

BEYOND FREEZING: NIR INSIGHTS INTO MEAT SUPERCHILLING AND RADIATION PENETRATION

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The cold chain plays a crucial role in preserving and transporting perishable food, ensuring quality and safety for consumers [1]. By optimising processes within the cold chain, we can not only reduce food waste but also promote sustainable resource management. In this context, superchilling has emerged as a promising strategy to extend the shelf life of fresh meat by 2-4 times compared to conventional refrigeration, while avoiding some of the disadvantages of freezing, such as quality degradation and higher energy consumption [2]. Despite its potential, the lack of fast and non-destructive tools for real-time monitoring of ice crystallisation during superchilling remains a significant challenge for both research and industrial applications [3]. Furthermore, understanding the penetration of NIR radiation into meat under different crystallisation conditions is crucial to optimise its application in food processes [4].

This study has two main objectives: 1) to monitor ice crystallization in real-time during superchilling and 2) to investigate the penetration depth of NIR radiation into pork loin samples treated under different thermal conditions. For the superchilling study, six pork loin cubes ($3 \times 3 \times 3$ cm) were exposed to airflow at -18°C and 1.3 m/s. The process was monitored using a MicroNIR spectrometer (Viavi Solutions, USA) and a temperature sensor (Elitech GSP-6, UK), with data recorded every 2 minutes. For the radiation penetration study, duplicate samples of three different sizes ($3 \times 3 \times 3$ cm, $2 \times 2 \times 2$ cm, and $1 \times 1 \times 1$ cm) were analyzed sequentially under three different thermal conditions: refrigerated, superchilled, and frozen. Principal Component Analysis (PCA) conducted on the NIR spectra, collected during superchilling process, showed a distribution pattern consistent with the theoretical freezing curve, supported by loadings revealing the influence of water's physical state.

Multivariate control charts, based on PCA scores, were calibrated considering four freezing tests, and subsequently validated with two independent tests. The initial and final point of the transition phase were determined by ΔPC1 between two consecutive samplings.

Regarding the penetration study, the results showed different depths of NIR penetration, indicating the influence of thermal history on the interaction between NIR radiation and the flesh matrix.

These findings demonstrate the potential of NIR spectroscopy not only for optimizing the superchilling process but also for providing valuable insights into the interaction between radiation and food matrices. The results lay the foundation for more efficient, precise, and sustainable industrial protocols for food transformation and preservation.

References

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