内容成分組成の異なる野菜・果実パウダーの添加がすり身ゲルの物性に及ぼす影響について

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Comparison of gel strength of Kamaboko containing powders from nine different vegetables and fruits

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Abstract: We investigated the biochemical characteristics of several types of vegetable and fruit powders and the gel strength of Kamaboko mixed with those powders to improve surimi gel quality. Burdock, onion, and carrot powders had high concentrations of fructan and total sugar. Three powders (purple sweet potato, Chinese yam, and East Indian lotus root) contained high amounts of starch. Pectin and polyphenol contents were high in Yuzu powder. Gel strength decreased after mixing with any of the powders. Although polyphenol contents seemed to decrease in the gel strength slightly, it was difficult to estimate gel strength by adding a particular powder and amount.

Key words: vegetable powder, fruit powder, Kamaboko, breaking strength, chemical composition

Introduction

Kamaboko is a traditional type of seafood made from fish and is an important fishery product in Japan. Imitation crab meat made from Kamaboko has become commercially available worldwide. Minced fish (surimi) is the main ingredient of Kamaboko. The production methods and physical properties of surimi and Kamaboko have been extensively investigated[1-4].

To enhance the gel strength of surimi, various food-grade ingredients and cross-linking enzymes such as microbial transglutaminase have been used[5-7]. However, the addition of some ingredients poses the adverse effects on the surimi gel, particularly on its flavor or color. Addition of the egg white is associated with allergy problems. Hence, the need of natural additives with an ability of protein cross-linking has been paid increasing attention for the surimi industry. Plants generally possess chemical compounds important for human health, i.e., polyphenols, vitamins, and carbohydrates. Several types of vegetable and fruits powders are used to improve the quality of processed foods. However, their ability to enhance the gel strength of Kamaboko have been less investigated because studies have focused on the proteins[8] and starches[9] derived from vegetables. There is a few report that a certain amount of polyphenol additions improve the gel strength of bigeye snapper surimi[10]. The use of polyphenols, which are ubiquitously in all plant organs, would be an effective to improve the gel property of surimi.

In this study, we investigated the concentration of polyphenol and several chemical components of nine types of vegetable and fruit powders and the gel strength of Kamaboko mixed with those powders to improve surimi gel quality.

Materials and methods

Materials

Nine vegetable and fruit powder were obtained from the market (**Table 1**). All powders were made from entire dried edible parts. Several lots of frozen SA grade walleye pollack (*Theragra chalcogramma*) surimi (Maruha Nichiro Co., Tokyo, Japan) was stored at −50° C before use and was thawed overnight at 5° C just prior to use.

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Table 1 Construct of model at natural tiger puffer vs. cultivated tiger puffer

Primary material	Scientific name	Product name	Company
East Indian lotus root	*Nelumbo nucifera* Gaertn.	RENKON fine powder	Mikasa Sangyo Co., Ltd. (Yamaguchi, Japan)
Burdock	*Arctium lappa* L.	GOBOU fine powder	
Spinach	*Spinacia oleracea* L.	HOURENSOU fine powder	
Carrot	*Daucus carota* L.	NINJIN fine powder	
Ashitaba	*Angelica keiskei* (Miq.) Koidz.	ASHITABA fine powder	
Purple sweet potato	*Ipomoea batatas* (L.) Lamk.	MURASAKIIMO fine powder	
Yuzu	*Citrus junos* Sieb. ex Tanaka.	YUZU fine powder	
Onion	*Allium cepa* L.	TAMANEGI powder (institutional use)	Nihonkenkoudoh Co., Ltd. (Shimoda, Japan)
Chinese yam	*Dioscorea opposita* Thumb. cv. Nagaimo	YAMAIMO powder (institutional use)	Okonomi foods Co., Ltd. (Hiroshima, Japan)

Chemical composition of the powders

Free sugars and water-soluble pectin from the nine powders were extracted with hot water. Each powder (0.5 g) was mixed with 9.5 ml distilled water and boiled for 10 min. The extracts were centrifuged at 8,000 × G for 10 min at 4° C, and the sediment was removed. Total carbohydrate (as D-glucose) , fructan, and water-soluble pectin (as D-galacturonic acid) contents in the supernatants were analyzed using a scaled-down version of the anthrone-sulfuric acid method[11], the thiobarbituric acid method[12] with a slight modification[13], and the carbazole-sulfuric acid method[14], respectively.

Starch was extracted from the nine powders according to the method of McCready et al.[15] Starch contents were colorimetrically determined as D-glucose using the anthrone-sulfuric acid method. Starch concentration was calculated as 0.9 times the glucose content.

Polyphenolic compounds were extracted from each powder with 70% ethanol according to the method of Hang et al.[16]. Each extract was adequately diluted with water, the polyphenolic contents were determined as described by Folin and Denis[17], with minor modifications[18]. All extractions and determinations were conducted two and three times, respectively.

Preparation of the surimi gel

Thawed walleye pollack surimi (300 g) was ground for 2 min at < 1,500 rpm (Arazuri process) using a universal food processing machine (UMC 5 ; Stephan Machinery GmbH, Hameln, Germany). Then, the surimi was ground for 2 min at < 1,500 rpm with at a ratio of 50% (w/w) water (or flaky ice) to surimi weight (Mizunobashi process). The surimi was ground for another 4 min at < 1,500 rpm with 9.0 g NaCl (Shiozuri process), and the salted surimi was mixed with several concentrations (0%, 5%, and 10% (w/w) of the salted surimi weight) of each vegetable and fruit powder by grounded for 4 min at 1,500 rpm. The surimi was chilled at − 5° C in a 50% ethylene glycol solution using a cyclic cooling system (CA-1112 ; Tokyo Rikakikai Co. Ltd., Tokyo, Japan) operated under a non-vacuumed or vacuumed condition using a vacuum pump (R5 KB0010D ; Busch GmbH, Viernheim, Germany). The salted surimi paste was stuffed into plastic vessels (3.7 cm diameter ; Kureha Co., Tokyo, Japan) and incubated at 30° C for 30 min (Water bath SCD-301 ; Sansyo Co. Ltd., Tokyo, Japan) prior to final cooking at 90° C for 20 min (Thermostatic water bath T104NA; Thomas Scientific, New Jersey, USA). The cooked surimi was chilled in the crushed ice for a night at low temperature room (4° C).

Breaking strength of the surimi gel

The cooked gels were incubated at 25° C for 20 min (Water bath SCD-301) and then those were removed from the vessels and cut into 2 cm lengths at room temperature. The breaking strength (N) of the gels (3.7 cm diameter x 2 cm height) were measured using a rheometer (RheonerII Creep Meter RE2-33005S ; Yamaden Co. Ltd., Tokyo, Japan) attached a sphere plunger (5 mm in diameter ; depression speed at 1 mm s^{-1}).

Results and discussion

Chemical composition of the powders

Total sugar (as glucose), fructan, starch, pectin, and polyphenolic contents in each powder are shown in **Fig. 1**. Large quantities of total sugars were universally found in all powders, except the Chinese yam (Fig.1-(1)). Fructan contents in each powder varied from 16.6 mg g^{-1} dry powder weight (DW) to 299.2 mg g^{-1} DW (mean, 127.5 mg g^{-1} DW) (Fig. 1-(2)). Fructans are present in onion bulbs[19, 20]. Ritsema and Smeekens[21] reported that fructans are often stored in specialized organs, such as the taproot of chicory (*Cichorium intybus*), the tubers of dahlia (*Dahlia variabilis*), and the bulbs of tulip (*Tulipa gesneriana*) and onion (*Allium cepa*). Burdock are known to their abundant inulin (a kind of fructan) content[22]. Muir et al.[23] reported that the Megazyme fructan HK assay (Megazyme International Ireland Ltd., Wicklow, Ireland) detects 1.0 g 100 g^{-1} DW fructan from spinach and carrot but does not detect fructan from yams.

Several powders (ashitaba, onion, carrot, spinach, and yuzu) contained very low starch concentrations (Fig. 1-(3)). Three powders (purple sweet potato, Chinese yam, and East Indian lotus root) had large amounts of starch (mean, 380.7 mg g^{-1} DW). The edible portions of these three plants are tuberous roots (purple sweet potato and Chinese yam) or rootstalks (East Indian lotus root), which are storage organs (sink tissue). These tissues accumulate starch as a reserve carbohydrate in most plants. The difference in the amount of starch in each powder was based on the different starch concentrations in each plant.

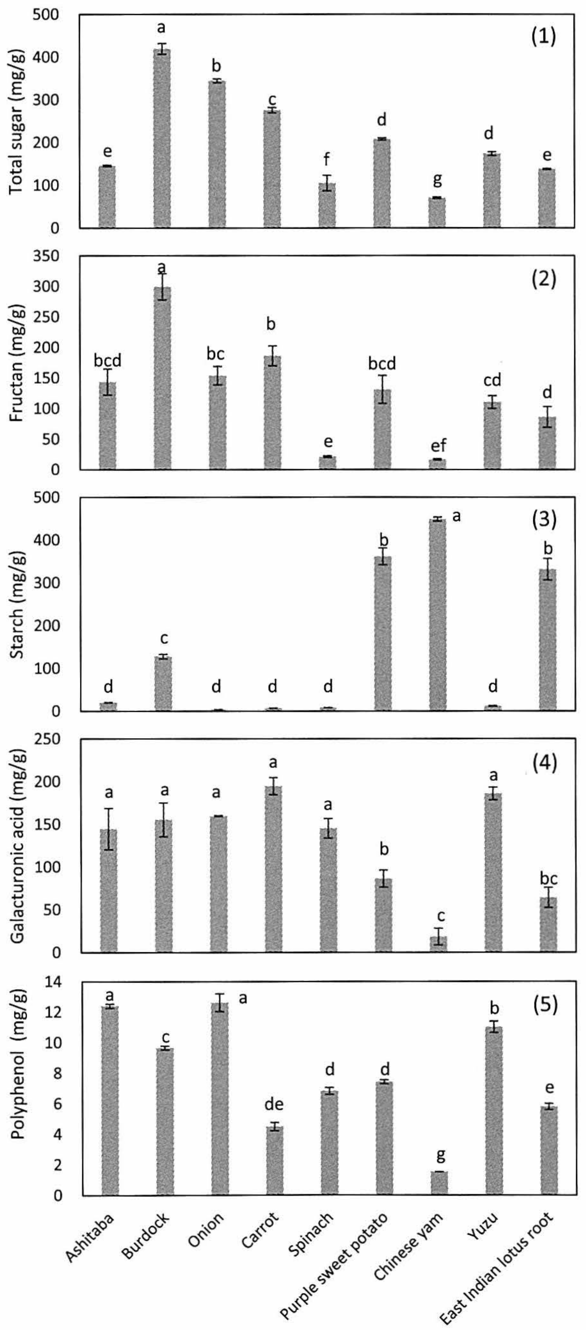

Fig. 1 Total sugar (1), fructan (2), starch (3), galacturonic acid (pectin) (4), and polyphenol contents (5) in the nine powders. Bars represent standard errors. Different letters indicate significant difference among powders at $P < 0.05$ (Tukey's test).

Six of the powders (ashitaba, Burdock, onion, carrot, spinach, and yuzu) had high concentrations (>140 mg g^{-1} DW) of water-soluble pectin (as D-galacturonic acid) Chinese yam contained very little water-soluble pectin (Fig. 1-(4)).

Polyphenol concentrations varied widely among the powders (mean, 7.99 mg g^{-1} DW) (Fig. 1-(5)). Onion powder had the highest polyphenol concentration (12.63 mg g^{-1} DW), and Chinese yam powder had least amount of polyphenols (1.53 mg g^{-1} DW). Sakakibara et al.[24] reported that onion contains large quantities of flavonoids (i.e., quercetin and quercetin glycosides), whereas Chinese yams have low polyphenol contents.

Breaking strength of the surimi gels

The breaking strength of each gel is shown in **Fig. 2**. Gels mixed with any of the vegetable or fruit powders had lower breaking strength than those without added powders. All gels containing 10% add powder had lower breaking strength than gels containing 5% add powder. The breaking strength for almost all gels containing powders made without a vacuum was lower than that for those prepared under a vacuum condition, except the 5% spinach, 5% carrot, and 10% burdock powder gels. Two-way ANOVA revealed a significant difference in the breaking strength between non-vacuumed and vacuumed conditions as well as powder concentrations ($P < 0.05$). Two-factor interaction between the powder concentration and non-vacuumed/vacuumed conditions was not detected. The gel strength would be decreased with increasing the powder concentrations in both non-vacuumed/vacuumed conditions. Yuzu powder decreased gel breaking strength under all conditions. High methoxyl or low methoxyl pectin content does not change the mechanical properties of surimi gels, but amidated low methoxyl pectin improves gelling properties[25, 26]. Although pectin was not classified in this study, the high quantity of pectin in Yuzu powder may have been the reason for the decreased gel strength. On the other hand, pectin was detected in carrot powder, but the addition of carrot powder did not change breaking strength, which may have been due to multiple actions of the chemical components. Except for the spinach and Chinese yam, an adequate amount of fructan was detected in each powder. However, the gel strength of each powder addition was similar regardless of the different fructan concentration. Fructan in the vegetable and fruit powders might not be important to change of the gel strength.

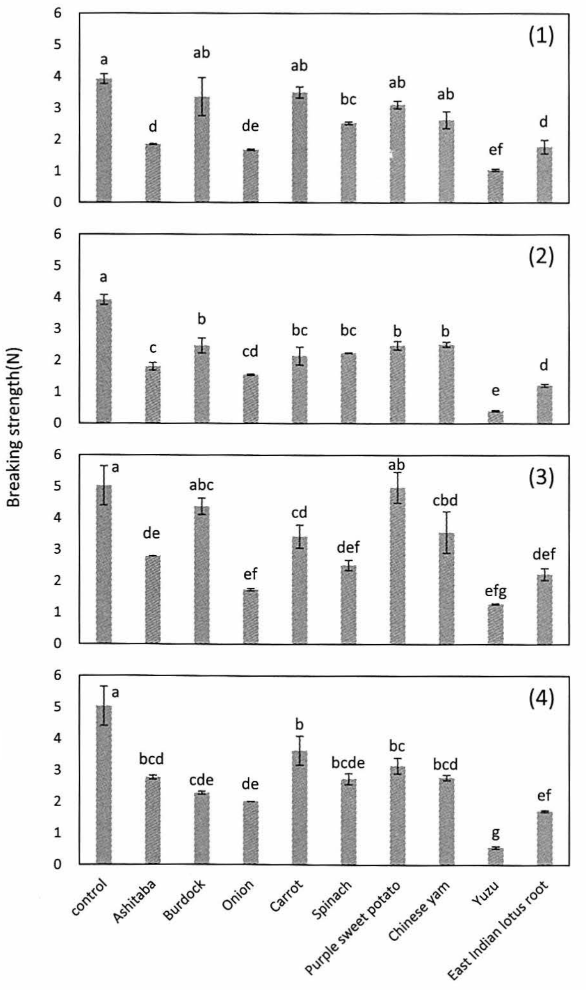

Fig. 2 Breaking strength of 5% and 10% concentrations of each of the nine powders added to gels and the control prepared without a vacuum or under a vacuum condition : 5% powders and non-vacuumed(1) ; 10% powders and non-vacuumed (2) ; 5% powders and vacuumed(3) ; 10% powder and vacuumed(4). Bars represent standard errors. Different letters indicate significant difference among powders at $P < 0.05$ (Tukey's test).

In the 5% powder addition and non-vacuumed condition, four powders (burdock, carrot, Chinese yam, and purple sweet potato) decreased gel strength slightly compared with that of gels without any added powder (Fig. 2-(1)). The burdock, Chinese yam, and purple sweet potato powders contained a detectable amount of starch. Starch improves the strength of surimi gels[27-30]. Low breaking strength was observed in gels containing the East Indian lotus root powder, which has abundant starch content. Kato[31] showed that East Indian lotus root contains large quantities of cell-wall polysaccharides, but the pectin content was lower than that of other root crops.

Accordingly, the East Indian lotus root may accumulate water-insoluble dietary fiber as cell-wall polysaccharides. Using dietary fiber from wheat decreases the strength and cohesiveness surimi gels[32]. Therefore, gel strength probably decreased because of the dietary fiber in the East Indian lotus root powder.

A regression analysis was performed between gel strength and vacuum condition, powder concentration, and the chemical composition of each of the powders (**Table 2**) . A weak positive correlation was observed between gel strength and non-vacuumed/vacuumed conditions and starch, fructan, and total sugar contents. A somewhat weak negative correlation was detected between gel strength and polyphenol concentration, suggesting that polyphenols in vegetable and fruit powders would contribute to decrease in the gel strength.

Polyphenols can range from simple molecules, such as phenolic acids, to highly polymerized compounds, such as tannins[33]. Balange and Benjakul[10] reported that the increase in the gel strength of bigeye snapper surimi was found when the oxidized phenolic compounds were added. Among the all used oxidized simple phenolic compounds in their study, the oxidized tannic acid exhibited the highest gel strengthening effect, compared with ferulic acid, catechin and caffeic acid. This suggested that different polyphenol additions showed a different effect for the gel strength. In Ashitaba, Burdock, Onion and Yuzu powders, polyphenol concentration was ranged from 9 to 13 mg g^{-1} DW, which was the near level reported by Balange and Benjakul[10]. Polyphenol was not classified in this study and the concentration of oxidized polyphenol in each powder was not revealed. Each powder might not contain an adequate amount of the oxidized polyphenol. Accordingly, polyphenols from the vegetable and fruit powders used in this study might not be effective to improve the gel formation of surimi.

Adding any of the vegetable or fruit powders decreased gel strength in this study, which may have been caused by multiple actions of the chemical components in the powders. Therefore, it was difficult to estimate gel strength by determining the type and amount of powder to add. The properties of the surimi gel can be affected by the type of ingredients (such as powders) used, in that they may alter the gelling environment by influencing the pH and water binding capacity and otherwise enhance or interfere with protein-protein association of the myofibrillar proteins[34]. The vegetable and fruit powders would be able to interfere the gel formation in this study. These powders might contain the cellulose of cell-wall constituent. Cellulose does not undergo any thermal transitions and thus no volume expansion that alter its viscoelastic properties[34]. The lack of tightly bound water and mass expansion during heating may explain why cellulose does not strengthen surimi gels[35]. Although the cellulose contents was not determined in this study, the cellulose in the grains of vegetable and fruit powders might contribute to decrease in the gel strength.

As a way to enhance the value of surimi using vegetable powder, Harada et al.[36] reported that Kamaboko mixed with the Japanese bunching onion (Welsh onion ; *Allium fistulosum* L.) powder increases oxygen radical absorbance capacity. The Japanese bunching onion contains an alien chromosome from shallot (*Allium cepa* L. Aggregatum group), which increases polyphenol contents compared with those in the normal Japanese bunching onion[18, 37]. Adding these vegetable and fruit powders increases the value of surimi seafood.

Table 2 Regression coefficients between gel strength and each element

	Vacuum condition	Powder concentration	Total sugar	Fructan	Starch	Pectin	Polyphenol
Breaking Strength	0.295	-0.285	0.082	0.207	0.281	-0.188	-0.388*

* significant at $P < 0.05$

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内容成分組成の異なる野菜・果実パウダーの添加がすり身ゲルの物性に及ぼす影響について

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要　旨

野菜および果実パウダーをすり身に添加した際に，各パウダーにおける化学内容成分組成の違いがゲル化能におよぼす影響を調査した，使用した九種類のパウダーの中で，ゴボウ，タマネギおよびニンジンパウダーはフルクタンや全糖含量が高く，ムラサキイモ，ヤマノイモおよびレンコンパウダーは高いデンプン含量を示した。水溶性ペクチンと総ポリフェノール含量はユズパウダーが高い値を示した。これらのパウダーを添加したすり身ゲルの物性を測定したところ，すべてのゲルで破断強度が低下していた。破断強度とポリフェノール含量の間にはやや弱い負の相関が認められたものの，パウダーの添加量やその成分組成からゲル強度を推定することは困難であった。