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Comparison of the Effect of Sago Starch and Potato Starch on the Textural Properties of Gels Cooked from Walleye Pollack Frozen Surimi

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Abstract The effect of sago starch on the textural properties of straight (80°C, 20 min) and two-step (30°C, 30 min - 80°C, 20 min) heating gels of walleye pollack frozen *surimi* was studied and compared with that of potato starch. The addition of sago starch to *surimi* increased the breaking strength, elongation and gel strength of both straight and two-step heating gels less than the addition of potato starch. Although the 30°C preheating increased the gel strength, it had little effect on the function of either starch. The addition of sago starch made the *surimi* gel lighter (higher in Hunter L) and more yellow (positive in Hunter b) than that of potato starch. The observation of the microstructure of starch-added gel by natural scanning electron microscopy clearly showed that the granule size of sago starch in the *surimi* gel network structure is smaller than that of potato starch. The findings suggest that sago starch has less capacity than potato starch for forming gel because sago starch swells less than potato starch.

Key words: sago starch, potato starch, walleye pollack frozen *surimi*, textural properties, gel network structure

スケトウダラ冷凍すり身加熱ゲルの物性に及ぼす サゴヤシデンプンの影響 — 馬鈴薯デンプンとの比較

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要約　サゴヤシデンプンを水産ねり製品に利用することを目的として，スケトウダラ冷凍すり身の直接加熱（80℃，20分）及び二段加熱（30℃，30分－80℃，20分）法によるゲルの物性に及ぼすサゴヤシデンプンの影響を馬鈴薯デンプンと比較・検討した．

両加熱ゲルの破断強度，破断伸び及びゲル強度はサゴヤシデンプン添加量が増すことによって増加したが，馬鈴薯デンプン添加の場合より，その効果は小さかった．また，二段加熱における30℃での予備加熱の影響はゲルの物性値を大としたが，両デンプンの効果に対する影響はほとんどないものと判断した．

すり身ゲルの色は，サゴヤシデンプンを添加したゲルの方が馬鈴薯デンプン添加より明るく黄色味

があった．

低真空走査型電子顕微鏡によりデンプンを添加したゲルの微細構造を観察したところ，すり身ゲルの網目構造の中にデンプン粒が見られ，サゴヤシデンプンの粒子は馬鈴薯デンプン粒子より小さかった．

以上の結果ならびにサゴヤシデンプンの膨潤度が馬鈴薯デンプンより小さいことから，サゴヤシデンプンによるゲル形成能の増加が馬鈴薯デンプンの場合よりも小さかったと推察した．

キーワード　サゴヤシデンプン，馬鈴薯デンプン，スケトウダラ冷凍すり身，ゲル物性，ゲル網目構造

Introduction

Most commercial *kamaboko* (traditional Japanese *surimi*-based product) generally contains more or less starch for the purpose of reinforcing *ashi* (gel strength) and increasing quantity (Takagi and Shimidu 1972). Usually the amount of starch to be added to *kamaboko* is around 3 %. Starch plays an important role in the formation of the network structure of *surimi*-starch gels and, therefore, is an important functional ingredient in the gels. Potato starch is the most common starch used for making *kamaboko*.

The use of sago starch from sago palm (*Metroxylon sagu*) has recently become common in Japan. Sago starch has been used for the preparation of jellies, puddings, and soups and is commonly used in the form of sago pearls (Takahashi 1986). The effect of sago starch on the elasticity of *kamaboko* from walleye pollack frozen *surimi* has been reported. (Yamamoto *et al*. 1997). However, the effect of sago starch on the texture and micro-structure of *kamaboko* gel has not been studied in detail. On the other hand, the type and content of starch profoundly affect not only the texture but also the color of gels. Different botanical sources of starches behave differently in regard to the texture of starch-added gels because the properties of starches are different (Park 2000).

In an effort to expand the utilization of sago starch, its potential as a substitute for potato starch in *kamaboko* processing was examined. Various concentrations of these two starches were added to walleye pollack frozen *surimi* and the changes in the textural properties, gel color and network of *kamaboko* gels were examined. The starch concentration added was 2 - 6% in consideration of the amount of starch in commercial *kamaboko*. In addition, since commercial *kamaboko* is generally made by preheating at low temperature (generally 30 - 40°C) prior to heating at high temperature (generally 80-90°C), the effects of starches on the gels were examined with and without preheating at 30°C prior to heating at 80°C.

Materials and Methods

Surimi and starch

Unsalted frozen *surimi* (SS1 grade, Maruha Co., Ltd. Japan) of walleye pollack was used as a material. Potato starch (Tachibana, moisture 17.3%) was purchased from the Tokai Dempun Co., Ltd. Japan. Sago starch（moisture 16.1%） was obtained in powder form from Mukah, Sarawak, Indonesia.

Preparation of surimi gel

Walleye pollack frozen *surimi* was kept overnight in a cold room (4°C) for thawing. *Surimi* (100g) adjusted to 80% in moisture content was ground by hands with 3% NaCl for 10 minutes with a motor and pestle. After that, the starch (0 - 6% by dry weight) was added into *surimi* paste and subsequently the paste was ground for an additional 10 min. The resulting *surimi* paste was stuffed into two stainless steel cylinder cases (3.1 cm in diameter and 3.0 cm in height), wrapped with polyvinylidene chloride film and then kept in ice water for 30 min. One sample was then heated in a water bath at 30°C for 30min (the temperature of the center reached 30°C in 20 min) and subsequently heated at 80°C for 20 min (two-step heating gel). Another sample was heated at 80°C for 20 min without preheating (straight heating gel). The gels were cooled immediately in ice water and kept at 4˚C until the measurement of the gel properties.

Measurement of the gel properties

The preparation of the test specimen and the measurement of the gel properties were carried out according to the method of Shimizu (Shimizu *et al.* 1981). The day after the sample gels were prepared, they were left at room temperature for 1 h and the measurement was carried out at approximately 25˚C. The cylindrical gels (ϕ 3.1 x 3.0 cm) were sliced at a thickness of 5 mm and cut into rings as shown in Fig.1. Five specimens were then used for the measurement. The stretching speed was 6 cm / min. The breaking strength (g/cm^2) and elongation ($\Delta L / L$: L sample length 1 cm) were measured with a stretching test using a rheometer (Sun Scientific Co., Ltd., Model CR-200D). The gel strength (g/cm^2) was assessed by multiplying the breaking strength and elongation. The gel quality was evaluated by dividing the breaking strength with the elongation. This value means rigidity of the gel.

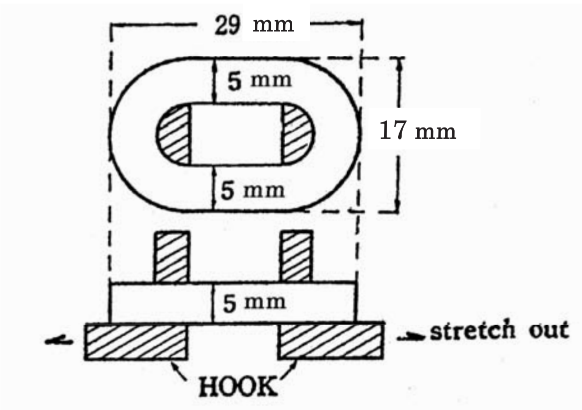

Fig. 1. Shape and size of samples used for a stretching test of gels. (cited from Shimizu *et al*. 1981)

Measurement of surimi gel color

The color of sliced gels was measured using a portable chromameter (Minolta CR-300) in the Hunter scale of L, a, and b at three points in each of 5 sliced samples. Therefore 15 values in one sample were obtained and averaged. Hereafter the values of L, a and b in Hunter scale were expressed as L value, a value and b value, respectively.

Microstructure observation of surimi gel

Small gel blocks (5 x 5 x 1 mm cubes) were cut from the center of the gel specimens with a razor blade. The samples were mounted on copper specimen holders with an adhesive of vinyl acetate and examined by using a natural scanning electron microscope (Hitachi model S-2380N) under the following conditions: stage temperature -10˚C, vacuum 7-20 Pa and accelerating voltage up to 15 kV at a magnification of 250.

Differential scanning calorimetry (DSC)

Differential scanning calorimeter was performed on a PerkinElmer Pyris 1 DSC (The PerkinElmer Japan Co., Ltd., Osaka). Samples (approx. 3mg) were accurately weighed in a pan to which 10 μl water was subsequently added, and the pan was then sealed. Water (approx. 15 μl) was sealed in another pan and used as the reference material. The scanning range was 0-100˚C at a heating rate of 10˚C /min.

Results and Discussion

Effect of starches on the textural properties

The effects of sago and potato starches on the textural properties of straight heating gels and two-step heating gels are shown in Fig.2. In the straight heating gels, the increase in every textural property resulting from adding sago starch tended to be slightly less than that resulting from adding potato starch at every addition amount, although the difference was not significant (significance level 5%). Furthermore, the gel quality did not differ between sago starch-added gel and potato starch-added gel. In the case of two-step heating, gels were stronger in their textural properties than straight heating gels due to the suwari effect, as reported previously (Okada *et al.* 1973, Suzuki 1981, Tanikawa 1971, Lanier *et al.* 1982). The addition of potato starch into a two-step heating gel increased all textural properties as in the case of straight heating gel. While the addition of sago starch did not increase the breaking strength above 2%., it showed a tendency to produce a smaller increase in elongation than potato starch. The gel elongation of sago starch-added gel was slightly weaker than that of the potato starch-added gel at every starch content. Therefore, the gel quality value of sago starch-added gel of two-step heating was slightly higher than that of potato starch-added gel at 2% starch, and it decreased above 4%. However, no significant difference in gel quality was found in the two starches. The gel strength of sago starch-added gel tended to be weaker than that of potato starch-added gel at every starch content. At 6 %, a significant difference was observed (significance level 5%).

Starch granules continue to absorb water and expand until they reach the limit imposed by the *surimi* gel matrix. Consequently, the expansion of starch granules results in a reinforcing effect on the gel matrix as well as on the gel strength (Park *et al*. 1997). The gelatinization temperature of sago starch at 74˚C is higher than that of potato starch at 64˚C (Kobayashi 1993). Furthermore, the gelatinization temperature increases in the presence of *surimi* and other ingredients (Park 2000). On the basis of the granule size, sago starch has lower swelling power than potato starch (Takahashi 1986). Therefore, the higher gelatinization temperature and lower swelling capacity of the sago starch, when compared to those of the potato starch, may account for the lesser effect of sago starch than potato starch on gel strength.

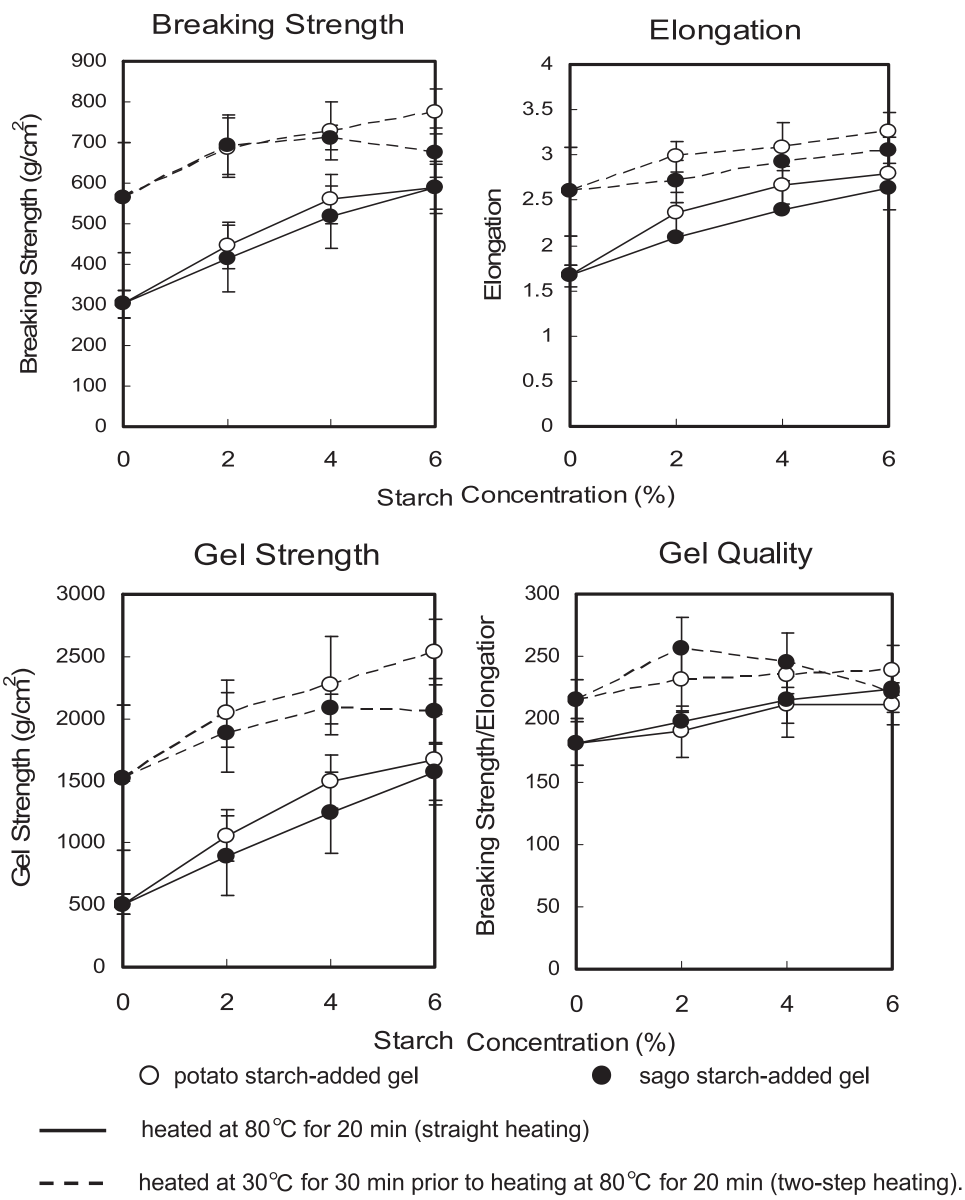

Fig. 2 Effect of sago and potato starches on the textural properties of gels cooked from walleye pollack frozen *surimi*. The vertical bars represent the standard deviation.

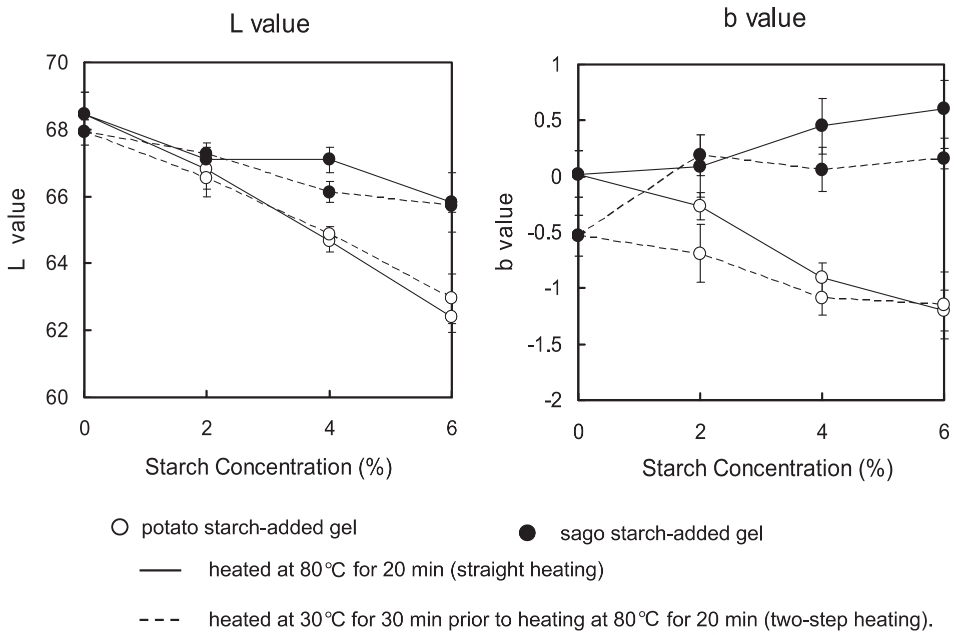

Fig. 3 Effect of sago and potato starches on the color of gels cooked from walleye pollack frozen *surimi*. The vertical bars represent the standard deviation.

Effect of starches on color

The increasing amount of starches made the L value of *surimi* gel lower than the control gel (Fig.3). Furthermore, the sago starch-added gel had a higher L value than the potato starch-added gel. This may be due to the fact that there is less swelling or gelatinization of sago granules than of potato granules. In addition, the two heating methods (straight heating and two-step heating) did not notably affect the whiteness of the gel.

The addition of potato starch also showed a decrease in the b value as the effect on the L value. However, the addition of sago starch increased the b value, indicating that the gels became slightly yellowish (positive b value) (Fig.3). It was reported that the fully swollen granules made the gel not only more translucent (lower L value) but also slightly blue (negative b value) (Yang and Park 1998). The whiteness of both starch powders was quite similar when viewed with the eye alone. Therefore, the findings suggested that the sago starch granules were less swollen than the potato starch granules in the *surimi* gel. In addition, the two-step heating gels were less in b value (more blue) than straight heating gels regardless of the addition of starches. This might be due to the finer structure of the two-step heating gel than that of the straight heating gel.

The addition of these two starches did not affect the a value (red color) of the *surimi* gel (data not shown).

Effect of starches on the microstructure

The microstructure of starch-added gels was observed with a Natural Scanning Electron Microscope (N-SEM), which does not require the treatment of samples before observation, at a magnification of 250).

Figure 4 shows the microstructures of the straight heating gels. A coarse structure with small pores was observed in the control gel (no starch gel). In the starch-added gels, granules were found in the small pores of the gel network. The higher the concentration of the addition was, the more filled the granules in the pores were. The size of the starch granules in the gels ranged from 50 to 55μm for sago and 67 to 73μm for potato, while the original size of granules before heating was about 45μm for sago and 55μm for potato. Sago starch granules expanded 1.1 - 1.2 times while potato starch granules expanded 1.2 - 1.3 times more than the original granules before heating. Therefore, both granules expanded by absorbing

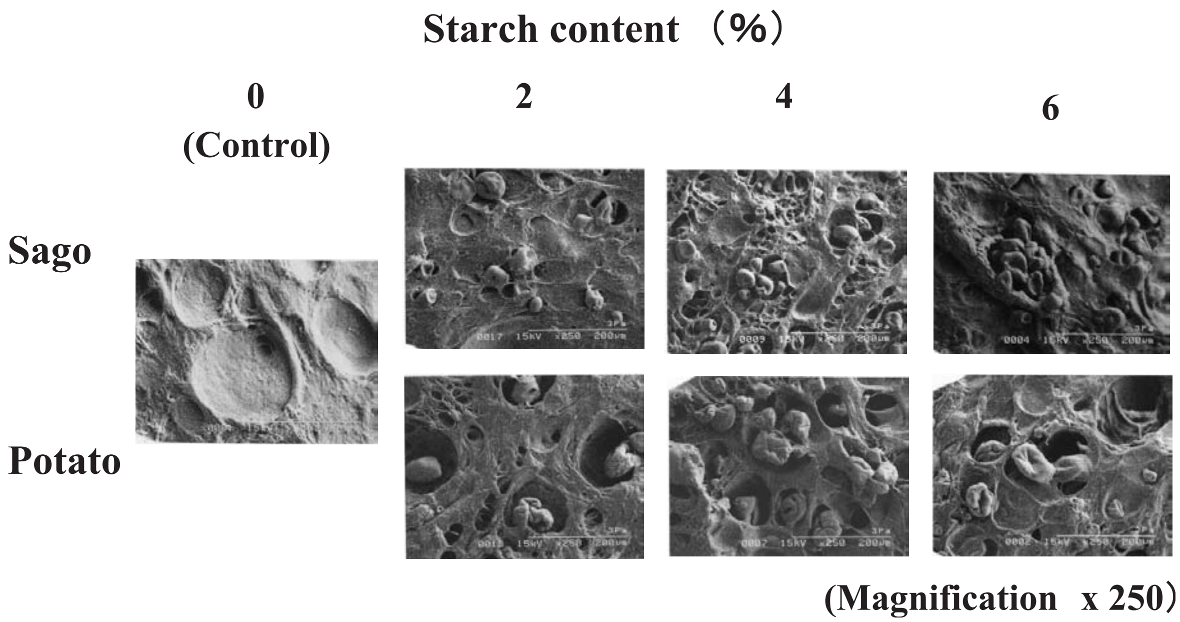

Fig. 4 Natural scanning electron microscopic observation of sago starch-added and potato starch-added gels of walleye pollack frozen *surimi* heated at 80˚C for 20 min (straight heating gel).

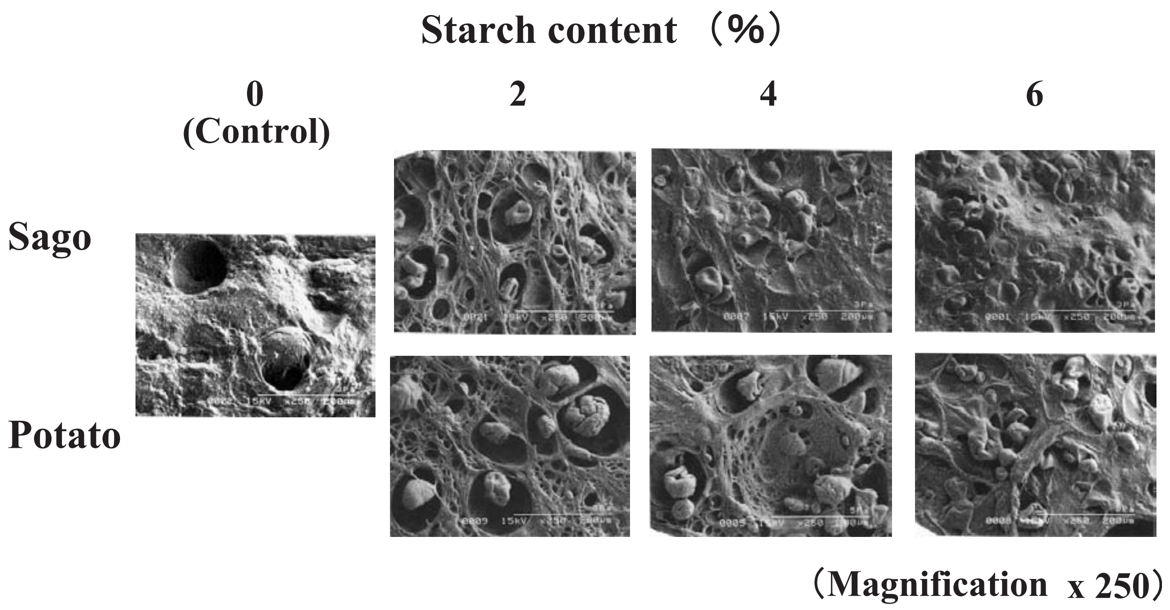

Fig. 5 Natural scanning electron microscopic observation of sago starch-added and potato starch-added gels of walleye pollack frozen *surimi* heated at 80˚C for 20 min after heating at 30 ˚C for 30 min (two-step heating gel).

water during heating, and the expansion of sago starch granules in the gels was smaller than that of potato starch granules in the gels.

Figure 5 shows the microstructures of two-step heating gels. The control gel of two-step heating showed a finer network or smoother surface than that of straight heating. In the starch-added gels, a uniform network structure was clearly observed and starch granules were found in the pores as in the straight heating gels. The size of the starch granules in the two-step heating gels ranged from 48 to 56μm (1.1 - 1.2 times) for sago and from 57 to 67μm (1.0 - 1.2 times) for potato, indicating a degree of swelling that was the same or less than that in straight heating gels. Preheating at 30˚C did not affect the swelling of starches. The smoother surface and finer network of the two-step heating gels than those of the straight heating gels seems to support the higher gel strength of the two-step heating gel than that of the straight heating gels.

A number of studies have reported on the effect of starch in heat-induced *surimi* gel (Takagi and Shimidu 1972, Kim and Lee 1987, Yamazawa 1990, Kong *et al*. 1999). Takagi and Shimidu (1972) suggested that starch granules act as a filler reinforcement agent in *kamaboko*. Kim and Lee (1987) reported that the composite gel-reinforcing effect of starch was probably due to starch granules embedded in a protein gel matrix which, when swollen, exerted pressure on the matrix and drew moisture from it. This caused the gel matrix to become more compact and firm. Yamazawa (1990) similarly indicated that the gel-reinforcing effect of starch might be largely attributable to concentrated *surimi* due to water absorption by starch granules. Recently, Kong *et al*. (1999) proposed that the starch granules bound in the *surimi* proteins had a "packing effect" on the *surimi* protein which increased the elastic modulus of the fish-meat gel. The starch granules trapped in the *surimi* needed the water bound in the surimi in order to swell and gelatinize.

In this experiment, there was no evidence that the starch granules bound with the *surimi* proteins. Spaces were clearly observed around the starch granules, in other words, the granules did not fill the pores fully. In the case of straight heating gels, starch granules exist in the pores of the gel network. On the other hand, in the case of two-step heating gels without starches, the microstructure looks smooth differently from the case of straight heating gels, and spaces were clearly observed around the starch granules in the starch-added gels. These spaces may be formed as water is absorbed from *surimi* around the granules, where the protein is concentrated in networks. Therefore, we assume that the gel-reinforcing effects of starch granules are due to protein-concentrating and packing effects. Moreover, as the concentration of starches added in *surimi* gel became higher, the number of starch granules packed in one pore of the gel network increased. This might increase the protein concentration and fill pores, resulting in a stronger gel. However, the lesser effect of sago starch above 4% than of potato starch on the gel strength might be due to the more incomplete expansion of sago starch than potato starch granules, as discussed below.

DSC

Using a Perkin Elmer Pyris 1 DSC, the onset temperatures of sago and potato starches used in this experiment were 71.09 and 59.43°C, respectively. This means that the gelatinization temperature of sago starch is higher than that of potato starch. Therefore the swelling of sago starch granules is less than that of potato starch granules at a certain temperature. Therefore, using a higher temperature and longer time to heat the sago starch-added paste seems to result in more swollen granules and a stronger and more translucent gel.

Conclusion

Although the addition of sago starch to gels prepared from walleye pollack frozen *surimi* increased the textural parameters, adding sago starch resulted in slightly lower gel strength than adding potato starch (not significant except at 6% starch).

Moreover, the addition of sago starch made the *surimi* gel whiter (higher L) and yellower (positive b) than the addition of potato starch.

The observation of the microstructure of starch-added gel by natural scanning electron microscope clearly showed that the granule size of sago starch in the mesh of the *surimi* gel network was smaller than that of potato starch.

The findings suggest that sago starch has less capacity than potato starch for forming gels because sago starch swells less than potato starch. In addition, the less swelling of sago starch is due to the higher gelatinization temperature of sago starch than that of potato starch. Although preheating at 30°C increased the gel strength, it only had a slight effect on the function of both starches.

In the future experiment, it is more meaningful to examine the effect of various starches such as corn starch, wheat starch, sweet potato, etc. in comparison with that of sago starch

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