Effect of Na-gluconate on heat-induced gelation of salt-ground meat from walleye pollack

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Summary: The quality of kamaboko gel prepared from walleye pollack surimi with sodium gluconate (Na-gluconate) was investigated in connection with the changes in myofibrillar protein accompanied with gelation. The gel stiffness of the kamaboko gel formed with Na-gluconate was higher than that with sorbitol at the same breaking strength, suggesting that the kamaboko gels with Na-gluconate were harder but not elastic. This characteristic of the kamaboko gel was mainly developed by the subsequent heating at 90°C, which caused no cross-linking reaction of myosin heavy chain. Furthermore, Na-gluconate strongly suppressed the progress of the myosin denaturation in the salt-ground meat. It was, therefore, suggested that Na-gluconate affected the formation of noncovalent intermolecular interaction between proteins through suppressing the myosin denaturation during preheating and promoted the production of the kamaboko gels with higher gel stiffness.

KEY WORDS: surimi, sodium gluconate, gelation, kamaboko gel, gel stiffness, denaturation, myosin

INTRODUCTION

Surimi-based product as represented by kamaboko gel is one of the most traditional processed seafoods. However, corresponding to the current varied consumer's needs, it becomes necessary to control the quality such as taste and texture conveniently. For this purpose, various food additives have been applied to the processing of surimi-based products.

Sodium gluconate (Na-gluconate) has faint salty taste, which is one fifth to that of NaCl. Furthermore, our previous papers have already revealed that Na-gluconate solubilized myofibrillar protein like NaCl in addition to having the protective effect against the protein denaturation like sugars.^{1,2)} Therefore, Na-gluconate is expected to be a substitute for NaCl and sugars in the processing of surimi-based products. Accordingly, we have recently investigated the quality of kamaboko gel formed with Na-gluconate and have revealed that the kamaboko gel formed with Na-gluconate was characterized as harder but not elastic in the quality.³⁾ However, the cause of the quality change of kamaboko gel induced by Na-gluconate is not fully elucidated.

The object of the current study is to investigate the quality change of kamaboko gel induced by Na-gluconate in connection with the changes in myofibrillar protein in the salt-ground meat (salt-ground surimi) during the preheating and the subsequent heating period.

MATERIALS AND METHODS

Preparation of preheated and two heated gels

The preheated and the two-step heated gels were prepared from walleye pollack surimi containing 8% sorbitol or Na-gluconate. Considering the increase in ionic strength of salt-ground surimi by addition of Na-gluconate, the surimi was ground with various amount of NaCl to adjust sodium ion concentration in the salt-ground surimi to 0.43 mol / kg. Na-gluconate gave no effect on pH of salt-ground surimi. The salt-ground surimis were preheated at 25°C for various durations (termed as preheated gel). The preheated gels were subsequently heated at 90°C for 30 min to produce kamaboko gels (termed as two-step heated gels).

Assessment of heat-induced gels

The breaking strength (g) and the breaking strain (mm) of the preheated and the two-step heated gels were measured with a rheometer (Fudoh Co. LTD) using a spherical plunger of 5 mm in diameter. Further to characterize the physical property of the gels formed with Na-gluconate, we also used the value of breaking strength divided by breaking strain which was termed as gel stiffness (g / mm).

Subunit content of myofibrillar proteins of heat-induced gels

To investigate the progress of the cross-linking reaction of myosin heavy chain (HC) via covalent type bond, a part of the preheated and the two-step heated gels was solubilized into 8 M urea - 2% SDS - 2% 2-mercaptoethanol - 20 mM Tris-HCl (pH 8.0) according to the method of Numakura *et al.*⁴⁾ The amount of the soluble proteins was determined by the biuret method.⁵⁾ The soluble proteins were applied to SDS polyacrylamide gel electrophoresis (SDS-PAGE).⁶⁾ The content of protein components in the gels was densitometrically determined.

Process of the denaturation of myofibrillar protein

A part of the preheated gels was immediately homogenized with 20 times of 0.1 M NaCl - 20 mM Tris-HCl (pH 7.5) by weight. The homogenate was used as myofibril specimen to follow the progress of the denaturation of myofibrillar protein during preheating period. Myofibrillar Ca-ATPase activity and the solubility of myosin into 0.5 M NaCl in the presence of 1 mM Mg-ATP were used as indice of myosin denaturation. The soluble myosin was determined by densitometry of SDS-PAGE.

RESULTS AND DISCUSSION

Change in the physical properties of salt-ground surimi during preheating and subsequent heating

Figure 1 shows changes in the breaking strength and the breaking strain of the preheated and the two-step heated gels formed with either Na-gluconate or sorbitol as a function of preheating time at 25°C. Irrespective of kind of additives, both physical properties of the preheated gels increased with the preheating time. However, the increase in the physical properties of the preheated gels with Na-gluconate proceeded more slowly and the maximum values were lower than those with sorbitol.

The subsequent heating markedly reinforced the breaking strength of both gels prepared with different additives regardless of the preheating time. The maximum values of the breaking strength of both two-step heated gels were almost the same as previously reported.³⁾ On the other hand, the maximum values of the breaking strain were slightly decreased by the subsequent heating irrespective of kind of additives.

Fig. 1 Changes in breaking strength and breaking strain of preheated and two-step heated gels formed with sorbitol or Na-gluconate as a function of preheating time.

The salt-ground surimi containing 8% sorbitol (◆,◇) or Na-gluconate (▲,△) was preheated at 25°C for various durations (preheated gels,◆,▲) followed by heating at 90°C for 30 min (two-step heated gels,◇,△). Breaking strength (A) and breaking strain(B) were measured with a rheometer.

Relationships between breaking strength and gel stiffness

Further to characterize the quality of the preheated and the two-step heated gels formed with Na-gluconate, the breaking strength of the gels preheated at 25°C were plotted against the gel stiffness (Fig.2). Although there were positive relations between both physical properties of the preheated gels with different additives, the relations were slight different each other. The subsequent heating enlarged the difference in the relations. Consequently, the gel stiffness of the two-step heated gels with Na-gluconate was considerably higher than that with sorbitol at the same breaking strength. These results indicated that the characteristic quality of the two-step heated gels with Na-gluconate was largely developed by the subsequent heating at 90°C.

Fig. 2 Relations between gel stiffness and breaking strength of the gels.

The data shown in Fig. 1 were used to illustrate this figure.

The symbols were same as in Fig. 1.

Progress of cross-linking reaction of myosin heavy chain during preheating and subsequent heating period

Next, we investigated the production of cross-linked HC in the gels preheated at 25°C as a function of the preheating time (Fig. 3). The cross-linked HC in the salt ground surimi with Na-gluconate increased more slowly than those with sorbitol during the preheating period.

The content of cross-linked HC in the two-step heated gels was almost equal with that in the preheated gels, indicating that no cross-linking reaction of HC took place during the subsequent heating period.

It was, therefore, suggested that Na-gluconate affected the formation of noncovalent type bonds such as hydrophobic bond between myofibrillar proteins during the subsequent heating period and consequently promoted the production of the two-step heated gel with higher gel stiffness.

Progress of protein denaturation during preheating period

The formation of hydrophobic interaction between proteins is considered to be closely related to the exposure of hydrophobic amino acid residue to the protein surface accompanied with protein denaturation. Accordingly, we investigated the progress of myosin denaturation in salt-ground surimi during preheating time.

Figure 4 shows the decrease in the myofibrillar Ca-ATPase activity and the salt solubility of myosin in the salt-ground surimi with different additives during the earlier period of the preheating at 25°C. The Ca-ATPase

Fig. 3 Changes in contents of cross-linked HC in preheated and two-step heated gels formed with sorbitol or Na-gluconate as a function of preheating time.

The contents of cross-linked HC were determined by densitometry of SDS-PAGE. The symbols were same as in Fig. 1

activity and the salt solubility of myosin in the salt-ground surimi with sorbitol dropped more rapidly than those with Na-gluconate did. Thus, Na-gluconate strongly prevented myosin molecule from denaturation during preheating period.

Finally, we investigated the stiffness of the kamaboko gel formed with Na-gluconate in connection with the denaturation rates of myosin in the salt-ground surimi during the preheating time. For this purpose, the two-step heated gels with various concentrations of sorbitol or Na-gluconate were prepared from SA and 2nd grade surimi and the relation between the breaking strength and the gel stiffness was analyzed. The intercepts on the abscissa termed as SBS0 were estimated by extrapolation of the linear relations between the breaking strength and the gel stiffness. On the other hand, the decreases in the Ca-ATPase and the salt solubility of myosin were analyzed by assuming the first order equation and denaturation rates were calculated. The relation between the SBS0 and the denaturation rate is shown in Fig. 5. The SBS0 drastically rose with decrease in the denaturation rate to less than 0.2 / h (for Ca-ATPase) or 0.5 / h (for NaCl solubility) irrespective of the grade of surimi used. It was, therefore, suggested that the addition of Na-gluconate affected the formation of intermolecular interaction with noncovalent type bond such as hydrophobic bond through the suppression of the myosin denaturation, presumably together with the increase in hydrophobicity of protein surface. As a result, the two-step heated gels with higher gel stiffness were produced upon addition of Na-gluconate.

Fig. 4 Changes in Ca-ATPase activity and salt solubility of myosin in salt-ground surimi during preheating period. The myofibril specimen was prepared from salt-ground surimi containing sorbitol (◆) or Na-gluconate (▲). Myofibrillar Ca-ATPase activity (A) and salt solubility of myosin (B) in the myofibrils were measured.

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Fig. 5 Relation between denaturation rates of myosin in salt-ground surimi during preheating and S_{BS0} of two-step heated gels. The salt-ground surimis containing various concentrations of sorbitol (◆, ◇) or Na-gluconate (▲, △) from SA (◇, △) or 2nd (◆, ▲) grade of walleye pollack frozen surimi were used in this experiment.

A; Ca-ATPase activity, B; Salt solubility

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