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

THE ALTERNATING ELECTRIC FIELD INHIBITED ICING AND IMPROVED THE QUALITY OF YAK MEAT DURING NON-CRYSTAL FREEZING STORAGE

Hengxun. Lin[1], Yiping. Pei[1], Yiping. Yang[1], Qiuyao. Xu[1], Yuan. Li[1], Xia. Li[1*], Christophe. Blecker[2], Chunhui Zhang[1*]

[1] Institute of Food Science and Technology, Chinese Academy of Agricultural Sciences, Beijing, China.

[2] Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium

*Chunhui Zhang email: zhangchunhui@caas.cn

I. INTRODUCTION

Ice crystallization has been the main cause of the deterioration of frozen meat quality, because ice crystal expansion causes mechanical damage to the muscle tissue. Non-crystal freezing (NCF) storage is a technological extension based on the theory of traditional supercooling, in which the technology breaks the traditional nucleation temperature of an organism (generally −1.5 ℃ to −3 ℃ for meat) by external means to achieve a lower preservation temperature (−4 ℃ to −8 ℃ and even lower temperature) compared with supercooling and without ice crystallization [1]. AEF triggered the chemical reaction of hydrogen bond networks, induced torque and thermal motion of water molecules and increased the difficulty of water molecules to enter the ice lattice [2]. In this study, we designed a specific AEF-assisted cryopreservation system to examine the potential and the stability improvement of AEF in NCF storage for inhibited ice nucleation and the quality of yak meat during NCF storage.

II. MATERIALS AND METHODS

Yak muscle (*Longissimus thoracis et lumborum*, LTL, N=9) were obtained from nine yaks (live weight of 250 ± 10 kg and aged two and a half years). Each LTL muscle was divided into 13 steaks (7 cm × 7 cm × 4 cm in size; ~250 ± 10 g each). These steaks were randomly numbered 1–13 for different treatments (3 storage methods × 4 storage time + 1 fresh sample). Thirty-nine steaks from three LTL muscles in each batch were allocated to three storage methods (chilling at 4 ℃; sub-freezing at −4.5 ℃; and NCF at −4.5 ℃ with AEF-assiting) for different storage times (7, 14, 21 and 28 days) and one fresh group, according to the steak serial number.

To continuously monitor the whether ice crystals form or not, we designed a NCF storage system with AEF-generating module, temperature control module, infrared thermal imager, and camera to continuously record the storage process of yak meat. The weight loss and pH of yak meat were detected . The measurements of shear force, total aerobic plate count (TAC) and total volatile basic nitrogen (TVB-N) followed Holman and Hopkins [3], the Chinese National Standard GB5009.228-2016, and GB4789.2-2022 respectively.

The whole experiment was repeated three times with three different batches. The analyses in each batch experiment were done at least in triplicate. All values are presented as means ± standard errors (SE). The Tukey's test was used to test the differences between means. A difference was significant at $P < 0.05$.

III. RESULTS AND DISCUSSION

As shown in Figs. 1a–c, all −4.5 ℃ samples exhibited phase transition and icing within 3 days of the storage period. When the phase transition occurs, the core temperature of the −4.5 ℃ samples rapidly increased to the freezing temperature (~−1.5 ℃) in <2 min owing to the release of latent heat. The phase transition and rapid temperature increase were not detected in the NCF samples, and the freezing curves of the NCF samples were similar to those of the 4 ℃ samples, indicating that the NCF samples maintained the non-frozen state during storage.

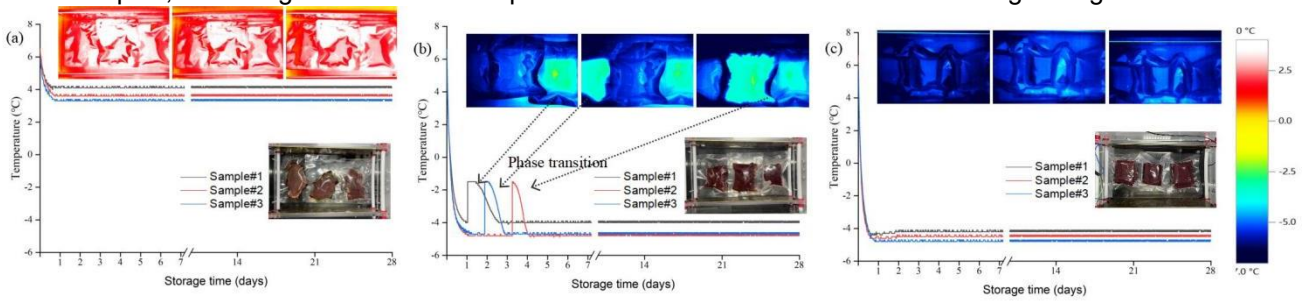


Figure 1. Temperature curves and thermal images of yak meat with (a) 4 ℃, (b) -4.5 ℃, and (c) NCF treatments.

As shown in Fig. 2a, weight loss of all groups increased with the extended storage time of 28 days. During the storage period, the −4.5 ℃ group had the highest weight loss among the other groups, followed by the 4 ℃ group.

Compared with −4.5 ℃ and 4 ℃ treatments, NCF storage reduced weight loss by an average of 5.95% ± 0.32% and 2.07% ± 0.33%. NCF storage delayed protein denaturation at temperatures below the nucleation point and exhibited ice formation. Thus, maintaining the low weight loss throughout the storage period.

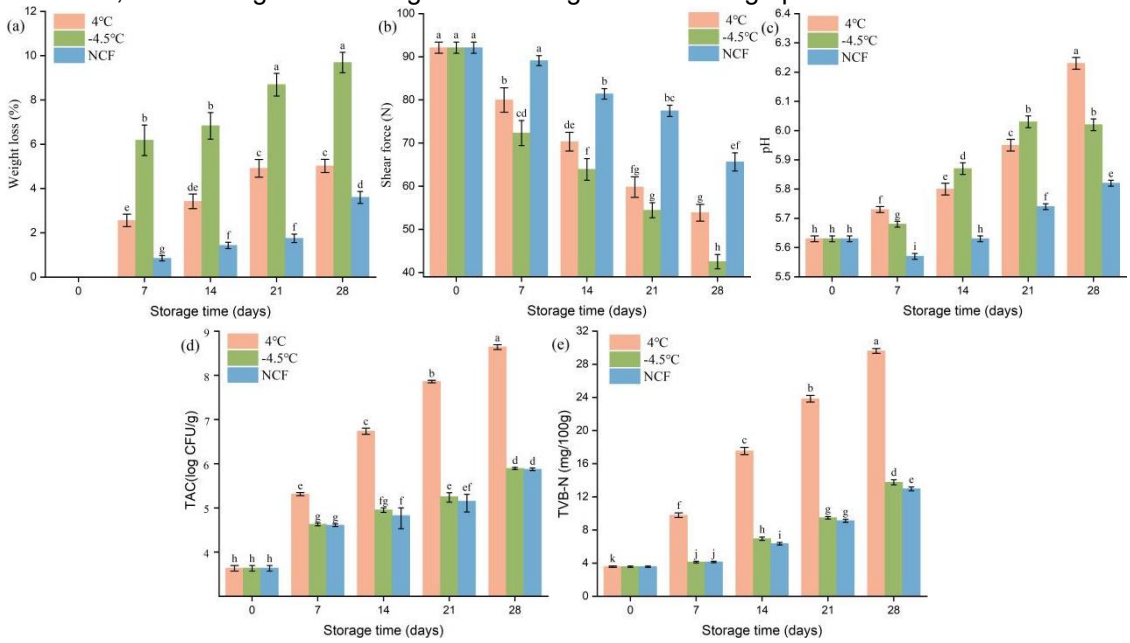


Figure 2.Weight loss (a), shear force (b), pH (c), TAC (d), TVB-N (e) of yak meat with different storage treatments.

All groups exhibited a gradual decrease in shear force over the storage period (Fig. 2b). Among them, the shear force of the −4.5 ℃ samples is significantly lower than that of the NCF samples, followed by the 4 ℃ samples.
As shown in Fig. 2c, the pH value of all groups increased with the extension of storage time. Compared with the −4.5 ℃ and 4 ℃ samples, NCF samples exhibited the slowest growth rate in pH value during the storage period.
As shown in Fig. 2d, compared with the NCF and −4.5 ℃ samples, the TAC of the 4 ℃ samples exhibited a faster increasing rate, from 3.43 log CFU/g on Day 0 to 8.44 log CFU/g on Day 28. The TAC of the 4 ℃ samples exceeded the limitation of food microbiological safety standards of 6.00 log CFU/g by Day 14. Meanwhile, the TAC of the NCF and −4.5 ℃ samples remained lower than 6.00 log CFU/g (5.48 and 5.78 log CFU/g, respectively) on Day 28. The low temperature of NCF and −4.5 ℃ treatments inhibited microbial growth compared to 4 ℃. The changing trend of TVB-N of all groups was similar to that of TAC (Fig. 2e).

IV. CONCLUSION

This study developed a novel NCF storage method by AEF, which could preserve yak meat at the temperature below ice nucleation temperature (−4.5 ℃) without ice formation. NCF inhibited icing and avoided freezing damage caused by ice crystals, which reduced weigh and shear force losses. Results of microbial and physicochemistry analyses indicate that compared with chilled samples (4 ℃), the low storage temperature achieved by NCF prolonged the shelf life of yak meat for >14 days. NCF may be a nove storage method that partially replaces traditional freezing for long-term transport and storage of meat, keeping it fresh and non-frozen.

ACKNOWLEDGEMENTS

This work was supported by Qinghai provincial central government guide local science and technology development fund project (2024ZY026) and the National Natural Science Foundation of China (No. 32172150).

REFERENCES

1. Lin, H.; Wu, G.; Hu, X.; Chisoro, P.; Yang, C.; Li, Q.; Blecker, C.; Li, X.; & Zhang, C. (2024). Electric fields as effective strategies for enhancing quality attributes of meat in cold chain logistics: A review. Food Research International, 193, 114839.
2. Lin, H.; Wang, J.; Chisoro, P.; Wu, G.; Zhao, S.; Hu, X.; Liu, Y.; Jia, W.; Yang, C.; Li, Q.; Zhang, C.; Blecker, C.; & Li, X. (2024). Changes in freezing parameters and temperature distribution of beef induced by AC electric field: Alleviation on freezing damage and myowater loss. Journal of Food Engineering, 387, 112343.
3. Holman, B.W.B.; & Hopkins, D.L. (2019). Contrasting the quality traits of aged bolar blade, topside and striploin cuts sourced from dark cutting and control Australian beef carcasses. Meat Science, 149. 24-30.