofibrillar [1].The shelf-life of meat is generally determined by appearance, texture, flavour, colour, microbial activity and nutritive value. Frozen food quality is dependent upon many factors, including storage temperature and time, packaging, rate of freezing [2] and thawing [3], temperature fluctuations and freeze–thaw abuse [4, 5]. Soyer, Ozalp, Dalm s, and Bilgin [6] studied the effects of frozen storage on lipid and protein oxidation in chicken leg and breast meat. During frozen storage of shrimp and other shellfish products, the quality changes caused by freezing oxidation, denaturation of proteins, sublimation and recrystallization of ice crystals were researched [7]. Nevertheless, no basic information concerning the effect of the frozen storage time and temperature on the porcine physicochemical properties has been reported. The objective of this study was to determine the influence of different frozen storage time and temperature on drip loss, cutting force, redness, protein and lipid oxidation.

II. MATERIALS AND METHODS

1.Sample preparation

The longissimus muscles (whole loins) were obtained from 4 pig carcasses about 6 months of age within 12 h after slaughter, sliced into 20-mm-thick chops. A minimum of 20 chops were used for each treatment. Individually chops were packaged in moisture-impermeable polyethylene bags and frozen at – 5°C, – 18 °C, – 26 °C, – 35 °C, – 70 °C for 12 month. The frozen chops were thawed, using running water (about 22 °C) until the core temperature reached 0 – 2 °C at 1, 3, 6, 9, 12 month, and used for analysis.

2. Thawing loss determination

The thawing loss of the thawed porcine chops was determined from the known weights of chop before and after thawing and expressed as (AOAC).

3. Cooking loss determination

Porcine chops were individually placed in plastic bags and cooked by immersion in a water bath at 85 °C until they reached an internal temperature of 75 °C. The meat temperature was monitored with an iron constantan thermocouple with a probe inserted into the geometric center of the chop.

4. Cutting force determination

The cutting forces of the cooked chops were measured using a texture analyzer (Stable Micro System; TA: XT2i, England) with a knife blade (HDP/BSW) attached to a 25 kg load cell. The cross-head speed of knife blade was 5 mm/s with the distance of 25 mm.

5. Redness determination

The surface color of porcine chop was measured by a Color Difference Meter (WSC-S, Shanghai Physics and Optics Instrument Co., Shanghai, China).

6. Carbonyl content determination

The method of Oliver, Ahn, Moerman, Golstein, and Stadtman was used with slight modifications.

7. TBARS determination

Lipid oxidation was evaluated by TBARS according to Sinnhuber and Yu [8] with slight modifications as described by Wang and Xiong [9].

8. Gel electrophoresis

Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) of pork was performed with a Mini-PROTEAN Tetra Cell (BIO-RAD, U.S.A). A 10% acrylamide resolving gel and a 3% acrylamide stacking gel were used [10].

9. Statistical analysis

The experiment was replicated twice with at least triplicate analyses. Data were analyzed by using the General Linear Models procedure of Statistix 8.1 software package (Analytical Software, St. Paul, MN) for microcomputer. Analysis of variance (ANOVA) was done to determine the significance of the main effects. Significant differences ($P < 0.05$) among means were identified using Turkey procedures.

III. RESULTS AND DISCUSSION

1. Changes in thawing loss and cooking loss

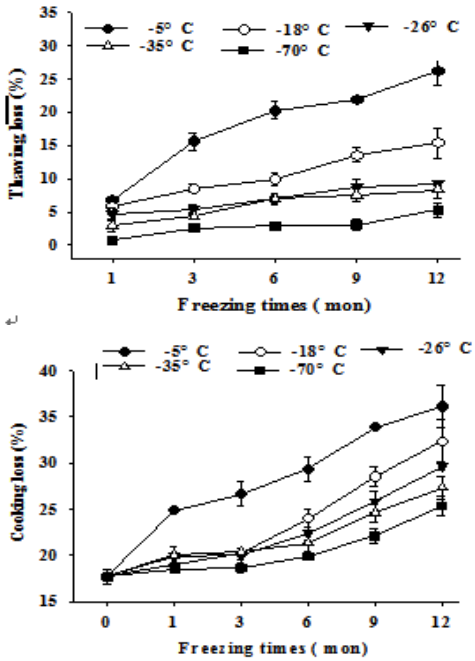

Fig.1. Changes in thawing loss and cooking loss of porcine longissimus dorsi at different frozen storage time and temperature

Effect of freezing time and temperature on thawing loss and cooking loss of porcine longissimus dorsi is presented in Fig. 1 during froze storage. Water loss was increased when the freezing time extended and temperature increased. Thawing losses of frozen porcine at – 5 °C, – 18 °C, – 26 °C, – 35 °C, – 70 °C were

30.3 %, 21.9 %, 20.4 %, 12.6 %, and 6.93 % for 12 month, respectively. And cooling losses of frozen porcine were 36.1 %, 33.9 %, 26.6 %, 29.4 %, and 24.9%, respectively. Increases of thawing loss and cooking loss over time in frozen storage had previously been reported in ground beef and ground pork [10]. Water loss was increased progressively during frozen storage due to protein aggregation and oxidative degeneration.

2. Changes in redness

Redness plays an important part in the appearance, presentation and acceptability of pork. Change in redness of froze pork are shown in Fig. 2. The a*-value decreased ($P < 0.05$) from 21.4 of fresh porcine to 10.3 (– 5 °C), 12.6 (– 18 °C), 14.8 (– 26 °C), 18.5 (– 35 °C), and 19.8 (– 70 °C) of frozen ones for 12 month. In pork, a decrease in a*-value (red color) of all samples were observed with the concomitant increase in TBARS formation (Fig. 4).

Jimenez-Colmenero, Serrano, and Cofrades [11] showed that extending frozen storage time could significantly decrease a* values. Generally, redness decrease is due to pigment degradation and lipid oxidation in meat. Yu, Lee, and Jong [12] also found that the increase of lipid oxidation in cooked turkey muscle was correlated with the decrease in redness. The denaturation of the globin moiety of the myoglobin molecule takes place at some stage during freezing, frozen storage and thawing [9]. The denaturation leads to an increased susceptibility of myoglobin to autoxidation and subsequent loss of optimum colour presentation.

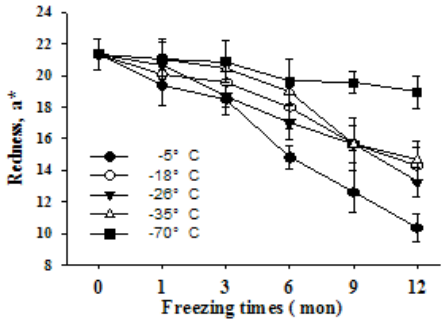

Fig.2. Changes in redness of porcine longissimus dorsi at different frozen storage time and temperature

3. Changes in cutting force

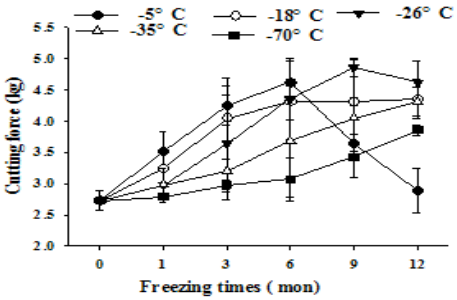

Fig.3. Changes in cutting force of porcine longissimus dorsi at different frozen storage time and temperature

The changes in cutting force were observed throughout the frozen storage up to 12 month (Fig. 3). Cutting force increased at – 18 °C, – 35 °C and – 70 °C as the frozen time extended. The increase in cutting force is correlated to the length of frozen storage. Hale, Waters [7] reported that thawed meat tends to display higher shear force than non-frozen meat . Nevertheless, cutting force increased and reached a maximum at 6 month (4.65 kg) and 9 month (4.86 kg) with a subsequent decrease up to the end of storage at – 5 °C and – 26 °C. The decrease in the shear force was attributed to the loss in membrane strength due to the ice crystal formation. The decrease in cutting force suggested loss in integrity of muscle fibers, resulting in the weakening of muscle 2. Frozen preocess causes protein denaturation, aggregation,or gelation which can result in the meat becoming either tenderized or toughened, depending on the temperature.

4. Changes in carbnonyl content and TBARS

The biochemical changes of protein oxidation in porcine longissimus dorsi were evaluated by measuring carbonyl content and sulfhydryl content. Oxidative phenomena in muscle foods take place immediately after slaughter (even pre-slaughter) when cellular mechanism controlling lipid oxidation no longer work. Protein and lipid oxidation appeared to occur simultaneously during frozen storage. Carbnonyl content and TBARS in the muscle of all samples increased during 12 month of frozen storage (Fig. 4). The oxidative denaturation of protein happened irrespective of the freezing rate, causing unfolding of the protein and resulting in

a higher cooking loss and thawing loss. This was possibly due to the susceptibility to denaturation of procine during the freezing process. The denaturation of muscle protein, induced by the freeze process, mainly contributes to the detrimental textural changes of muscle by ice crystal.

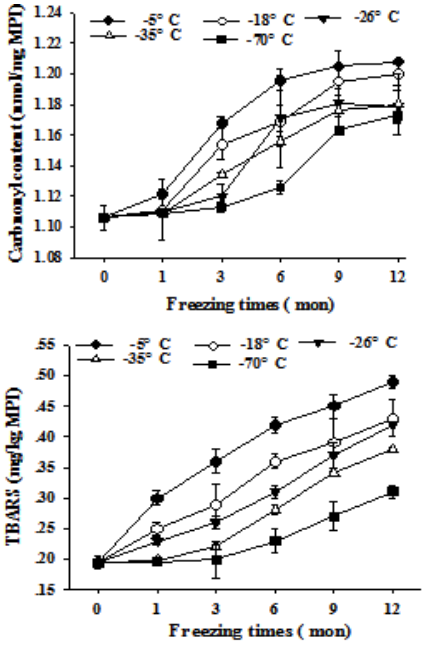

Fig.4. Changes in carbnonyl content and TBARS of porcine longissimus dorsi at different frozen storage time and temperature

5. Proteolytic changes

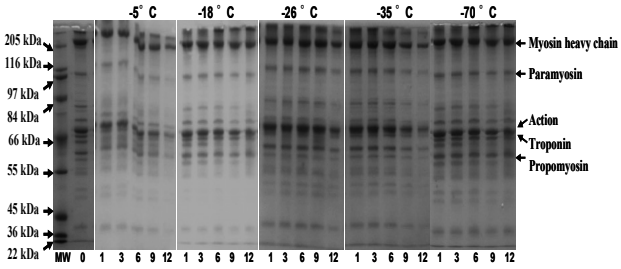

Fig. 5. Changes in SDS-PAGE pattern of porcine myofibrillar protein during frozen storage

SDS-PAGE patterns of porcine myofibrillar proteinsubjected to frozen storage are shown in Fig. 5. Electrophoretic band patterns of MP from frozen muscles were similar, but when compared with fresh muscle, the changes were very much evident. There was markedly loss of myosin heavy chain, actin, and other bands of MP from frozen meat within frozen storage. Myosin and actin are the major proteins which contribute to most of the functional properties of myofibrillar proteins.

IV. CONCLUSION

Porcine longissimus dorsi underwent quality changes and protein and lipid oxidation during frozen storage. Greater changes were observed in the samples kept under –5°C than in those. And at the same frozen temperature, the longer frozen time was, the more the qualities loss was. Therefore, the time and temperature of the sample storage induced the loss of meat quality during freezing. It would consequently be very beneficial to evaluate the drip composition of such samples using more modern techniques, such as proteomics.

ACKNOWLEDGEMENTS

This study was supported by Natural Science Fund of Heilongjiang Province in China (Grant no. C201122), Surface Program for Education Department of Heilongjiang Provincial (Grant no. 12511053) and Doctor Start Fund of Northeast Agriculture University (Grant no.2012RCB28).

REFERENCES

1. Benjakul, S., Visessanguan, W., Thongkaew, C., & Tanaka, M. (2003). Comparative study on physicochemical changes of muscle proteins from some tropical fish during frozen storage. Food Research International, 36: 787-795.
2. Hwang, J. S., Lai, K. M. & Hsu, K. C. (2007). Changes in textural and rheological properties of gels from tilapia muscle proteins induced by high pressure and setting. Food Chemistry, 104:746-752.
3. Xia, X. F., Kong, B. H., Liu, Q., & Liu, J. (2012). Physicochemical change and protein oxidation in porcine longissimus muscle as influenced by different freezeethaw cycles. Meat Science, 83:239-245.
4. Srinivasan, S., Xiong, Y. L., & Blanchard, S. P. (1997). Effects of freezing and thawing methods and storage time on thermal properties of freshwater prawns. Journal of Science and Food Agriculture, 75: 37−44.
5. Xia, X. F., Kong, B. H., Xiong, Y. L., & Ren, Y. M. (2010). Decreased gelling and emulsifying properties of myofibrillar protein from repeatedly frozen-thawed porcine longissimus muscle are due

to protein denaturation and susceptibility to aggregation.Meat Science, 3(85): 481-486.
6. Soyer, A., Özalp, B., Dalmıs, Ü. & Bilgin. V. (2010). Effects of freezing temperature and duration of frozen storage on lipid and protein oxidation in chicken meat. Food Chem, 120:1025-1031.
7. Hale, M. B., & Waters, M. E. (1981). Frozen storage stability of whole and headless freshwater prawns, Marine Fish Review, 42, 18−21.
8. Sinnhuber, R. O., & Yu, T. C. (1977). The 2-thiobarbituric acid reaction, an objective m easure of the oxidative deterioration occurring in fats and oils. Journal of Japan Oil Chemists' Society, 25:259-267
9. Wang, L. L., & Xiong, Y. L. (2009). Inhibition of lipid oxidation in cooked beef patties by hydrolyzeed potato protein is related to its reducing and radical scavenging ability. Journal of Agricultural and Food Chemistry, 53: 9186-9192
10. Benjakul, S., Seymour, T. S., Morrissey, M. T., & An, H. (1997). Physicochemical changes in Pacific whiting muscle proteins during iced storage. Journal of Food Science, 62:729−733.
11. Jiménez-Colmenero, F., Serrano, A., Ayo, J. & Solas, M, T. (2003). Physicochemical and sensory characteristics of restructured beef steak with added walnuts. Meat science, 123:1391-1398.
12. Yu, L. H., Lee, E. S., & Jong, J. Y. (2005). Effects of thawing temperature on the physico- chemical properties of pre-rigor frozen chicken breast and leg muscles.Meat Science, 71: 375-382.
13.Tokur, B., Ozkütük, S., Atici, E., Ozyurt, G & Ozyur, C. E. (2006). Chemical and sensory quality changes of fish fingers, made from mirror carp during frozen storage (− 18° C). Food Chemistry, 58:1245-1252.
14. Benjakul, S. &Bauer, F. (2001). Biochemical and physicochemical changes in catfish muscle asinfluenced by different freeze–thaw cycles – Food Chemistry, 72:207-212.
15. Jeong, J. Y., Kim, G. D., Yang, ,H. S. & Joo, S. T., (2011). Effect of freeze–thaw cycles on physico-chemical properties and color stability of beef muscle. Food Research International, 44: 3222-3229.
16. Leygonie, C., Britz, T.J. & Hoffman,L. C., (2012). Impact of freezing and thawing on the quality of meat: Review. Meat science, 91:93-99.