P-09-20

Relationship Between Freezing Rate And Protein Denaturation (#318)

Yuemei Zhang, Per Ertbjerg

University of Helsinki, Department of Food and Nutrition, Helsinki, Finland

Introduction

Freezing and thawing has been reported to decrease water-holding capacity of meat in terms of thaw loss, drip loss and cooking loss, presumably attributed to the mechanical damage caused by ice crystallization and protein denaturation [1]. Slow freezing has often been reported to produce more thaw loss compared to fast freezing [1]. Protein denaturation that takes place during freezing potentially contributes to a decrease in water-holding capacity of meat resulting in the formation of thaw loss [2], presumably due to an increased concentration of solutes in the unfrozen water phase of meat tissue. Denaturation of myofibrillar protein has been reported in frozen-thawed meat by observing lower denaturation enthalpy during heating [3]. The importance of protein denaturation for the formation of thaw loss is thus still not well understood. This paper aims to examine the effect of rate of ice crystal formation induced by slow and fast freezing on the denaturation of myofibrillar proteins in porcine *longissimus thoracis et lumborum* (LTL) muscle.

Methods

Six pork LTL muscles were cut into 12 steaks which were assigned to three treatments: 1) non-frozen control (stored at 2 ± 1 °C), 2) fast and 3) slow freezing (frozen at -20 °C and -80 °C, respectively). Frozen samples were thawed at 2 ± 1 °C for 24 h. Purge loss including thaw loss was taken as the average amount collected after cold storage for 24 and 48 h. Water-holding capacity of myofibrils was determined as described by Zhang & Ertbjerg [2]. Surface hydrophobicity of myofibrils was determined according to Liu et al. [4]. Each analysis was performed in triplicate. The relationship was evaluated by Tukey HSD test by the IBM SPSS Statistics 24 software.

Results

Freezing-thawing increased ($P < 0.01$) purge loss from 5.3% (non-frozen) to 6.3% (fast freezing) and 8.3% (slow freezing). Compared to fast freezing, slow freezing also resulted in decreased water-holding capacity of myofibrils and increased surface hydrophobicity of myofibrils (Fig. 1). This provides clear evidence for involvement of protein denaturation due to a negative relationship (r= -0.74) between surface hydrophobicity and water-holding capacity of myofibrils. A previous study on freezing of turkey meat also reported increased surface hydrophobicity, suggesting an unfolding of myofibrillar proteins [5]. We here propose a model of the influence of protein denaturation on the formation of thaw loss and the relationship with the freezing rate (Fig. 2). The water migration from inside of muscle fibers to outside during freezing will result in dehydration and transversal shrinkage of muscle fibers and myofibrils. Freezing at fast rate forms within a short time small ice crystals distributed inside and outside of fibers in parallel with moderate transversal shrinkage of muscle fibers. However, slow freezing results in more water migration to form large extracellular ice crystals, leading to a more severe transverse shrinkage of the fibers and a higher concentration of solutes and a corresponding lower pH in the unfrozen water, resulting in more severe myofibrillar protein denaturation as compared to a fast freezing rate. Upon thawing, more dehydrated and denatured structural proteins will reabsorb less water and hence explain the higher thaw loss in slow freezing.

Conclusion

Slow freezing caused a greater water loss upon thawing, as well as decreased water-holding capacity of myofibrils and increased surface hydrophobicity of myofibrils, indicating that slow freezing caused a larger denaturation of myofibrillar proteins than fast freezing.

Acknowledgements

The authors thank the China Scholarship Council for the financial support.

References

1. Calvelo, A. (1981). Recent studies on meat freezing. In R. Lawrie (Ed.), Developments in Meat Science. Vol 2. (pp. 125-156). London: Elsevier Applied Science.

2. Zhang, Y., & Ertbjerg, P. (2018). Effects of frozen-then-chilled storage on proteolytic enzyme activity and water-holding capacity of pork loin. Meat Science, 145, 375-382.

3. Wagner, J. R., & Anon, M. C. (1985). Effect of freezing rate on the denaturation of myofibrillar proteins. International Journal of Food Science & Technology, 20, 735-744.

4. Liu, J., Arner, A., Puolanne, E., & Ertbjerg, P. (2016). On the water-holding of myofibrils: Effect of sarcoplasmic protein denaturation. Meat Science, 119, 32-40.

5. Chan, J. T. Y., Omana, D. A., & Betti, M. (2011). Effect of ultimate pH and freezing on the biochemical properties of proteins in turkey breast meat. Food Chemistry, 127, 109-117.

Notes

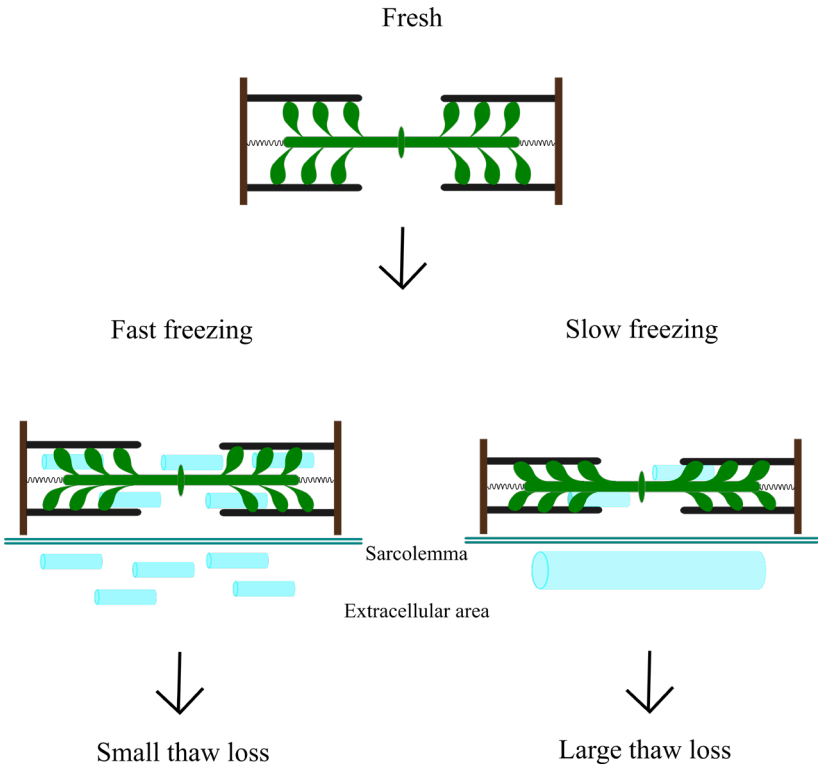

Figure 2 Model of freezing rate in relation to thaw loss.
The model explains how the freezing rate affect myofibrillar structure and thaw loss within the sarcomere (light blue color represents ice crystals).

Notes

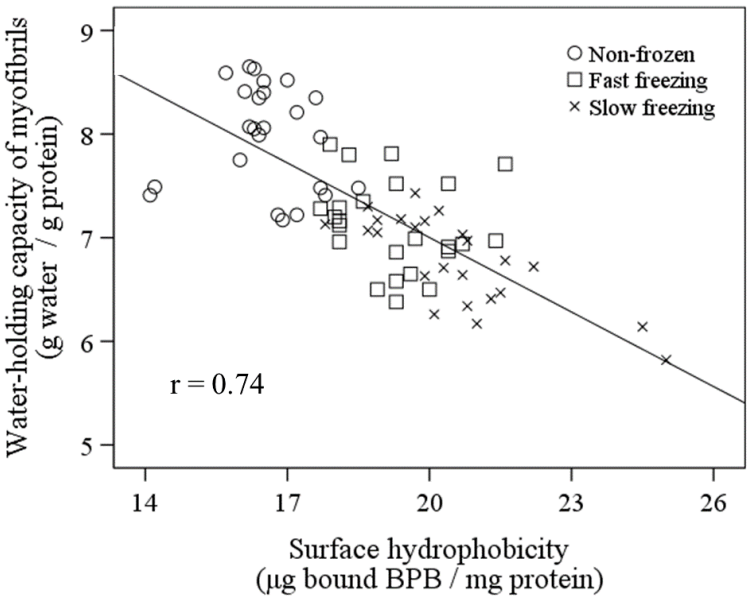

Figure 1 Relationship between water-holding capacity of myofibrils and surface hydrophobicity.
BPB: bromophenol blue.

Notes