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THE SECRET TO PREVENT THE THAW RIGOR - THE EFFECT OF THAWING TEMPERATURE ON THE SHEAR FORCE OF PRE-RIGOR FROZEN BEEF

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I. INTRODUCTION

Cold shortening and thaw rigor of muscles are related to the low temperature treatment of pre-rigor muscles. In our recent study, it was found that very fast freezing of *pre-rigor* muscle to -10 °C, did not cause thaw shortening. It is unknown, whether the thawing temperature of *pre-rigor* frozen muscles is particularly critical to the rate of development of *rigor mortis* and the muscle contracture of post-thawing beef muscle. In this study, frozen *pre-rigor* M. *Longissmus lumborum* (LL) were thawed under three different temperature-controlled conditions (0, 6, and 12 °C). The initial shear force was determined and the pH declines were monitored to identify the optimal thawing conditions that prevent "thaw shortening" in *pre-rigor* frozen beef.

II. MATERIALS AND METHODS

Six carcasses from Simmental crossbred cattle (18 to 24 months) were selected at random from a commercial abattoir. About 1 h after bleeding, the M. *Longissmus lumborum* (LL) were removed from the carcasses and then cut into 10×5×5 cm thick steaks. Within 3 h postmortem, the steaks were vacuum-packed and rapidly chilled by immersion in a cryogenic medium (-35 °C) until the core temperature reached -18 °C. Subsequently, they were transferred to a freezing room (-18 °C) and stored for 24 h. The frozen steaks were thawed in stages (thawed at 0 °C for 13 h until the center temperature reached -2 °C, followed by further thawing at 0 °C, 6 °C and 12 °C, respectively). Muscle samples (70 g) were taken at 0, 1, 3, 5, 7, 12, 24 and 48 h, and then frozen in liquid nitrogen and stored at -80 °C for subsequent pH determination, following the method of Sikes et al [1]. In addition, after reaching the ultimate pH (pHu), each steak was cut into two steaks, vacuumed and stored at 0- 4 °C, and the shear force measured after aging for 0, 3, 7 and 14 days[2]. The data for pH and shear force were analyzed by a two-way ANOVA using the MIXED procedure of SAS (Version 9.2, SAS Institute, Cary, USA), with treatment (thawing temperature), thawing time and their interaction as fixed terms for pH data and treatment (thawing temperature), storage time and their interaction as fixed terms for shear force, with carcass as a random term.

III. RESULTS AND DISCUSSION

As shown in Figure 1, the interaction of thawing temperatures and thawing time had a significant effect on the pH of *pre-rigor* frozen beef during thawing ($P < 0.05$). When thawed to -2 °C (0 h), all treatment groups exhibited relatively high pH values at around 6.5. As the thawing time increased, a decrease in pH was observed across all treatment groups ($P < 0.05$). This indicates that the very fast freezing treatment retains the glycogen in the muscle at initial levels. During the thawing process, metabolic activities in the muscle tissue resumed as indicated by the change in pH. The residual glycogen undergoes glycolysis, leading to the production of lactic acid and the accumulation of H^+. This biochemical process ultimately results in a decrease in pH. Following 7 and 12 h of thawing at 12 °C and 6 °C respectively, the pH values of the thawed samples decreased from about 6.5 to 5.4-5.8. Thawing for 24 h, the pH of 0 °C treatment group decreased to 5.7, and with the extension of thawing time, no significant differences were observed. Compared with the 0 °C and 6 °C thawing groups, the pH in the 12 °C group decreased at a faster rate, which is attributed to the relatively higher activity of enzymes related to energy metabolism, such as those involved in glycolysis, thus increasing the rate of pH decline. The interaction of the thawing treatments and storage time had an effect on the shear force of the beef steaks ($P < 0.05$). According to a previous study, tenderness changes in beef are detectable by a consumer when WBSF changes by either 5 Nor 10 N [3]. As shown in Figure 2, the shear force of the treatment groups at 0 °C and 6 °C were all below 75 N, approximately half that of the 12 °C treatment group. The observed shear force difference significantly exceeded the consumer acceptance threshold, indicating a

perceptible improvement in tenderness through sensory evaluation. With the extension of storage time, a decrease ($P < 0.05$) was observed in the shear force values for all treatment groups. Beef *longissimus lumborum* steaks with Warner-Bratzler shear force (WBSF) values exceeding 55.43 N were perceived as "tough", while those below 41.4 N were classified as "tender", which were disliked and liked by Chinese consumers [4]. After 14 days of storage, the shear forces of the 0 °C and 6 °C thawing groups decreased to below 40 N, which were tender and were liked by Chinese consumers. In contrast, after 14 days of storage, the shear force of the 12 °C thawing group was shown as 90 N, which remained higher than the initial shear forces of the 0 °C and 6 °C thawing groups, indicating tough. The shear force of 12 °C treatment group was higher than that of the 0 °C and 6 °C treatment groups ($P < 0.05$), indicating that thaw rigor occurred in the 12 °C treatment group, resulting in significant toughening, which may be related to the mild pH decline rate in 0 °C and 6 °C treatment groups, this inhibiting the energy metabolism, indicating that, slow energy metabolism during thawing may play a role in inhibiting the occurrence of thaw shortening.

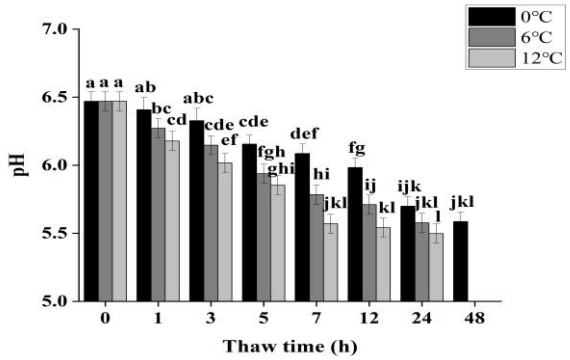


Figure 1. Effect of thawing temperature on pH decline of bovine M. *longissimus lumborum*. Different letters (a–l) indicate significant differences ($p < 0.05$).

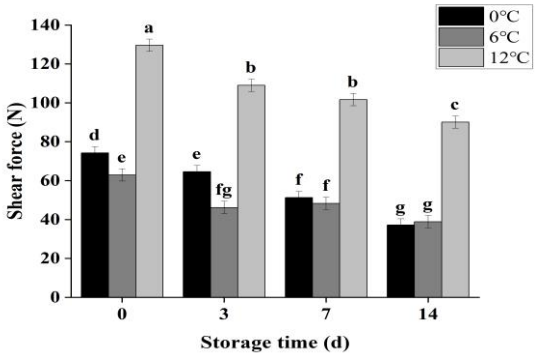


Figure 2. Effect of thawing temperatures on shear force of bovine M. *longissimus lumborum*. Different letters (a–g) indicate significant differences ($p < 0.05$).

IV. CONCLUSION

The effect of thawing temperature on the pH decline and shear force of *pre-rigor* frozen beef during the thawing period was found to differ significantly. Thawing *pre-rigo*r beef muscle at 0-6 °C prevented thaw shortening , while a thawing temperature of 12 °C did not, as the evidence showed that the former ones had almost half the values for shear force compared with the later one during the entire aging time for 14 days. In conclusion, freezing-thawing temperature plays a critical role in affecting muscle fiber contraction and tenderization. Future studies will elucidate the underlying mechanisms by which thawing temperature influences muscle fiber contraction and tenderization, in terms of enzyme activity of energy metabolism and changes in the microstructure. Furthermore, refinement of the optimal thawing temperature range, along with identification of the critical threshold for thaw shortening , will also be an essential component . The results obtained from this study has broken the myth that *pre-rigor* muscles cannot be frozen, and it has the great potential to be applied in red meat plants commerially to enhance the working efficeney and decrese weight loss during conventional carcass chilling.

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