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Differing Effects of NaCl Concentration on Rheological and Microstructural Properties of Cooked Meat Balls Made from Chilled and Frozen Storage Picnic Shoulder Pork

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Abstract

A rheometer and Microwatcher were utilized to study the rheological and microstructural properties of cooked meat balls made from chilled and frozen storage picnic shoulder pork with different NaCl concentrations of 1, 2, 3, 4 and 5%. The breaking strength of the meat balls made from chilled picnic shoulder pork increased with each added NaCl level from 1 to 4%, and, with the exception of those containing an added 5% NaCl, proved stronger than the samples made from frozen storage picnic shoulder pork. There was a tendency for, the longer the time of chilled or frozen storage, the lower the breaking strength of the cooked meat balls. They were also found to have a uniform interfacial protein film with a matrix of protein holding fat globules. At different NaCl concentrations and under different storage conditions (chilled and frozen storage), no further effects on this interfacial protein film were observed.

Introduction

In this paper, we consider the conventional low-cost production of processed pork meat balls of desirable quality and palatability in the far East and South-East Asia. From the consumer's point of view, texture is one of the most important parameters in the edibility of meat[2]. Normally, such sensory characteristics in processed meat balls are very important as they influence whether the product will meet with consumer acceptance. The initial cutting of a hog carcass, the storage temperature and time of the raw meat, and the machinery utilized could all bear some relation on those sensory characteristics[19]. Consequently, there is a clear need to establish the relationship between certain measurable parameters pertaining to the handling of a carcass and the ultimate texture of cooked meat.

In the processed meat products industry, ham muscle, whose muscle fiber is longer and contains less connective tissue than that of picnic shoulder muscle[15], is the raw material for processed pork meat balls emulsified by a kneading machine. Sodium chloride has long been recognized as a key ingredient in the stablization of comminuted meat products[10], and differences in protein functionality depend on the species and muscle fiber type[18]. On the other hand, chilling and frozen storage can cause chemical and structural changes in raw meat materials, depending on the characteristics of those materials and their storage conditions (temperature, duration, temperature fluctuations etc.). Such changes occur largely as a result of alterations in the characteristics of the proteins with a consequent loss of functional quality[3,8]. The objective of this study was to investigate the effect of different NaCl concentrations on the rheological and microstructural properties of cooked meat balls made from chilled and frozen storage picnic shoulder pork.

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Materials and Methods

Muscle sample

Chilled picnic shoulder pork and fat was purchased from a local meat packing plant and processed in the Meat Lab of Rakuno Gakuen University. After trimming off the covering fat from the picnic shoulder pork, it was then cut into 3-5cm size chunks and separated into two lots: the first lot consisted of 15 bags, each bag including 2.4kg of picnic shoulder pork and 0.6kg of back fat. These were stored in a chilled room (2-3℃) for 2, 4, and 6 days. Before processing, they were stored in a −20℃ freezer to decrease the internal temperature to between −3 and −5℃; the second lot, treated in the same way as the first, was stored in a freezer (−15 to −20℃) for 1, 2 and 3 months. Thirty-six hrs before processing, the frozen picnic shoulder pork and back fat were removed from the freezer (−15 to −20℃) and tempered in a chilling room (2-3℃) until the internal temperature of the samples reached between −3 and −5℃.

Preparation of cooked meat balls

The meat block was formulated to between 24% and 25% fat (Table 1) and contained 3% sugar, 0.25% sodium tripolyphosphate, and 0.3% white pepper. These concentrations were calculated based on the weight of the picnic shoulder pork and back fat. The trimmed picnic shoulder pork and back fat were ground through 3mm plates on a grinder (Bankeryd, Japan), and the meat emulsion made in a Seydelmann food chopper (Model K21, Ras 87161-1, Germany), with the chopper bowl being placed in crushed ice between each batch. The lean ground picnic shoulder pork was chopped for 30 seconds with sodium tripolyphosphate at low speed. Then, after the addition of salt, it was chopped again at 2-3℃ at high speed (2000-2500 rpm), at which time the fat portion, sugar and white pepper were also added. Chopping continued for 10 min until the emulsion reached a temperature of 5-7℃. From this emulsion, the meat balls were formed by hand, put in an ice water bath (5 to 10℃) for 30 minutes, then transferred to a waterbath (75 to 80℃) for 20 min for cooking. They were removed from the water bath when their internal temperature reached 70℃. The finished meat balls were chilled in ice water until their internal temperature reached 35-40℃, then packaged in polyethylene bags and stored in a −20℃ freezer in order to later determine their rheological and microstructural properties.

Table 1 Formulation of Emulsion Ingredients under Experimental Conditions.

	% sodium chloride* in emulsion				
Ingredients(g)	1	2	3	4	5
Picnic shoulder pork[1)]	2,400	2,400	2,400	2,400	2,400
Pork back fat	600	600	600	600	600
Sugar	90	90	90	90	90
White pepper	9	9	9	9	9
Sodium tripolyphosphate	7.5	7.5	7.5	7.5	7.5
Sodium chloride	30	60	90	120	150

*Sodium chloride was calculated based on the weight of picnic shoulder pork and pork back fat.
1) Picnic shoulder pork contained about 5% of fat.

Texture measurement

Evaluation of the rheological properties of the cooked meat balls was performed with a Rheo-Meter (Model NRM 2010-J-CW, Fudoh Kogyo Co., LTD, Japan). The meat ball samples were punched using a cylinder with a core diameter of 1.2cm and cut into 1cm lengths prior to measurement of breaking strength. The samples were placed on the platform of the rheometer and the upward speed adjusted to 5cm/min. The diameter of the adaptor was 4mm and the breaking strength range of the rheometer was set at 0-2kg. The experiment was repeated at least three times.

Microstructural observation

Observation of the microstructure of the cooked meat balls was performed using a Microwatcher (VS-30H, Mitsubishi Kasei Corporation, Japan) put on-line with a scanner and printer. To observe three dimensional characteristics of the cooked meat balls, the samples were carefully cut to a size of 5mm in thickness using parallel double microtome blades (S 35 type, Feather Co. Japan). The three dimensional microstructure of the meat balls was then recorded for comparison.

Results and Discussion

The effects of different NaCl concentrations on the breaking strength of cooked meat balls made from 2, 4 and 6 days chilled storage picnic shoulder pork are shown in Fig. 1. The breaking strength of the cooked meat balls increased with each added NaCl level from 1 to 4%, with the exception of those with an added 5% NaCl level. This was due to the effect of high NaCl concentration on the gelation of the polymer of the myosin heavy chain formed by emulsification with salt[9]. Nishiwaki et al.[16] also reported that ATPase activity in myofibrils decreased at high salt concentrations; and the gel strength of myosin has a positive relation to ATPase activity[7]. On the other hand, the pH effects of phosphates were found to be more important to emulsion stability than soluble protein levels and doubling the added sodium chloride level had no significant effect on soluble proteins according to Knipe et al.[10], further, emulsification has been found to be unstable in the presence of high NaCl concentrations[17]. These reports could possibly explain the results of this study (Fig. 1). Increasing the number of days in chilled storage would effect the drips of raw picnic shoulder pork. Here, compared with that on the breaking strength of the cooked meat balls (Fig. 1), this effect was found to be positive on emulsion stability. The breaking strength of the cooked meat balls showed a tendency to decrease with increase in number of days in chilled storage. This indicates that the influence of the freshness of raw meat on the quality of processed products is important for emulsification.

The effects of the different NaCl concentrations on the breaking strength of the cooked meat balls made from 1,2 and 3 months frozen storage picnic shoulder pork are shown in Fig. 2. The breaking strength of the cooked meat balls increased with added NaCl levels from 1 to 3%, slightly decreasing at 4 and 5% levels. Compared with the results shown in Fig. 1 and Fig. 2, the breaking strength of the cooked meat balls made from frozen storage picnic shoulder pork was approximately half the value of that for those made from chilled storage picnic shoulder pork. Verma et al.[22] also reported that emulsified pork

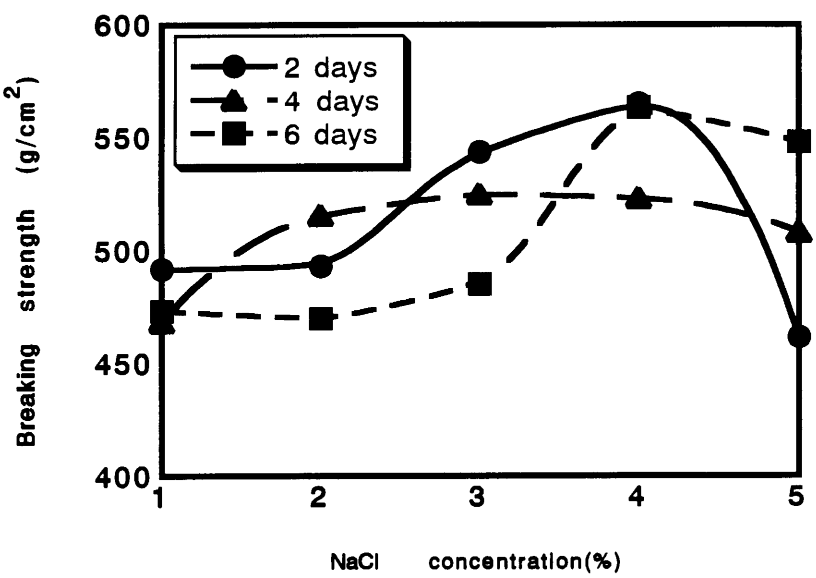

Fig. 1 Effect of different NaCl concentrations on breaking strength of cooked meat balls made from 2, 4, 6 days chilled storage picnic shoulder pork.

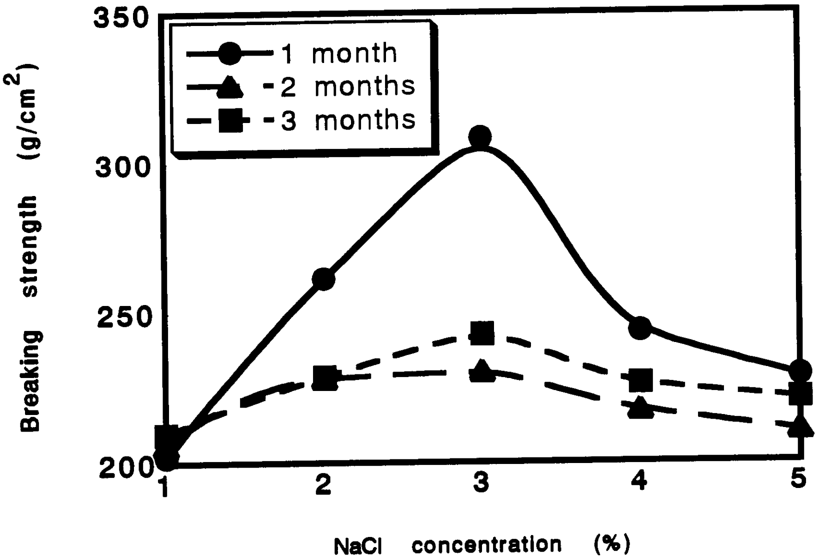

Fig. 2 Effect of different NaCl concentrations on breaking strength of cooked meat balls made from 1, 2, 3 months frozen storage picnic shoulder pork.

sausage prepared from frozen storage (up to 52 weeks at −18℃) minced meats showed a significant decrease in texture with increased age of meat. These findings were due to the quantity of the myofibrillar and sarcoplasmic proteins extractable from pork muscle decreasing with increase in duration of frozen storage at −17.8℃[14]; also the freeze-thawing of meat causes a loss of quality in emulsion products in which meat is the raw material[8]; moreover, thawed meat containing a low pH value[3,11,13] would decrease Ca-ATPase activity and protein solubility, giving a lower breaking strength for the emulsion gelation than fresh chilled meat[9].

Comparing the microstructure of our experimental samples, the micrographs look very much alike, as can be seen from the results presented in Fig. 3, (2, 4, 6 days chilled storage picnic shoulder pork) and Fig. 4 (1, 2 and 3 months frozen storage picnic shoulder pork).

The micrographs (Fig. 3.a; Fig. 4.a) of the samples containing 1% level NaCl showed a uniformly bright matrix of protein (brown color) containing fat globules. These fat globules were slightly elongated in shape, and continuous in clusters. Figs. 3.b, c and d and Figs. 4. b, c and d are the micrographs of the cooked meat balls with an added 2, 3 and 4% level of NaCl. Compared with Fig. 3.a and Fig. 4.a, the micrographs look very much alike, but Figs. 3. b, c and d , and Fig. 4. b, c and d have a denser protein matrix and fewer fat clusters. Several researchers have reported that, in emulsion meat products, the higher the added NaCl level, the more salt-soluble proteins (SSP) that were extracted, and that these SSP were involved in the formation of the interfacial protein film between the fat globules and the surrounding matrix[4,20,21]. Hansen[6] has also suggested that salt-soluble proteins may be attracted to and concentrated at the surface of fat globules before heat treatmeat, and that heat treatment during cooking stabilizes this film[1,5]. These reports appear to agree with the results on breaking strength shown in Fig. 1 and Fig. 2.

The micrograph (Fig. 3.e and Fig. 4.e) of the sample containing a 5% level of added NaCl had a matrix similar to that of the other samples. However, the protein matrix was brighter than that for the samples containing 2, 3 and 4% levels of NaCl. However, the globules did not coalesce when heated, probably because the matrix physically restricted movement of the fat globules[4]. Lee et al.[12] also reported that the physical prop-

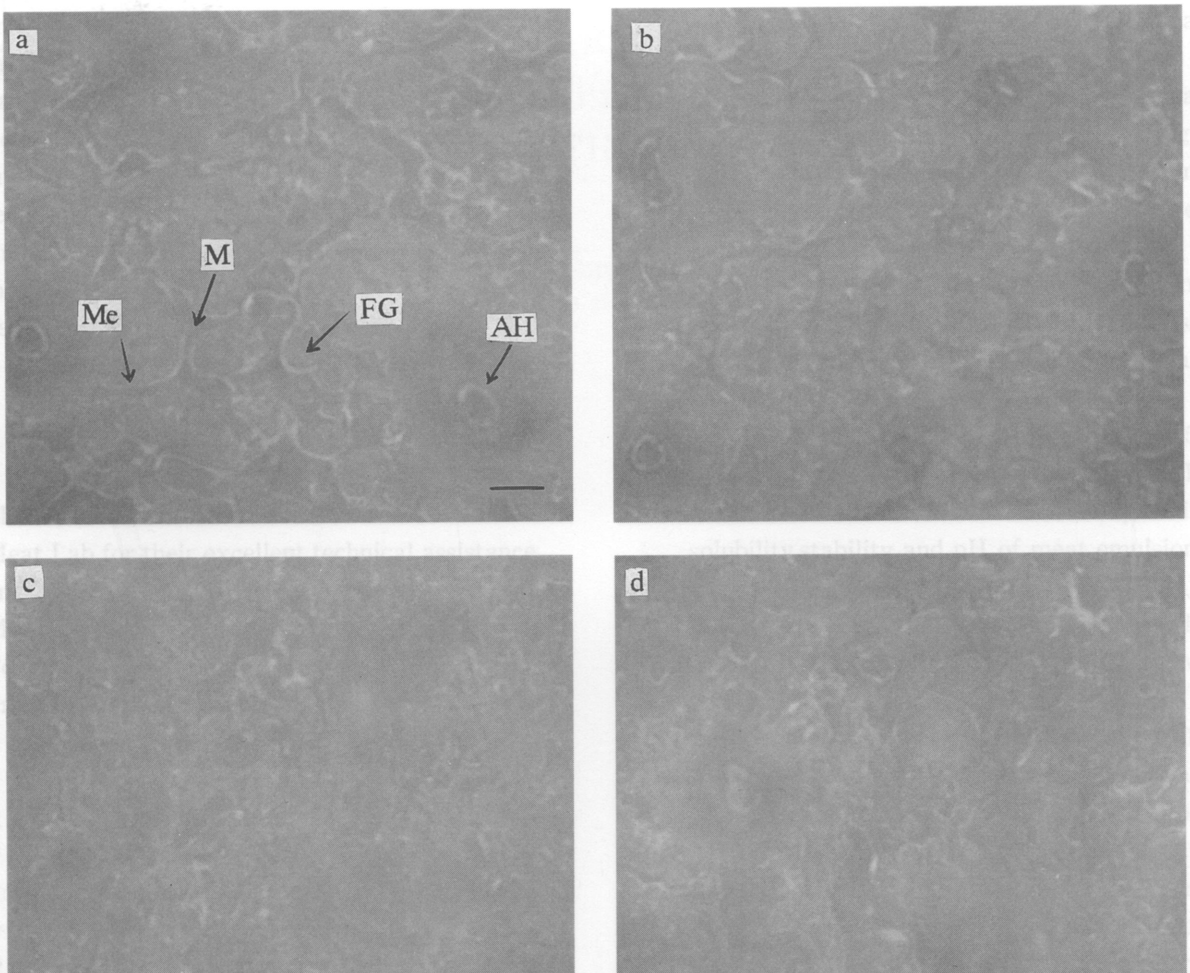

Fig. 3 Micrograph of cooked meat balls made from 2, 4 and 6 days chilled storage picnic shoulder pork with different NaCl concentrations.
FG: fat globule; Me: membrane; M: matrix; AH: air hole; bar length (----) 20 μm.
a: 1%; b: 2%; c: 3%; d: 4%; e: 5%.

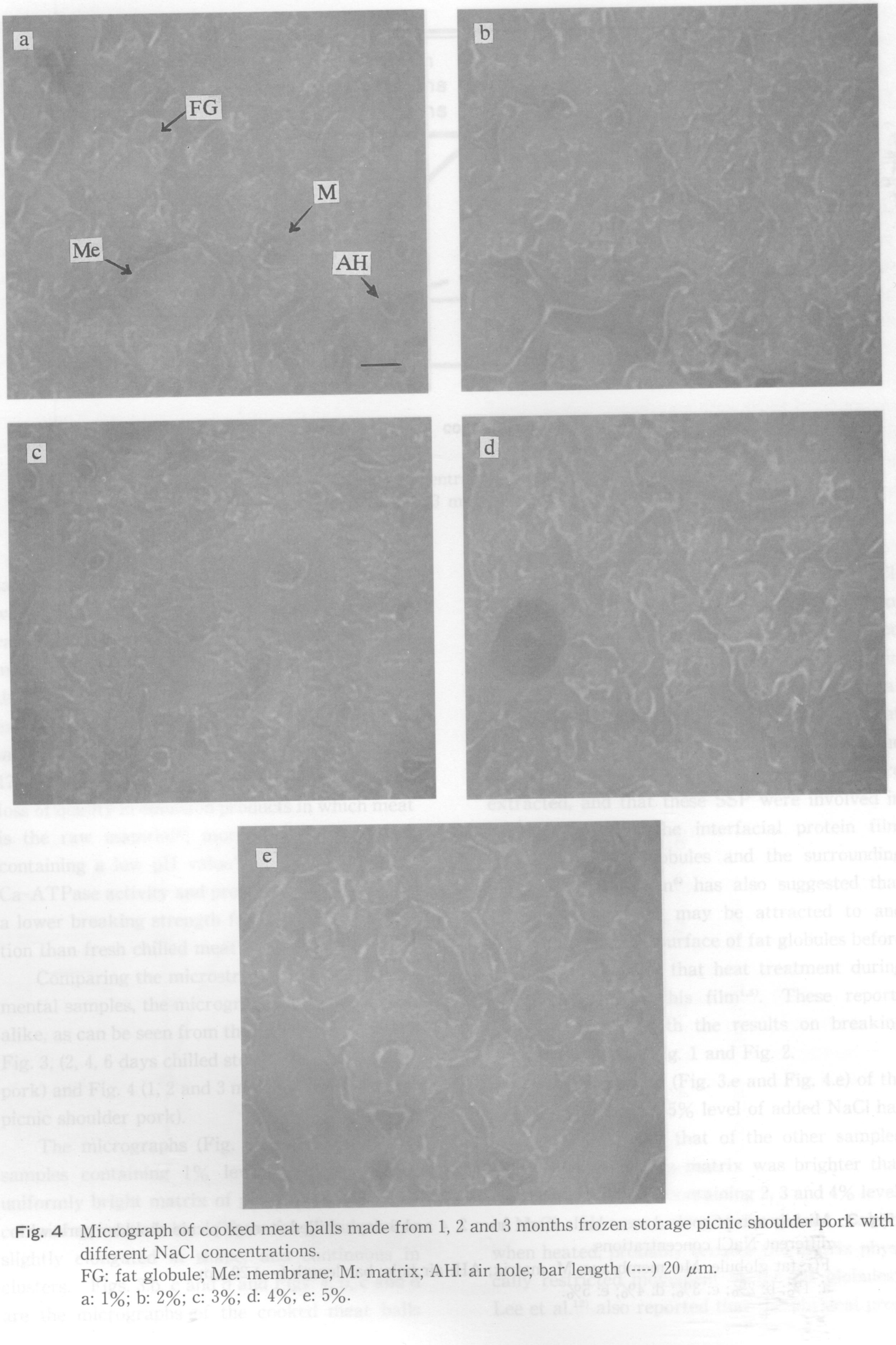

Fig. 4 Micrograph of cooked meat balls made from 1, 2 and 3 months frozen storage picnic shoulder pork with different NaCl concentrations.
FG: fat globule; Me: membrane; M: matrix; AH: air hole; bar length (----) 20 μm.
a: 1%; b: 2%; c: 3%; d: 4%; e: 5%.

erties of the protein matrix and the incorporated fat affected emulsion stability. On the other hand, it has been found that high salt concentration may effect ATPase activity in the myofibrils and the gelation properties of salt-soluble proteins[7,9,16]. This appears to agree with our results showing a lower breaking strength for cooked meat balls with a 5% level of added NaCl, as can be seen in Fig. 1 and Fig. 2.

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要　　約

異なった塩濃度（１～５％）で処理した冷蔵および冷凍豚肩肉で製造したミートボールの破断強度と微細構造をそれぞれレオメーターとマイクロウオッチャーによって測定した。

冷蔵豚肩肉から作ったミートボールの破断強度は，食塩濃度が１から４％まで増加するにつれて強くなり，冷凍肉から作ったミートボールのそれよりも強かった。また，冷蔵あるいは冷凍の期間が長くなるにつれて，ミートボールの破断強度は弱くなることが明かになった。これらのミートボールの微細構造は，脂肪球を囲むように均一のフイルム状タンパク質マトリックスの形成が観察され，さらに塩濃度や原料肉の冷蔵あるいは冷凍による貯蔵期間の違いによってこれらのタンパク質フィルムに見かけ上大きな違いは見られなかった。