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Weight loss in superchilled pork as affected by cooling rate

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ABSTRACT

This study aimed to identify in which extent cooling rate in pork subjected to superchilling influences the final weight loss after storage. Different cooling systems (brines at −15 °C and -9 °C, forced air at −18 °C and still air −24 °C) led to a range of cooling rates in pork model systems. The ice crust on the surface of pork grew faster in those systems with a higher energy flux. Higher cooling rates led to lower weight loss after superchilling storage, highlighting the importance of using fast cooling systems for superchilled pork.

1. Introduction

The economic advantage of commercializing fresh compared to frozen pork is evident, due to the better quality, higher price and lower energy costs of the former. However, the shelf-life of chilled pork is not long enough for reaching distant markets.

Superchilling (SC) is a process in which foods are kept at temperatures slightly below their initial freezing point (Kaale et al., 2011), which in pork means −1 to -2 °C. Microbial spoilage in superchilled meat is delayed compared to conventional chilling, which prolongs the shelf life of pork up to 16 weeks (Duun et al., 2008; Kaale et al., 2011).

In SC, during cooling, the temperature of the surface is brought below the freezing point of pork, usually by impingement freezing equipment, and a layer of ice is formed on the surface (Duun et al., 2008). The temperature equalizes within the product during storage, and the ice crust may remain or not depending on the storage conditions (Kaale et al., 2011). Crust freezing during the initial phase of cooling may cause structural damages to muscle cells, leading to a higher drip loss and consequently, to a lower meat quality (Kaale et al., 2013). It seems clear that a higher amount of frozen water might lead to more relevant damage of the muscle structure and lower meat quality. The size and distribution of ice crystals formed upon cooling also have an effect on meat quality: faster freezing rates lead to a higher amount of smaller and intracellular crystals, while slower freezing contributes to a higher proportion of bigger extracellular ones (James, 2009). Upon crust-freezing, this could have a subsequent influence on the quality of the superchilled meat once the temperature has equalized during the storage.

This study aimed to elucidate in which extent some of the commercially used cooling rates for SC pork could influence weight loss.

2. Material & methods

Four different cooling systems were studied: immersion in two different brines (−15 °C and -9 °C), dynamic (forced air) cooling at −18 °C and static (still air) cooling at −24 °C. Heat transfer coefficients were calculated to ensure that they were representative of the systems used in industrial settings. Their cooling rates were calculated, both by following the drop of temperature at different depths in a controlled pork model, and by following the formation of the ice crust in pork models. Weight loss in the samples cooled under the four different systems after 7 days of superchilling storage (−1.5 °C) was determined.

2.1. Calculation of heat transfer coefficients

Heat transfer coefficients were determined by measuring the thermal response in an aluminium block with the same geometry as the pork samples. The high thermal conductivity of aluminium

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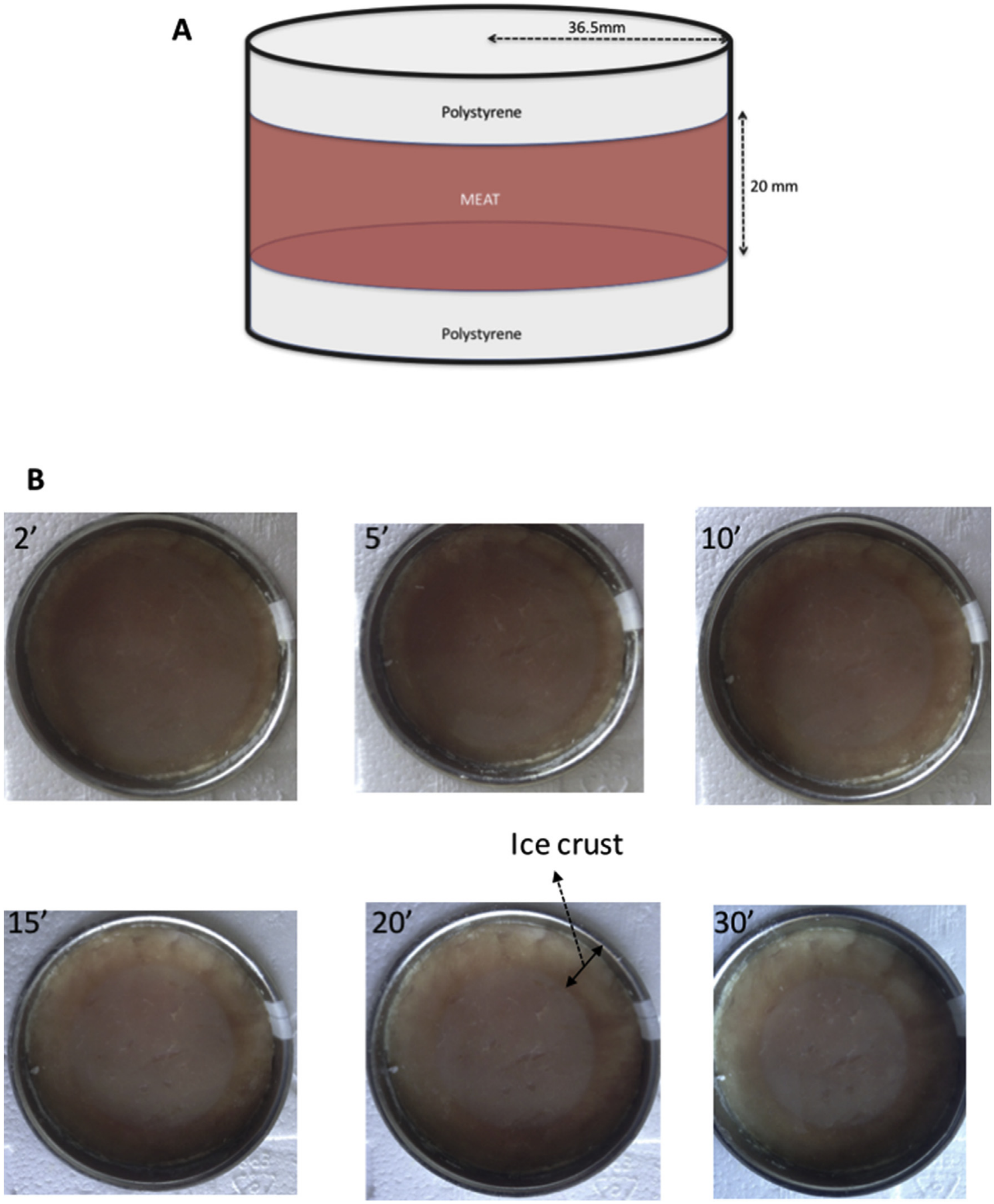

Fig. 1. (A) Scheme of the meat model system used for evaluating temperature drop at different depths with different cooling rates. The same system was used for calculating the ice crust formation. The set of pictures (B) shows the growth of the ice crust in pork cooled down in a brine at −15 °C.

($200\ \mathrm{W\ m^{-1}\cdot K^{-1}}$) ensures a uniform thermal response and the heat transfer coefficients can be calculated from the thermal curve by equation (1):

$$\Omega = \left(\frac{T_s - T}{T_s - T_0}\right) = e^{-\left(\frac{h \cdot A}{m \cdot c_p}\right) \cdot t} \tag{1}$$

Where T_s is the temperature of the surrounding medium, T is the actual measured temperature of the aluminium block at time t, and T_0 is the initial temperature of the aluminium block. A is the exposed surface area of the block, m is the mass and c_p is the specific heat capacity of aluminium. The determined heat transfer coefficients (h) were 900–1000 $\mathrm{W\ m^{-2}\ K^{-1}}$ for the brines, 17–18 $\mathrm{W\ m^{-2}\ K^{-1}}$ for the dynamic air system and 5–6 $\mathrm{W\ m^{-2}\ K^{-1}}$ for the static air system.

2.2. Cooling rates

In order to address the heat flow in meat under different cooling rates, an infinite cylindrical meat model was used. A total of 4 *Longissimus dorsi* muscles were cut using a sharpened edge stainless steel cylinder of 73 mm diameter. Cylindrical shaped meat pieces were fitted into aluminium cans of the same diameter,