The effect of freezing rate of meat on rheological property of pork sausage

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Introduction

Freezing is an effective method of storage and distribution for most foods to ensure their microbiological safety, and is available worldwide. It is known that some foods undergo changes in their physical properties by freezing, for example, whole potatoes, raw radish and tofu. Generally, it has been accepted that the degree of freezing denaturation of meat as a result of freezing is relatively low. Frozen rather than fresh meat is usually used in the meat industry in the preparation of emulsion-style products. Freezing, however can cause chemical and structural changes in meat, depending on the species and storage conditions (temperature, duration, temperature fluctuations, *etc*) (Matsumoto, 1980; Calvelo, 1981; Smith, 1987). Such changes occur largely as a result of alterations in the characteristics of proteins, which consequently lose functional quality (Jimenez C. F. and Borderias, 1983), leading to loss of product quality (Miller *et al.*, 1980; Verma *et al.*, 1985). Miller *et al.* (1980) found that the use of frozen meat in frankfurters adversely affected their texture, although they found no significant differences in the colour, juiciness or cooking loss (Verma *et al.*, 1985). The purpose of this study was to reduce the freeze denaturation of meat to ensure high quality sausage.

Materials and methods

Sample preparation Post-rigor pork loin of 10 pigs was divided into two lots: one lot was frozen to -50°C in an air-breast freezer for 2 hours (rapid freezing) and other lot was frozen to -20°C in a still-air freezer at -30°C for 4 days (slow freezing). Part of all loins was sampled before freezing as a control (not frozen). These frozen blocks were stored at each respective temperature (-50°C or -20°C) for 3 days and thawed in a chill room at 4°C for 4 days to reach 0–4°C.

Thaw yield Thaw yield (%) was calculated as below:

$$\text{Thaw yield (\%)} = \frac{\text{Sample weight after thawing (g)}}{\text{Initial weight of sample (g)}} \times 100.$$

Water-holding capacity (WHC) WHC of minced meat of each sample was determined by centrifuging at 1,200 ×g for 15 min, using a modified method of Kocher and Foegeding (1993). The amount of water separated was converted to a percentage of water separation, calculated by the equation:

$$\text{Water separation (\%)} = \frac{\text{Separated water (ml)}}{\text{Initial weight of sample (g)}} \times 100.$$

The greater amount of water separated indicates the lower the water-holding capacity.

Microscopic observation Formalin-fixed paraffin sections prepared from each sample were observed by optical microscope.

Measurement of ATPase activity Myofibrillar protein was prepared from each sample by a modified method of Busch (1972). The assay was carried out in the presence of 2 mM ATP, 50 mM KCl, 20 mM Tris-HCl, 0.5 mM $CaCl_2$, 2.5 mM $MgCl_2$ and 0.4 mg/ml myofibrillar proteins. The inorganic phosphate liberated was determined by the method of Fiske and Subbarow (1925), and the results expressed as specific activity in terms of μmol of inorganic phosphate liberated/min/mg protein.

Extractability of myosin Each minced meat sample was homogenized in 10 volumes of 2.0% NaCl with or without 0.4% of phosphate. The homogenate was centrifuged (15,000 ×g, 40 min) after leaving for 3 hours at 4°C. The supernatant was subjected to sodium dodecyl sulfate-polyacrylamide gel electrophoresis, according to Laemmli (1970).

Rheological property of sausages Pork sausages were prepared by adding 1.5% of NaCl, 0.02% of $NaNO_2$ and 0.12% of sodium ascorbate, with or without 0.45% of phosphate. After stuffing into polyvinylidene chloride casing, they were cooked at 78°C for 30 min. Each sample was cut into small pieces (1 × 1 × 2 cm), and the shear force value and distortion factor were measured using a Rheometer (RE2-33005N, Yamaden, Japan).

Results and discussion

The thaw yield of pork loins is indicated in Table 1. In contrast to slow freezing, rapid freezing produced very few drips (P>0.05); however, water separation of minced meat showed no significant differences between slow and rapid freezing. Sakata *et al.* (1995) indicated that freezing at -20°C and -80°C had no effects on the WHC of meat at those different freezing rates from our study. In spite of achieving the same temperature, a slower freezing rate may increase thaw drip. Ngapo *et al*. (1999) suggested that storage time also has an effect on the drip loss of meat. In this experiment, we stored each sample for only 3 days, but long-term storage may cause a great drip difference between freezing rates.

Figure 1 shows micrographs of cross-sections of meat samples before freezing and after thawing. The muscle fiber structure was highly retained in A (Control), B (Rapid freezing) and C (Slow freezing), although ice crystals were formed during freezing in B and C (data not shown).

ATPase activity could be an indicator of denaturation of myofibrillar proteins. There were no significant differences in ATPase activity between rapid and slow freezing during storage for 3 days.

SDS-PAGE of extracted myosin prepared from frozen meat is shown in Figure 2. The major band on the gel with a molecular mass of 200 kDa was considered to be myosin heavy chain. Phosphate extracted a large amount of myosin from both frozen and non-frozen meat, although there were no differences between freezing rates.

The rheological behavior of pork sausages prepared from each meat sample with phosphate is shown in Figure 3. Shear force values and distortion rates decreased with both rapid and slow freezing. There were no differences between rapid and slow freezing in phosphate-free sausage, but some differences were observed in phosphate-added sausage. The effect of phosphate on the rheological properties of sausage may be intensified by rapid freezing.

Table 1. Thaw yield of block of loins and water separation of minced meat by centrifugation

	Rapid freezing		Slow freezing	
	Not frozen	After thawing	Not frozen	After thawing
Thaw yield (%)	-	99.7 ± 0.2a	-	98.8 ± 0.8b
Water separation (%)	4.7 ± 1.5	6.5 ± 1.9	5.5 ± 2.5	5.1 ± 0.8

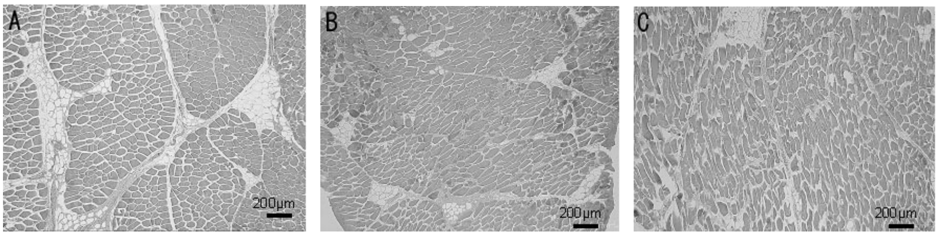

Figure 1. Cross-section of meat samples. A = Control (Not freezing). B = Rapid freezing (After thawing). C = Slow freezing (After thawing).

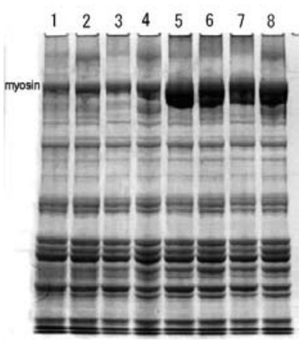

Figure 2. SDS-PAGE of myofibrillar proteins extracted by meat.
1–4 = extracted without phosphate. 5–8 = extracted with phosphate. 1, 3, 5, 7 = prepared before freezing. 2, 4, 6, 8 = prepared after thawing. 2, 6 = exposed rapid freezing. 4, 8 = exposed slow freezing.

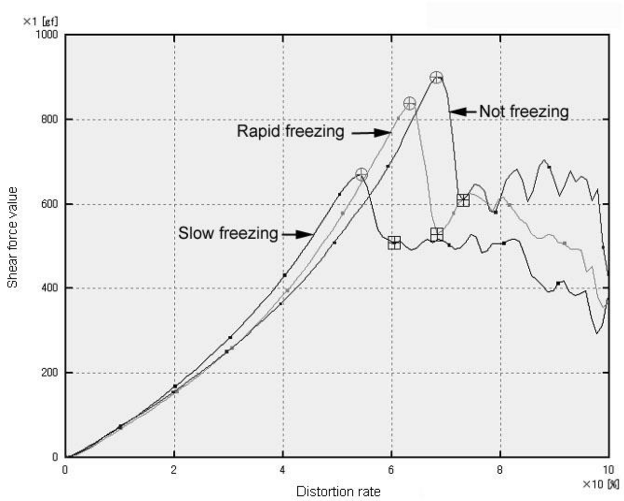

Figure 3. Effects of freezing rate on rheological properties of phosphate-added sausages.

Conclusions

From these results, it is indicated that rapid freezing reduced the thaw drip loss of meat and provided higher elasticity of sausage when compared with slow freezing, though no significant differences in ATPase activity, microstructure and myosin extractability were found.

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