Effect of Calcium-Compound Addition on the Physical Properties and Tissue Structure of Seasoned 'Umeboshi': Investigation of Actual Conditions of Commercially Prepared Products and Verification of Products Prepared in a Laboratory

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Physical properties which influence the quality of seasoned umeboshi were examined and microscopic observations and sensory evaluations were undertaken on 13 commercially prepared products and 4 laboratory-prepared samples pickled with calcium hydroxide. The physical properties of alcohol insoluble solid (AIS) content, pectin composition, calcium content bound to AIS and adhesiveness varied in the commercially prepared samples, and the differences were believed to be due to the condition of the materials and methods used. A high correlation was observed between adhesiveness-AIS and adhesiveness-water soluble pectin. Among the commercially prepared products, some were assumed to have had calcium compounds added during the process because of the high values of calcium in AIS, and microscopic observations revealed that cell walls had been strengthened by calcium just beneath the skin of these products. Laboratory-prepared samples pickled with 0, 0.05, 0.10 and 0.15% calcium hydroxide showed that the addition of calcium had the effect of reducing damage to the skin and flesh of umeboshi during the rest of the process, and there were no differences in the physical properties except for the calcium content bound to AIS even with differences in the calcium concentrations. The areas just beneath the skin which were affected by the added calcium deepened progressively depending on the calcium concentration, and the sample pickled with a concentration of 0.1% had a skin strong enough to prevent damage and yet thin enough to be sensory-evaluated appropriately.

Keywords: ume fruit, salted ume fruit, calcium, pickles, SEM, texture

Since salt-reduced 'umeboshi', the pickles of ume fruit, have now become popular (Ogawa, 1993), the seasoning technique and processing method have become more complicated compared with the conventional technique and method (Maeda, 1994). The conventional method of making umeboshi was relatively simple (Fig. 1): the ume fruit was pickled with a certain amount of sodium chloride, after which the pickled fruit was sun-dried; umeboshi products these days, in contrast, are mainly so-called 'seasoned umeboshi,' i.e. 'umeboshi' which are desalted after pickling and have various seasonings added to compensate for the reduced saltiness and improve preservation. It is, in fact, difficult now to purchase conventional 'umeboshi.' Consequently, the taste has changed from a combination of saltiness and sourness in the conventional product to a harmony of various tastes consisting of umami and sweetness derived from the added seasonings and slight intrinsic saltiness and sourness in the modern product. The palatability of 'umeboshi' is not only evaluated by the chemical taste alone, but physical properties such as an appropriate degree of softness or adhesiveness of the flesh are also essential. The degree of ripeness of fresh ume fruit has a considerable effect on the softness of flesh of the final product. With the change from immature to ripe to overripe, the flesh

gradually becomes soft and the ripened fruit can be used for 'umeboshi' (Otoguro & Kaneko, 1993). This softness of the ripened fruit is due to the decreased content of cell-wall polysaccharide, which is an important constituent maintaining the structure in the flesh tissue. Consequently, damage often occurs to the skin and flesh of the fruit during processing. Modern processing involves the newly introduced seasoning step which was not necessary in the conventional method, and the skin can be more easily damaged during this seasoning step. Furthermore, the cultivation of ume fruit trees is confined to certain regions of Japan and the production of umeboshi is also an oligopoly (Kinkinouseikyoku, 1995). Consequently, transportation by trucks and other means is indispensable for distribution and the shaking during the transport affects the quality of the skin and flesh. Not only domestic transportation is involved: recently imported ume materials from Taiwan and China, which have already been salted, are also being used because of their low cost. In this case, damage sometimes occurs even before the materials arrive in Japan.

Thus, physical properties which influence the quality of 'seasoned umeboshi' were focused on in this study, and the actual conditions of commercially prepared products were

Fig. 1. Comparison of the preparation of conventional and salt-reduced seasoned products.

Fig. 2. Flow chart of the preparation for laboratory-prepared seasoned umeboshi.

first investigated. A pickling method using calcium compounds which prevents damage to the skin and the flesh of 'seasoned umeboshi' was then proposed.

Materials and Methods

Commercially prepared seasoned umeboshi products

Commercially prepared products of 13 types from 12 umeboshi-makers which are generally available on the market were purchased in Japan. The items were the following: 4 small-size ume fruits (samples Nos. 1-4, materials harvested in Japan), medium-size ume fruits (Nos. 5-7, harvested in Taiwan, and Nos. 8-12, harvested in Japan) and a large-size ume fruit (No. 13, harvested in Japan). All the samples were classified as seasoned 'umeboshi' products. The flesh was cut by knife and then homogenized using a homogenizer (HITA-CHI, HG-30) for measurements and analyses.

Preparation of laboratory-prepared seasoned umeboshi samples Small ume fruit (Japanese apricot, *Prunus mume* Sieb. et Zucc. var. *microcarpa* Makino, cv. Koshu Koume) was harvested on June 12, 1997, at Yatsushiro in Yamanashi Prefecture. Ripened fruit, which is the most suitable for producing umeboshi, was used and the basic properties of the materials were as follows: mean weight of one fruit 7.2 g, water content 90.9%, titratable acidity 5.28%, pH 2.52, hardness, 4.09 N, colour (a-value) -5.2, citric acid 3.93%, malic acid 1.92%, alcohol insoluble solid (AIS) 2.076%.

The flow chart of the preparation is shown in Fig. 2. Two kilograms of ume fruit was washed in water and pickled using 350 g sodium chloride (17.5% of the fruit weight) and calcium hydroxide of 0, 1.0, 2.0, and 3.0 g (0, 0.05, 0.1 and 0.15% of the fruit weight, respectively) in polystyrene vessels (5 l) with lids. The vessels were stored for 40 days at room temperature, and the pickled ume fruit was dried under the sun for 3 days in July (5 h per day). The dried fruit was packed in polyethylene packages and aged for 2 months at room temperature. Five hundred grams of the fruit was then soaked in 750 g seasoning solution for 1 week at room temperature, and washed using 50%-ethyl alcohol for 30 s. The final products were obtained after sun-drying for 1 h.

Yield rate of the laboratory-prepared umeboshi was expressed as the weight ratio before and after sun-drying and after seasoning in relation to the weight of the fresh material. The rate of damaged fruit was calculated by the ratio of the

number of damaged pieces to the total number after sun-drying and seasoning.

The seasoning solution was prepared using the recipe most commonly used by umeboshi-makers. The content was as follows: acetic acid 1.54%, ethyl alcohol 3.54%, free amino acids 1.78% (glutamic acid 0.81%, glycine 0.33%, alanine 0.64%), saccharide 7.05% (sorbitol 2.33%, isomaltose 2.15%, glucose 1.76%, fructose 0.81%), sodium chloride 1.24%, nucleic acid 0.06% (5'-IMP 0.03%, 5'-GMP 0.03%), powdered sea weed 0.33%.

General analyses The water content was evaluated by measuring the change in weight before and after drying at 105°C. The sodium chloride content was measured by the Mohr method (AOAC, 1965) after diluting the ashed substances at 550°C for 5 h. Titratable acidity was evaluated by titration with a 0.1 N-sodium hydroxide solution for the filtrate of homogenized ume flesh with 20 times the volume of water, and was calculated in terms of citric acid. The pH was measured with a pH meter (HORIBA, B-212).

Fractionation of pectic substances An alcohol insoluble solid (AIS) was first obtained by the following method (Otoguro *et al.*, 1993a; Kaneko, 1996). Approximately 100 g of ume flesh was homogenized (NIHONSEIKI, AM-8) in 70% ethyl alcohol at 15,000 rpm for 5 min. After being boiled with a reflux condenser for 15 min and cooling down, the substance was filtered by glass filter (25G3) and repeatedly washed in 70% ethyl alcohol until the reaction of the phenol-sulfuric acid method turned negative. The substance was then dehydrated using 99.5% ethyl alcohol and the alcohol was subsequently removed using ethyl ether. The substance after drying in an evacuated condition for 3 days was an AIS, and it was kept in a desiccator.

Pectic substances were obtained from the AIS by subsequent extraction, and water soluble pectin (WSP), 0.4% hexametaphosphate soluble pectin (PSP), 0.05 N-hydrochloric acid soluble pectin (HSP) and 0.05 N-sodium hydrox-

ide soluble pectin (SSP) were fractionated and calculated in terms of anhydrous galacturonic acid by measuring using the carbazole-sulfuric acid reaction. The procedure for the extraction of each pectin fraction was as follows. One gram of AIS was stirred in 200 ml water, and water soluble pectin was obtained after two extractions over 24 h at 20°C. The residue was washed until the filtered supernatant turned negative to the reaction of phenol-sulfuric acid method. The washed residue was put in a 0.4% hexametaphosphate solution of 200 ml, and hexametaphosphate soluble pectin was obtained after the two extractions over 2 h at 20°C. Washing was also repeated as described above, and the washed residue was put in a 0.05 N hydrochloric acid solution of 200 ml. To extract hydrochloric acid soluble pectin, a vessel with a reflux condenser containing the mixture was immersed in boiling water for 1 h and cooled down. Two extractions were undertaken, washing was also repeated as described above, and the washed residue was put in a 0.05 N sodium hydroxide solution of 200 ml. The mixture was allowed to stand at 30°C for 2 h and was then neutralized using hydrochloric acid. The filtered solution of the mixture was sodium hydroxide soluble pectin.

Calcium content bound to alcohol insoluble solid Ashed AIS at 550°C for 1 h was dissolved in a 0.5 N-hydrochloric acid solution, and the Ca content was measured using an atomic absorption spectrochemical analyser (SEIKO, SAS760).

Adhesiveness The first quality evaluated just after umeboshi is eaten is related to the condition of the surface of the fruit and thereafter the softness and adhesiveness of the flesh paste have a substantial influence on the evaluation. It is difficult to measure both properties simultaneously; therefore, initially only adhesiveness of the flesh paste was investigated. The surface condition was studied using microscopic analysis described in the next paragraph. The physical properties of umeboshi paste have not been studied before and we measured the adhesiveness of the paste using a rheometer (FUDOH, NRM-2010J-CW) at 25°C. The paste was placed in a styrol container (22.5 mm i.d.×40 mm) to a depth of 25 mm, and the container was fixed to the sample stage. A cylindrical plunger with a bottom measuring 15 mm in diameter was inserted in the paste to a depth of 20 mm at a speed of 20 mm/min, and after being allowed to stand for 20 s the plunger was pulled up at the same speed until no paste clung to it. The energy required for this action was calculated and expressed as the adhesiveness of umeboshi paste.

Scanning electron microscopic observation A scanning electron microscope observed the condition of the surface of commercially prepared umeboshi products (Nos. 7, 8 and 13) and laboratory-prepared samples. Specimens were carefully separated from stones and fixed in 2.5% glutaraldehyde solution adjusted to pH 7.2 by a 1/15 M phosphate buffer and then postfixed in a 1% osmium tetroxide solution adjusted by the same buffer. After being dehydrated using an alcohol solution series, and critical-point dried (HITACHI, HCP-2), each sample was split. The halves were ion-sputtered (JEOL, JEE-3X), before being observed by SEM (JEOL, JXA-840A) under an acceleration voltage of 15 kV.

Sensory evaluation Commercially prepared products

were evaluated for texture according to a 5-level numerical scale by a panel of 20 assessors comprised of umeboshi-makers and food researchers (14 males and 6 females). The result was analysed by ANOVA.

Laboratory-prepared samples pickled with calcium hydroxide were evaluated by 20 students from Yamanashi Women's Junior College according to a 7-level numerical scale in comparison with the product without calcium hydroxide. The assessors were asked about the thickness of the skin, the softness of the flesh and preference, and the result was analysed by *t*-test. The basic composition of the laboratory-prepared samples was as follows: sodium chloride 9.8–10.3%, titratable acidity 3.11–3.33%, pH 3.0, free amino acids 1.08–1.15% (glutamic acid 0.44–0.47%, glycine 0.35–0.38%, alanine 0.35–0.38%), organic acids 3.17–3.47% (citric acid 1.56–1.80%, malic acid 0.90–1.11%, acetic acid 0.64–0.67%), nucleic acids 0.026% (5'-IMP 0.012%, 5'-GMP: 0.014%), saccharide 4.06% (sorbitol 1.24%, glucose 1.19%, fructose 0.34%, isomaltose 1.29%), ethyl alcohol 1.78%, the difference among samples was slight.

Results and Discussion

Physical properties of commercially prepared umeboshi products The physical properties of umeboshi paste were evaluated with regard to flesh softness and adhesiveness because product quality is influenced by these factors. We chose four kinds of analyses to decide the physical properties of umeboshi flesh: the content of AIS, the content and composition of pectin substances, the content of calcium bound to AIS and adhesiveness (Table 1). The content of AIS was from 2.97 to 5.25%. Eighty percent of AIS is constructed of cell-wall polysaccharide (pectic substances, hemicellulose and cellulose), and pectic substances, which are the main composition of the cell-wall polysaccharide, have an effect on the flesh condition (Otoguro, 1994). The pectic substances gradually decrease with fruit maturity (Otoguro *et al.* 1993a) and AIS content increases because of the concentration resulting from sun-drying (Otoguro & Kaneko, 1993). From these facts, the content of AIS is thought to depend on harvesting conditions, ways of pickling and the degree of sun-drying. The products (Nos. 2, 3, 4, 5, 8 and 12) which showed adhesiveness greater than 290 μ J contained more than 4% AIS, while those (Nos. 1, 9, 11 and 13) which showed adhesiveness less than 200 μ J contained about 3% AIS. Among the products whose AIS content was almost the same, the ratio of WSP to protopectin (HSP+SSP) increased as the adhesiveness of the products became greater. It thus became clear that a high correlation of $r=0.728$ was obtained between adhesiveness and the AIS content (Fig. 3). Furthermore, a correlation of $r=0.819$ was also observed between adhesiveness and WSP content, which was between 52 and 79% in AIS. WSP has a considerable effect on the physical properties of fruit and vegetables; the content in conventional umeboshi (sodium chloride content 20–24%, titratable acidity 5.3–5.8%) was as high as 77–79%, and the WSP/HSP ratio was 9.5–12.5 (Otoguro & Kaneko, 1993). However, the ratio of the commercially prepared product used in this study (sodium chloride content, 7.5–14.6%; titratable acidity 2.4–4.3%) indicated lower values of 4.0–11.4. The values of products Nos.

Table 1. Physical properties of commercially prepared umeboshi.

Sample No.	AIS ^{a)} (%)	WSP(W) ^{b)}	PSP ^{c)}	HSP(H) ^{d)} mg/100 g ^{b)}	SSP(S) ^{e)}	Total	Ratio of W/(H+S)	Ratio of W/H	Ca ^{f)} (mg/100 g AIS)	Adhesiveness ^{g)} (μJ)
1	3.25	698 (79.3)	98 (11.1)	61 (6.9)	23 (2.6)	880 (100)	8.31	11.4	76	179
2	5.25	1065 (73.8)	182 (12.6)	150 (10.4)	47 (3.3)	1444 (100)	5.41	7.1	61	327
3	4.51	1006 (76.9)	126 (9.6)	118 (9.0)	59 (4.5)	1309 (100)	5.68	8.5	177	431
4	4.05	781 (75.9)	109 (10.6)	95 (9.2)	44 (4.2)	1029 (100)	5.62	8.2	420	357
5	4.52	807 (66.4)	164 (13.5)	197 (16.2)	47 (3.9)	1215 (100)	3.31	4.1	376	371
6	3.93	648 (69.8)	127 (13.7)	128 (13.8)	26 (2.8)	929 (100)	4.21	5.1	182	220
7	4.16	586 (63.7)	150 (16.3)	147 (16.0)	37 (4.0)	920 (100)	3.18	4.0	516	222
8	4.09	925 (72.7)	206 (16.2)	111 (8.7)	31 (2.4)	1273 (100)	6.51	8.3	178	364
9	3.25	517 (65.5)	153 (19.4)	82 (10.4)	37 (4.7)	789 (100)	4.34	6.3	472	164
10	2.97	687 (77.7)	99 (11.2)	66 (7.5)	32 (3.6)	884 (100)	7.01	10.4	58	203
11	3.32	785 (72.9)	167 (15.5)	92 (8.5)	33 (3.1)	1077 (100)	6.28	8.5	109	190
12	5.17	959 (67.5)	259 (18.2)	146 (10.3)	56 (3.9)	1420 (100)	4.75	6.6	146	291
13	3.05	424 (51.9)	285 (34.9)	80 (9.8)	27 (3.3)	816 (100)	3.96	5.3	1066	87

^{a)}alcohol insoluble solid; ^{b)}water soluble pectin; ^{c)}0.4% hexametaphosphate soluble pectin; ^{d)}0.05 N-HCl soluble pectin; ^{e)}0.05 N-NaOH soluble pectin; pectin substances were obtained from AIS by sequential extraction; ^{f)}calcium bound to AIS which was measured with an atomic absorption spectrochemical analyser after ashing at 550°C and dissolving in a 0.5 N-HCl; ^{g)}measured by rheometer; ^{h)}values in brackets indicate percentages.

Fig. 3. Relationship between adhesiveness and AIS or WSP content of commercially prepared umeboshi. ●, adhesiveness [x]–AIS [y] is expressed as $[y]=0.0055 [x]+2.52$ ($r=0.728$); ○, adhesiveness [x]–WSP [y] is expressed as $[y]=1.56 [x]+353$ ($r=0.819$).

Fig. 4. Drawing of sample section for SEM.

5–7, in particular, were lower, 4.0–5.1 compared with Nos. 8–11, which were 6.3–10.4. All these were medium-size ume fruit. However, the materials of Nos. 5–7 were from Taiwan and those of Nos. 8–11 were obtained in Japan. The calcium content bound to AIS also varied in samples from 58 to 1066 mg/100 g AIS. The ume fruit which was pickled with 0.3% calcium hydroxide in relation to the fruit weight contained 1700 mg calcium which was bound to 100 g AIS, and the value was 170 mg when no calcium hydroxide was added (Otoguro, 1994). The sun-drying process has no effect on the content of calcium. From these facts, it is assumed that calcium compounds had been added during processing to products No. 4, 5, 7, 9 and 13 which contained a high level of calcium. The reason for this addition was believed to be to prevent damage to the skin and flesh; to confirm this assumption, the tissue was observed by scanning electron microscopy. A drawing of the section of umeboshi and the results is shown in Figs. 4 and 5, respectively. A clear cell shape surrounded by the cell wall was observed just beneath the skin in products No. 7 (Fig. 5a) and No. 13 (Fig. 5c and d) which contained high calcium, 516 mg and 1066 mg/100 g

AIS, respectively. A similar condition of the cell wall was clearly observed in No. 13 (Fig. 5c) as shown in the section of the hardened ume pickle called 'karikari-ume' (Otake *et al.*, 1995), which was pickled with the addition of calcium compounds. This is evidence of the addition of calcium compounds. However, this area was limited to the area just beneath the skin, unlike 'karikari-ume' in which the condition was uniform throughout the section from the skin to the innermost part of the flesh. At the inner part of the flesh of the umeboshi section, there was no clear-shaped cell wall and the cells had collapsed. It was apparent from these observations that the flesh was divided into two parts: an outer part solidified by calcium, and an inner part which was not influenced by calcium (Fig. 5d). All the cells had collapsed and the flesh was observed to be uniform in the section of product No. 8 which contained only 178 mg of calcium per 100 g AIS (Fig. 5b). These observations confirmed that some products were made by adding calcium compounds to prevent damage to the skin and flesh of the umeboshi.

Sensory evaluation of commercially prepared umeboshi products Thus, there were differences in the physical properties of the commercially prepared umeboshi products, and a sensory evaluation of the texture of these products was carried out (Fig. 6). Product No. 8, whose adhesiveness was high, was given the highest rating, and from the result of calcium content in AIS it was assumed that this product

Fig. 5. Scanning electron micrographs of vertical section of commercially prepared samples. a, sample No. 7 $\times$ 180; b, sample No. 8 $\times$ 180; c and d, sample No. 13 $\times$ 180, $\times$ 45, respectively. Bars indicate 100 μ m.

contained no calcium or that only a slight amount had been added. Products Nos. 4, 5, 6 and 7 were poorly evaluated; Nos. 5, 6 and 7 were made using materials from Taiwan and the worst, No. 7, contained a high level of calcium in AIS and had low adhesiveness. Product No. 13 was evaluated moderately in spite of a thick area strengthened by calcium beneath the skin. This was a large-size product and the ratio of this strengthened part to the total flesh was apparently small enough not to be evaluated poorly; the thickness was negligible for the sensory evaluation.

Damage rate and general analysis results of laboratory-prepared umeboshi samples From the results obtained from the commercially prepared products, it was clear that the contents of AIS and WSP, the ratio of WSP to protopectin, the calcium content bound to AIS, and the adhesiveness influenced the quality of umeboshi products. Some products were assumed to be pickled with calcium in order to prevent damage to the skin and flesh. However, it was difficult to make a precise comparison of these 13 products because of the differences in materials and pickling methods. Consequently, seasoned umeboshi were prepared in our laboratory by pickling with calcium compounds to identify an appropriate method for making umeboshi which has both a thin skin sufficiently strengthened by calcium to prevent damage and yet still retains a soft flesh. The calcium concentration bound to the cell wall polysaccharide immediately beneath the skin was reported as being under 0.15% of the fruit weight in the case of calcium hydroxide (Otoguro *et al.*, 1993b). If a higher

Fig. 6. Result of sensory evaluation of commercially prepared umeboshi. The quality of the texture of commercially prepared products was evaluated by 5-level numerical scale. Significant differences were obtained as follows with the former sample number being worse than the last: 7-2*, 7-3*, 7-9*, 7-10**, 7-11**, 7-8**, 4-3*, 4-9*, 4-10*, 4-11*, 4-8**, 5-10*, 5-11*, 5-8**, 6-10*, 6-11*, 6-8**, 12-8**, 13-8** and 1-8*. **, significant level at $p < 0.01$; *, significant level at $p < 0.05$.

concentration of calcium hydroxide is added during the pickling process, calcium ions would disperse to the inner side of the flesh and all the flesh would become uniformly hard. Accordingly in this study calcium hydroxide of 0.05% (Ca-1), 0.10% (Ca-2) and 0.15% (Ca-3) of the fruit weight was added to the sodium chloride during the pickling process. A sample pickled without calcium hydroxide was also prepared as a control (Table 2). The control sample had 7.3 and 19.5% damaged fruit after sun-drying and seasoning, respectively, and 27% of all the fruit was damaged. However, with more calcium hydroxide added, the percentage of damaged fruit decreased to 16%, 8% and 4% in Ca-1, Ca-2 and Ca-3, respectively. It is concluded, therefore, that calcium acted effectively to prevent damage to the skin and flesh. The other measurements, moisture, titratable acidity, sodium chloride content and pH, showed differences between each process, although, the differences between samples in the same process were only slight.

Physical properties of laboratory-prepared umeboshi samples From these results, it was clear that the addition of calcium during the pickling process reduced damage to umeboshi samples. However, too much calcium affects the quality of the flesh, and the appropriate concentration must be known to achieve a desirable condition. Accordingly the physical properties of laboratory-prepared samples were also investigated (Table 3). The AIS content of salted, sun-dried and seasoned samples was 2.3–2.5%, 3.9–4.2% and 3.0–3.3%, respectively, and differences were observed only among the processes. The addition of calcium did not produce any effect in the same process. Samples to which more calcium was added contained less WSP and more HSP after salting, and the differences were smaller after sun-drying and seasoning. The calcium content bound to AIS, on the other hand, increased correspondingly with the increase the addition of calcium in each process. Adhesiveness also changed to a lesser degree with the addition of calcium, although, the differences between samples were smaller at the end of the seasoning

process. Regardless of the addition of calcium, the values of AIS content, pectic substance content and adhesiveness were not different from each other at the end of the seasoning process. This is believed to be because the added calcium remained just beneath the skin and did not disperse to the inner part of the flesh. Consequently, reactions to the flesh of samples were almost the same even when the volume of calcium added was different. The phenomenon which occurred in the flesh of all samples was thus the same: organic acids and sodium chloride were concentrated by water evaporation after sun-drying, and these substances acted to split the calcium linkages between protopectin and cellulose. Then, the pectic composition was transposed from HSP and SSP to PSP and WSP, and subsequently PSP was transposed to WSP by the elimination of calcium. After soaking in a seasoning solution, the same kinds of seasonings moved to the inner part of the flesh of all the samples and intrinsic organic acids and sodium chloride diffused out from the flesh. The reaction caused by the intrinsic organic acids and sodium chloride was thus suppressed in all samples after seasoning. From the results of investigations using umeboshi made from the same materials and by the same method, it is concluded that the physical properties of AIS content, pectin composition and adhesiveness related to flesh quality were independent of the addition of calcium, and that the calcium content bound to AIS was apparently only affected by the addition of calcium. The differences in the commercially prepared products were them believed to be caused by differences in condition and quality of materials or the method of preparation.

Regardless of whether or not there were differences in the adhesiveness of flesh, the calcium content in AIS increased correspondingly with the addition of calcium. Consequently, calcium was assumed to exist just beneath the skin, and this area was observed by SEM (Fig. 7). The section of the flesh pickled without calcium was uniform from the skin to the inner part of the flesh, the cells had collapsed completely and

Table 2. Changes in damaged fruit rate and general analysis results of laboratory-prepared seasoned umeboshi during processing.

Sample		Calcium hydroxide concentration (%)	Yield rate ^{a)} (%)	Damaged ^{b)} fruit rate (%)	Moisture ^{c)} (%)	Titratable ^{d)} acidity (%)	Sodium ^{e)} chloride (%)	pH ^{f)}
Fresh		—	100	—	90.99	5.28	0	2.5
After salting	Control ^{g)}	0.00	79.71	—	75.40	3.92	15.71	2.0
	Ca-1 ^{h)}	0.05	78.47	—	75.59	3.93	15.89	2.1
	Ca-2 ⁱ⁾	0.10	77.92	—	75.57	3.90	15.92	2.1
	Ca-3 ^{j)}	0.15	78.62	—	75.51	3.82	15.80	2.2
After sun-drying	Control	0.00	48.29	7.3	59.20	5.51	22.38	1.8
	Ca-1	0.05	49.07	1.8	59.16	5.45	22.29	1.8
	Ca-2	0.10	49.57	0.6	59.17	5.41	22.00	1.8
	Ca-3	0.15	51.64	0.0	60.04	5.22	20.14	1.9
After seasoning	Control	0.00	60.02	19.5	75.90	3.31	10.06	2.9
	Ca-1	0.05	59.18	14.3	76.53	3.23	9.93	2.9
	Ca-2	0.10	59.05	7.5	76.11	3.24	10.27	2.9
	Ca-3	0.15	60.52	4.0	76.33	3.11	9.78	3.0

^{a)}weight ratio of before and after each process to the weight of the fresh material; ^{b)}ratio of the number of damaged fruits to the total after each process; ^{c)}change in weight before and after drying at 105°C; ^{d)}titration with a 0.1 N-sodium hydroxide solution for the filtrate of homogenized ume flesh with 20 times volume of water and calculated in terms of citric acid; ^{e)}measured by the Mohr method after diluting the ashed substances at 550°C for 5 h; ^{f)}measured by pH meter; ^{g)}pickled without calcium hydroxide; ^{h)}pickled with 0.05% calcium hydroxide in relation to fruit weight; ⁱ⁾pickled with 0.10% calcium hydroxide in relation to fruit weight; ^{j)}pickled with 0.15% calcium hydroxide in relation to fruit weight.

Table 3. Changes in physical properties of laboratory - prepared seasoned umeboshi during processing.

Sample		Calcium hydroxide concentration (%)	AIS (%)	WSP(W)	PSP	HSP(H)	SSP(S)	Total	Ratio of W/(H+S)	Ca (mg/100g AIS)	Adhesiveness (μJ)
				mg/100 g (%)							
Fresh		—	2.08	103 (19.2)	40 (7.5)	362 (67.5)	31 (5.8)	536 (100)	0.26	60	—
After salting	Control	0.00	2.42	461 (68.3)	111 (16.4)	79 (11.7)	24 (3.6)	675 (100)	4.48	127	—
	Ca-1	0.05	2.48	393 (53.5)	138 (18.8)	176 (23.9)	28 (3.8)	735 (100)	1.93	190	—
	Ca-2	0.10	2.30	309 (46.3)	104 (15.6)	224 (33.6)	30 (4.5)	668 (100)	1.22	230	—
	Ca-3	0.15	2.25	261 (39.3)	102 (15.4)	270 (40.7)	31 (4.7)	664 (100)	0.87	665	—
After sun-drying	Control	0.00	4.24	918 (71.3)	285 (22.1)	68 (5.3)	17 (1.3)	1288 (100)	10.80	129	421
	Ca-1	0.05	4.11	879 (68.1)	309 (24.0)	82 (6.4)	20 (1.6)	1290 (100)	8.62	210	426
	Ca-2	0.10	4.02	831 (66.1)	311 (24.7)	95 (7.6)	20 (1.6)	1257 (100)	7.23	260	398
	Ca-3	0.15	3.92	712 (62.5)	286 (25.1)	115 (10.1)	27 (2.4)	1140 (100)	5.01	817	323
After seasoning	Control	0.00	3.15	686 (68.3)	240 (23.9)	56 (5.9)	22 (2.2)	1004 (100)	8.79	138	177
	Ca-1	0.05	3.04	628 (66.2)	236 (24.9)	63 (6.6)	21 (2.2)	948 (100)	7.48	269	196
	Ca-2	0.10	3.21	627 (66.7)	220 (23.4)	71 (7.6)	22 (2.3)	940 (100)	6.74	320	172
	Ca-3	0.15	3.26	604 (65.5)	202 (21.9)	89 (9.7)	27 (2.9)	922 (100)	5.21	846	143

Symbols and the methods of measurements are as indicated in Table 1.

Fig. 7. Scanning electron micrographs of vertical section of laboratory-prepared samples. a, Control $\times 180$; b, Ca-1 $\times 180$; c, Ca-2 $\times 180$; d, Ca-3 $\times 180$. Bar indicates 100 μ m. Preparation conditions of control, Ca-1, Ca-2 and Ca-3 are shown in Table 2.

the shape of the cell wall could not be identified (Fig. 7a). The area just beneath the skin in the calcium-added samples, however, were different from the control sample (Fig. 7b–d). The cell shape was clearer when more calcium was added, and the calcium reacted progressively more deeply from the skin, with a depth of 12.5 μ m in Ca-1, 25.0 μ m in Ca-2 and 37.5 μ m in Ca-3 as shown by arrows. These observations confirmed that prevention of damage to the skin and flesh of

umeboshi was caused by the thickened and strengthened area just beneath the skin, the cell wall of which was bound by added calcium.

Sensory evaluation of laboratory-prepared umeboshi samples It is evident that the addition of calcium can prevent damage to the skin and flesh of umeboshi; however, too much calcium caused poor sensory evaluation with regard to texture. Consequently, sensory evaluation was made

Table 4. Result of sensory evaluation of laboratory-prepared umeboshi.

	Calcium concentration (%)	Skin	Flesh	Preference
Ca-1	0.05	-0.10 ^{a)}	0.10 ^{a)}	-0.10 ^{a)}
Ca-2	0.10	-0.15 ^{a)}	0.10 ^{a)}	-0.10 ^{a)}
Ca-3	0.15	0.85 ^{b)}	0.10 ^{a)}	-0.40 ^{b)}

Calcium added samples were judged in comparison to non-added sample by 7-level numerical scale. Skin was judged from extremely thin (-3) to extremely thick (+3), flesh from extremely hard (-3) to extremely soft (+3) and preference from extremely bad (-3) to extremely good (+3).

^{a)}not significant; ^{b)}significant level at $p < 0.01$.

of skin thickness and the softness of the flesh, and a 7-level numerical scale was used to determine preference of calcium-added laboratory-prepared umeboshi samples in comparison with a product without calcium hydroxide (Table 4). The skin of Ca-3, to which the most calcium had been added, was evaluated as being significantly thicker ($p < 0.01$) while the skin of the other samples (Ca-1 and Ca-2) was not significantly different from the control sample. There were no significant differences between calcium-added samples and the control sample with regard to flesh softness; this result corresponded to the values of the physical properties. The preference of Ca-3 was given a significantly poor evaluation ($p < 0.01$) on account of the thick skin. From these sensory evaluation results, it is proposed that the addition of 0.1% calcium hydroxide during the pickling process in relation to the fruit material weight was enough to prevent damage to the skin and flesh during the sequential processes of sun-drying

and seasoning and the thickness of the skin was negligible with regard to textural evaluation.

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