71st ICoMST
GIRONA - CATALONIA - SPAIN
3rd-8th August - 2025

EFFECT OF CRYOGENIC FREEZING ON COLOUR AND TEXTURE OF BEEF

Alberto Brugiapaglia[1*], Riccardo Provera[2], Jacopo Pio Salvatico[1], Marzia Pezzolato[2], Elena Bozzetta[2], Giovanna Esposito[2]

[1] Department of Agricultural, Forest and Food Sciences, Grugliasco (Turin), Italy

[2] Istituto Zooprofilattico Sperimentale del Piemonte, Liguria e Valle d'Aosta, Turin, Italy

*Corresponding author email: alberto.brugiapaglia@unito.it

I. INTRODUCTION

In the food industry, cryogenic cabinet freezers are typically used for the quick freezing of food products. As regards meat and meat products, the cooling rate during freezing can greatly influence their microstructure and overall quality. In fact, a slow cooling rate promotes the formation of large ice crystals, and consequently a more pronounced deformation of the original cell structure. In meat, large crystals can also mechanically damage myofibrillar structures and cause a decrease in water holding capacity, which, in turn, negatively affects colour, flavour, tenderness and juiciness. In contrast, faster cooling rates results in the formation of smaller crystals, and therefore less damage to the cellular structure. For this reason, fast cooling rates are preferred for freezing food products in general and meat products in particular. In addition, cryogenic freezing is not only beneficial for physicochemical quality attributes but also offers better microbiological safety. It was reported that the cryogenic freezing resulted in a greater loss of bacterial cell viability (especially mesophiles and psychrotrophs) compared with conventional freezing methods. The present study is part of a project founded by the Italian Ministry of Health, which was aimed at exploring the possibility of improving meat safety through cryogenic freezing. In particular, the aim of this study was to assess the effect of the cryogenic freezing on beef colour and texture, which are the most important quality attributes that determine the overall acceptance of meat by consumers.

II. MATERIALS AND METHODS

A total of 12 female young Piemontese cattle, on average 16±1 months of age and 490±68 kg of live weight, were slaughtered in an EU-licensed slaughterhouse. After 3 days in which the carcasses were chilled at 4°C, the *Triceps brachii* (TB) was taken from the right side of each carcass and immediately transported under refrigerated conditions to the "La Granda" facilities and stored at 4°C for four days. On day seven of total aging time, two adjacent 3 cm thick steaks were cut from each TB. The steaks were individually weighed, labelled, and packaged at an intermediate degree of vacuum. Twelve steaks, obtained from each TB, were assigned to cryogenic freezing (CF), while the other 12 steaks (UF) were used as a reference. Cryogenic freezing was performed in a Dohmeyer cabinet freezer (model DOH-BOX-CUL-EASY-LIN) equipped with liquid nitrogen. The steaks were frozen at -60°C for 20 min. A series of trials were initially conducted to estimate both the final temperature of the product and the freezing time. After freezing, the steaks were stored at −21±1°C for 2 days before thawing and testing. The thawing process occurred in a chilling room at 4°C for 24 h. Conversely, the unfrozen steaks were stored at 4°C for 2 days and then processed. Immediately after, steaks were removed from their packages, blotted dry and weighed. The ultimate pH (pHu) of each steak was directly measured by using a portable pH-meter equipped with a penetration electrode (Crison; model PH25 +). The colour measurements were taken after 1 hour of blooming in three different locations on the surface of each steak with a Minolta CM600d Spectrophotometer set with the specular component excluded, D65 illuminant and 10° standard observer. The results were expressed as lightness (L^*), redness (a^*), and yellowness (b^*) values in the CIE $L^*a^*b^*$ colour space [1]. The parameters Chroma (C^*), related to colour intensity, and hue angle (h^*), related to the change of colour from red to yellow, were calculated as follows: $C^*=(a^{*2}+b^{*2})^{0.5}$; $h^*= \tan^{-1} b^*/a^*$. The measured colour parameters were also used to calculate total colour changes $[\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}]$ between frozen and unfrozen steaks. Reflectance spectra data were used to calculate myoglobin (DMb), oxymyoglobin (OMb) and metamyoglobin (MMb) values according to Kryzwicki [1]. Instrumental beef texture was evaluated by Warner Bratzler shear force (WB) and Texture Profile Analysis (TPA) tests using a TA HD plus Texture Analyzer [2]. For WB assessment, steaks were weighed and cooked in a water bath to an internal temperature of 71°C. After cooking, steaks were allowed to equilibrate to room temperature, blotted dry, and reweighed. On the following day, at least six square cross-section cores of 1 cm^2 were removed parallel to the muscle fibre orientation. Cores were subsequently sheared perpendicular to the longitudinal direction of the muscle fibres. The shear force was expressed as the average maximal force in Newtons (N). TPA was carried out on raw meat samples. Six samples, with a cross-sectional area of 1 cm^2, parallel to the longitudinal orientation of the muscular fibres were taken. Samples were compressed, perpendicular to muscle fibre orientation, in two consecutive cycles to 50% of their original height using a cylindrical probe of 10 mm diameter. The strips were placed in a Plexiglass device fitted with two lateral walls to prevent transversal elongation of the sample.

Hardness (N) and chewiness (N) were determined. Data were subjected to ANOVA by considering the freezing treatment as a fixed factor (IBM SPSS statistics, version 29).

III. RESULTS AND DISCUSSION

A significant difference in the pHu values was observed, as the pHu value of CF steaks was higher than that of UF steaks ($p<0.05$). However, as samples were collected 3 days *post mortem*, the difference was relatively minor (~0.1 pH unit; CF and UF: 5.56 *vs* 5.51, respectively), and the two pHu values fell within the normal range of beef ultimate pHu [3]. The freezing treatment slightly influenced the colour of the steaks. CF steaks showed lower a^* (23.98 *vs* 25.85) and C^* (25.91 *vs* 27.74) values ($p<0.05$), which translate into a product which is dull in appearance, while the impact of the cryogenic freezing on L^* and b^* values was not significant (p-value: 0.933 and 0.614, respectively). In this study, despite the statistical significance, the differences in colour between CF and UF steaks are less than 2 units, which would be practically less meaningful. This could be attributed to the fact that in this study, the CF steak were aged prior to freezing, which likely assisted blooming ability by suppressing oxygen-utilizing enzyme activities during aging [4]. Concerning the chemical state of myoglobin, the CF steaks showed a lower OMb (59.74% *vs* 65.40%; $p<0.05$) and a higher MMb percentage than that of UF steaks (22.21% *vs* 15.7%; $p<0.05$). According to [5], freezing and thawing may favour the denaturation of the globin moiety of the myoglobin molecule, which ultimately increases its susceptibility to be oxidised. The colour difference, expressed as ΔE, was equal to 1.89. Based on ΔE, it is possible to predict whether the consumer will notice a change in meat colour. This is a very important consideration in retail displays, where beef consumers make their purchasing decisions mainly based on beef colour [6]. In this case, a colour difference value (ΔE) less than 2 indicates that the colours are very similar, and only an expert with a trained eye or a consumer with significant experience might notice the difference. Regarding texture, while most of studies have reported positive relationships between freezing and tenderness [7] in our experiment, no significant effect of the freezing process on meat tenderness was observed in terms of Warner-Bratzler (30.21 N *vs* 28.34 N), Hardness (12.15 N *vs* 12.56 N) and Chewiness (5.57 N *vs* 5.61 N) values for CF and UF, respectively.

IV. CONCLUSION

Small or no significant impacts of cryogenic freezing on colour and texture attributes of aged TB were found. These observations could suggest that cryogenic freezing of previously aged meat minimizes the amount of water loss due to the freezing/thawing process and thus add more value to the aged-frozen meat products also by minimizing the differences in colour and texture parameters.

ACKNOWLEDGEMENTS

This study was supported by the Italian Ministry of Health, under Grant nr. IZS PLV 04/23 RC.
The Authors would like to thank the staff of the breeder's Consortium "La Granda" for technical assistance and for providing meat samples.

REFERENCES

1. King, D. A., Hunt, M. C., Barbut, S., Claus, J. R., Cornforth, D. P., Joseph, P., Kim, Y. H., Lindahl, G., Mancini, R. A., Nair, M. N., Merok, K. J., Milkowski, A., Mohan, A., Pohlman, F., Ramanathan, R., Raines, C. R., Seyfert, M., Sørheim, O., Suman, S. P., Weber, M., (2023) "American Meat Science Association Guidelines for Meat Color Measurement", *Meat and Muscle Biology* 6(4): 12473, 1-81.
2. Belk, K. E., Dikeman, M. E., Calkins, C. R., King, D. A., Shackelford, S. D., Hale, D., Laird, H. (2015). Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. American Meat Science Association, Champaign, IL. pp. 6–104.
3. Stafford, C.D., Taylor, M.J., Spurling, R.A., Crump Z.C., Alberto A.F., Alruzzi M.A., Ali L.A., Okamoto L.L., Bird, T.R., Page, C.M., Thornton K.J., Dai, X., K. Matarneh S.K.(2024). The influence of different freezing and thawing conditions on the quality of beef rib primals. Food Science and Technology, 209. 116771.
4. Kim, Y. H. B., M. Frandsen, K. Rosenvold. (2011). Effect of ageing prior to freezing on colour stability of ovine longissimus muscle. Meat Sci. 88:332–337. https://doi.org/10.1016/j. foodchem.2012.04.109
5. Jeong, J.Y., Kim, G.D., Yang, H.S., Joo, S.T. (2011). Effect of freeze–thaw cycles on physicochemical properties and color stability of beef semimembranosus muscle. Food Research International, 44, 3222–3228.
6. Tkacz, K., Modzelewska-Kapituła, M., Więk, A., Nogalski, Z., (2020). The Applicability of Total Color Difference ΔE for Determining the Blooming Time in *Longissimus Lumborum* and *Semimembranosus* Muscles from Holstein-Friesian Bulls at Different Ageing Times. Applied Science, 10, 8215.
7. Biglia, A., Messina, C., Comba, L., Ricauda Aimonino, D., Gay, P., Brugiapaglia, A., (2022). Quick-freezing based on a nitrogen reversed Brayton cryocooler prototype: Effects on the physicochemical characteristics of beef *Longissimus thoracis* muscle. Innovative Food Science and Emerging Technologies, 832, 103208.