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Improving energy efficiency in meat processing: accelerated cooling of pork in sodium chloride solutions

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GOAL OF THE STUDY

This study aimed to evaluate the effect of NaCl concentration on the cooling rate of pork meat, weight change, and salt uptake during immersion chilling under controlled refrigerated conditions. Four experimental groups were established, each using NaCl solutions at concentrations of 1, 5, 10, and 15%, respectively. A control group using distilled water was included in each experimental cycle for comparison.

METHODOLOGY OF THE INVESTIGATION

All samples were completely submerged in their respective NaCl solutions and placed in a refrigeration unit maintained at a nominal temperature of 2°C. However, it is important to note that external environmental conditions may have influenced the consistency of the internal temperature. The experiments corresponding to the four different NaCl concentrations were conducted over four consecutive days. In each trial, two samples were prepared: one control sample using distilled water and one experimental sample containing a NaCl solution of varying concentration. Specifically, the first experiment involved Sample 1 (distilled water) and Sample 2 (1% NaCl); the second involved Sample 3 (distilled water) and Sample 4 (5% NaCl); the third included Sample 5 (distilled water) and Sample 6 (10% NaCl); and the fourth comprised Sample 7 (distilled water) and Sample 8 (15% NaCl).

Temperature data were recorded at 2 min intervals over a 16 h period using a "Therma Data Logger". The primary cooling performance indicator was the time required for the core temperature of the meat to reach 4°C and 3 °C –thresholds considered critical for suppressing microbial activity and ensuring product safety.

Upon completion of the 16 h refrigeration cycle, all samples were retrieved. Final mass was measured to assess net weight variation resulting from immersion, and the NaCl content (%) in the meat was analysed to quantify NaCl diffusion during the cooling process. This methodology facilitated a comprehensive evaluation of cooling effectiveness, as well as the extent of water and solute migration and the influence of solution salinity on thermal behaviour.

Statistical analysis: All experiments were performed at least three times. The data is presented as mean ± standard error.

MAIN RESULTS FROM THE STUDY

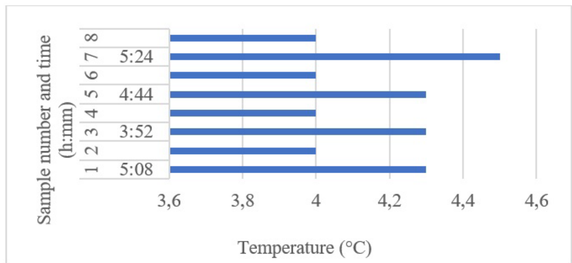

Fig. 1. Cooling time to 4 °C for pork samples in NaCl solutions versus distilled water

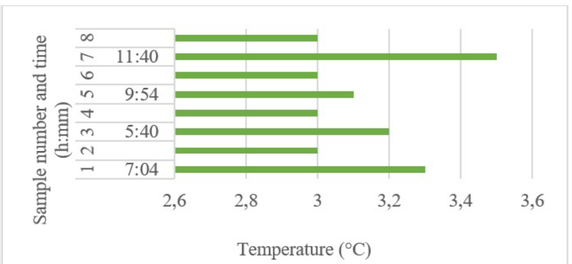

Fig. 2. Cooling time to 3 °C for pork samples in NaCl solutions versus distilled water

Comparing the temperature reached at the same time point at which the NaCl-treated samples attained 4°C, the respective distilled water samples had slightly higher internal temperatures: samples 1, 3, and 5 recorded 4.3°C, and sample 7 recorded 4.5°C. A similar trend was observed at the 3°C threshold, where the corresponding control samples reached 3.3°C (sample 1), 3.2°C (sample 3), 3.1°C (sample 5), and 3.5°C (sample 7). These findings confirm the enhanced thermal transfer properties of the saline environment, promoting faster and more efficient cooling of the pork samples. Upon completion of the cooling process, the core temperatures of all meat samples were recorded. Additionally, variations in sample weight and NaCl content were assessed. The corresponding data are presented in Table 1.

Table 1. Final core temperature, weight variation, and NaCl content of meat samples after cooling

Sample number	Temperature at the end of cooling (16 h), °C	Weight after cooling (g)	Difference in weight, %	NaCl content in the sample, %
1	1.8	39.45±0.36	3.76	-
2	1.5	41.04±0.39	7.80	0.62
3	2.1	40.88±0.38	5.66	-
4	2.1	43.78±0.40	11.63	2.48
5	2.7	36.95±0.35	-0.96	-
6	2.7	40.97±0.38	9.05	7.56
7	2.7	37.42±0.35	-1.01	-
8	2.2	40.44±0.38	6.51	8.37

CONCLUSIONS

Across all tested concentrations (1, 5, 10, and 15%), samples immersed in NaCl solutions reached target core temperatures of 4°C and 3°C more rapidly – up to twice as fast in some cases – indicating enhanced thermal conductivity and energy efficiency. The final salt content measured in the meat samples indicates the conditions under which pre-packaged chilling may be necessary. While the presence of NaCl clearly enhances cooling performance, the variation in cooling speed between different concentrations appears limited. This suggests that increasing salinity beyond a certain point does not linearly improve thermal transfer. Therefore, further investigation into the thermophysical and thermodynamic properties of the solutions is necessary to fully explain the observed differences in heat transfer rates. These findings support the potential of NaCl immersion chilling as an energy-efficient and quality-preserving method in meat processing, with room for optimization based on solution properties.