Effect of Calcium Gluconate Addition on the Properties of Ume Fruit (Japanese Apricot) Products

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Two types of ume fruit (Japanese apricot) products, hardened fruit and salted and sun-dried fruit, were prepared using calcium gluconate, a calcium compound which has attracted interest recently because of the proliferation of *Lactobacillus bifidus*, as a substitute for calcium hydroxide; the properties of the products were compared with conventional products prepared using calcium hydroxide. Calcium gluconate acted as a hardener similar to conventional calcium hydroxide in hardened ume fruit products. The color of the product lost some of its redness and turned more yellowish. Since calcium hydroxide made the surface of the hardened ume fruit product redder, which is not preferred by consumers, calcium gluconate had a favorable effect on the surface color. Another problem regarding taste was also solved by using calcium gluconate. The product prepared using calcium hydroxide tasted bitter, while calcium gluconate did not leave a bitter taste in the hardened ume fruit product, and the difference was significant ($p < 0.01$). The bitterness threshold in the solution was also lower with calcium gluconate compared with the case of calcium hydroxide. The effect of calcium gluconate on the salted and sun-dried ume fruit product was the same as calcium hydroxide and it was apparent that calcium gluconate prevented damage to the skin.

Keywords: ume fruit, Japanese apricot, salted ume fruit, calcium gluconate, calcium, pickles

There are two types of ume fruit products, the first is a hardened product salted with calcium compounds with a crisp flesh texture, and the other is a salted and sun-dried product with a soft and pliable texture. Many calcium compounds of reagents such as calcium hydroxide, calcium lactate, calcium carbonate and calcium oxide were investigated for use in hardened ume fruit products (Otake *et al.*, 1995a), and the hardening effect was also studied using ashed substances from eggshell (Kaneko *et al.*, 1993; Otaguro *et al.*, 1994; Otaguro *et al.*, 1995a; b), oyster shell (Kaneko *et al.*, 1993) and seaweed (Otaguro *et al.*, 1997). The results showed that all the reagents excluding calcium carbonate had the effect of hardening ume fruit flesh, and the degree of hardness of the fruit salted with calcium carbonate was 85% that of the other products. It was also reported that the ashed eggshell acted differently according to the ashing temperature, the oyster shell made ume fruit sufficiently hard, however, the ashed sea weed was less effective in its hardening action. Use of higher concentrations of calcium hydroxide to make ume fruit hard made the taste bitter (Otake *et al.*, 1996) and the colour of the surface became redder (Otake & Otaguro, 1996). Salted and sun-dried ume fruit has a very thin skin and an extremely soft and pliable flesh. Consequently, the product is often squashed or burst; this product is generally made without adding any calcium compound. The rate of yield rose and the incidence of squashed or burst fruit was lower with the addition of small amounts of calcium hydroxide, however (Otake *et al.*, 1999). The intention of Otake *et al.* (1999) was to make the surface harder by applying the technique used to

make hardened ume products.

Calcium compounds have recently attracted attention because calcium is the only nutritional compound ingested by Japanese at below the recommended dietary intake. Several calcium compounds such as fermented calcium lactate, calcium gluconate and calcium lactate gluconate have appeared as food additives. In particular, it has been reported that calcium gluconate had the effect of prompting the growth of *Lactobacillus bifidus* (Asano *et al.*, 1994; Asano *et al.*, 1997). This additive has two advantages, viz. as a source of calcium and as means of improving the intestinal condition. The aim of this study was to apply calcium gluconate to ume fruit products, and to measure the degree of hardening of the flesh, and the effect of increasing the yield rate of salted and sun-dried ume fruit products. Some advantageous aspects concerning the use of calcium gluconate in ume fruit products were also investigated.

Materials and Methods

Fruit materials Small-size ume fruit (Japanese apricot, *Prunus mume* Sieb. et Zucc. var. *microcarpa* Makino, cv. Koshu Koume) was used for preparing ume samples. Fresh fruit was harvested on May 20th 1998 for hardened samples, and materials for salted and sun-dried samples were harvested on June 12th 1997. The materials were harvested at optimal periods from the same field at Yatsushiro in Yamanashi Prefecture.

Hardening materials Calcium gluconate (food additive) was purchased from Fujisawa Pharmaceutical Co., Ltd.

Calcium hydroxide as a reagent class was purchased from Wako Pure Chemical Industries, Ltd.

The minimum concentration of calcium hydroxide required to obtain sufficient hardness for hardened ume fruit products was 0.3% of the fruit material weight (Otoguro *et al.*, 1993). The corresponding concentration of calcium alone is 0.16% of the fruit material weight. To obtain the same concentration of calcium ion, a converted concentration of more than 1.79% calcium gluconate was needed because calcium gluconate contains 8.94% calcium ion by weight. In this experiment, the fresh ume materials were salted by adding 2.0% (hereafter referred to as HG-1), 3.0% (HG-2) and 4.0% (HG-3) calcium gluconate in relation to the fruit material weight, respectively. The abbreviation "H" is derived from hard which expresses the ume sample flesh property, and "G" represents gluconate. The corresponding concentrations of calcium hydroxide to the same concentration of the calcium ion in calcium gluconate were 0.331% (HC-1), 0.497% (HC-2) and 0.662% (HC-3), respectively. The abbreviation "C" represents control sample.

The purpose of adding calcium hydroxide to the salted and sun-dried ume fruit product is to prevent squashing or burst flesh of the hardened fruit surface induced by added calcium. However, too much calcium hydroxide damages the soft and pliable flesh texture. The sample salted with 0.05%–0.10% calcium hydroxide had both a hard surface and soft flesh, and the fruit salted with 0.15% of calcium hydroxide had a significantly thicker surface which the sensory evaluation panel found decreased the palatability (Otake *et al.*, 1999). The desirable concentration of calcium alone is calculated as 0.027%–0.054%, and the corresponding concentration of calcium gluconate is 0.3%–0.6%. In this experiment, salted and sun-dried ume fruit samples were prepared by salting with 0.3% (SG-1) and 0.6% (SG-2) calcium gluconate of the fruit material weight; a sample salted with an excess concentration of 0.9% (SG-3) calcium gluconate was also prepared. The abbreviation "S" is derived from soft which expresses the ume sample flesh property. The results were compared with the control samples which were salted with the same concentrations of calcium ion to the same concentration of calcium hydroxide of 0.05% (SC-1), 0.10% (SC-2) and 0.15% (SC-3), respectively, reported by Otake *et al.* (1999).

Preparation procedure for hardened ume samples

Hardened ume samples were prepared in the manner described by Otake and Otoguro (1996): Two kilograms of fresh ume fruit was brined in lidded polystyrene cylindrical

vessels of 25.0 cm diameter×20.5 cm height with 1200 ml of a 5% sodium chloride solution to which the prescribed concentrations of calcium gluconate and calcium hydroxide had been added. Thirty-two grams of sodium chloride, corresponding to 1% of the total weight of the fresh ume fruit and brining solution, was added to the brine once a day for 23 days until the sodium chloride concentration in the fruit had reached 20%. The brining procedure was carried out in a room with the temperature of 20°C. A batch to which no calcium compound had been added was also prepared as described above (H-0). In addition to these laboratory scale samples, another batch, a full plant scale manufacture was also prepared: A fiberglass reinforced plastic tub of 176.0 cm (Length)×122.5 cm (Width)×72.5 cm (Height) on the outside, 164.5 cm (L)×110.0 cm (W) on the inside at the top, 157.5 cm (L)×103.0 cm (W) on the inside at the bottom, and 62.5 cm (Deep) was used. The thickness of the tub wall was not uniform from the top (11.5 cm) to the bottom (19.5 cm), and the inside volume was 1070 l. Five hundred kilograms of fresh ume fruit was brined with 300 l of a 5% sodium chloride solution to which the same concentration of calcium gluconate of HG-1 had been added. This batch was referred to as HGP-1, and the abbreviation "P" is from plant. The rest of the procedure was the same as the laboratory scale sample. After 2 months of brining, salted fruit was desalted and seasoned by soaking in a seasoning solution (Table 1) in a ratio of 1 kg of salted fruit to 600 ml of seasoning solution at room temperature for 1 week.

The solubility of calcium hydroxide is 0.17 g to 100 g water at 25°C, and deposits of it were found to adhere to the surface of the ume fruit. However, since the solubility of calcium gluconate is 3.5 g to 100 g water at 25°C, there was no deposit of calcium gluconate in any of the samples, and it was realized that calcium gluconate was more advantageous for dissolving.

Preparation procedure for salted and sun-dried ume samples Salted and sun-dried ume fruit samples were prepared in the manner described by Otake *et al.* (1999).

General measurements Hardness, sodium chloride content, total acid content and content of each acid component (citric acid and malic acid), colour (*L*-, *a*- and *b*-values), alcohol insoluble solids (AIS) and Ca content bound to AIS of the hardened ume sample were measured as described by Otake *et al.* (1995a). The content of gluconic acid in the hardened ume samples was also measured using an F-kit for *d*-gluconic acid and *d*-glucono- δ -lactone (Boehringer Mannheim). Yield rate, damaged fruit ratio, water content, titratable

Table 1. Composition of seasoning solution for hardened ume products.

	(%)
Malic acid	1.00
Citric acid	1.00
Sodium acetate	0.50
Acetic acid	1.50
MSG	1.72
Glycine	0.50
Stevioside	0.36
Sorbit	2.96
Reducing sugar	0.88

Table 2. Concentration of calcium hydroxide and calcium gluconate for measuring recognition threshold.

No.	Calcium	Calcium hydroxide	Calcium gluconate
1	0.00135	0.0025	0.0151
2	0.00271	0.005	0.0303
3	0.00541	0.01	0.0605
4	0.01082	0.02	0.1211
5	0.02164	0.04	0.2421
6	0.04328	0.08	0.4842
7	0.08656	0.16	0.9684

Calcium hydroxide and calcium gluconate were dissolved in water and 18.84% of the seasoning solution shown in Table 1.

ble acidity, sodium chloride content, pH, AIS and Ca content bound to AIS and adhesiveness of the salted and sun-dried ume samples were measured as described by Otake *et al.* (1999).

Scanning electron microscopic observation Flesh sections of the hardened ume samples and the salted and sun-dried samples prepared by adding calcium gluconate were observed by scanning electron microscopy according to the following method described by Otake *et al.* (1995 b; 1999).

Sensory evaluation Recognition threshold and detection threshold of bitterness for calcium gluconate were investigated according to the following method described by Otake *et al.* (1996). Seven different concentrations (Table 2) of sample solutions were prepared by dissolving calcium hydroxide or calcium gluconate into 18.84% of seasoning solution (Table 1). This percentage is the equivalent perceived concentration of the taste in hardened ume samples during mastication by the panel (Otake *et al.*, 1996). The recognition threshold was measured as follows: Sample solutions (10 ml) were served to 20 assessors with the concentration of the calcium compound solutions in ascending order. The assessors were asked if the solutions were bitter or not, and if the answer was positive, they were also asked to choose the degree of their confidence in the judgment from 3 categories: perhaps, probably and definitely. The score of each sample solution was calculated as

$$\text{Score (-)} = A \times 1 + B \times 2 + C \times 3,$$

where *A* was the number of assessors who answered "perhaps bitter", *B* those who answered "probably bitter" and *C* those who answered "definitely bitter". If all assessors answered that the sample solution was not bitter, the score was 0 and if they all answered definitely bitter, the score was 60. The same concentrations of the calcium compound solutions were prepared to measure the bitterness detection threshold. These solutions were paired with the solution to which no calcium compounds had been added, and triangle tests were performed by the 20 assessors. This time, sample solutions were

served with the concentration of calcium compounds solution in descending order. The detection threshold was decided as the concentration when the significant difference was more than 5%.

For ume samples, 10 assessors were asked whether HC-3 and HG-3 were bitter or not, and the bitterness of HG-3 was evaluated according to a 5-level numerical scale in comparison with HC-3. The thickness of the skin and the softness of the flesh in SG-1, 2 and 3 were evaluated according to a 5-level numerical scale in comparison with S-0 which was salted without calcium compounds.

Results and Discussion

Hardened ume sample The measured properties of hardened ume samples are shown in Table 3.

Hardness The hardness is one of the most important properties of hardened ume products. The hardness of fresh ume fruit was 8.06 N, and it dropped to 0.70 N after salting without adding any calcium (H-0). On the other hand, the hardness of HC-1 and HG-1, which were salted with the least amount of calcium compounds, showed 6.87 N and 6.91 N, respectively. According to a previous study (Kaneko *et al.*, 1993), salted ume fruit with a hardness of more than 5.88 N is considered suitable, and the hardness obtained in this study was sufficient and acceptable. With regard to calcium hydroxide, the hardness increased to 6.87 N, 6.91 N and 7.58 N as the concentration of calcium increased. In the case of calcium gluconate, the hardness also increased to 6.91 N, 6.97 N and 7.27 N. Comparing calcium hydroxide and calcium gluconate in the same calcium concentration (HC-1 vs. HG-1, HC-2 vs. HG-2, and HC-3 vs. HG-3), the hardness of the samples salted with calcium gluconate was greater than those salted with calcium hydroxide. The hardness of the plant scale sample (HGP-1) was 7.74 N and was greater than the sample salted with the same concentration of calcium gluconate in the laboratory scale sample. From these results, it was concluded that calcium gluconate was sufficient to harden the ume products.

Table 3. Data obtained from fresh and salted ume (hardened product).

		Fresh ume ^{a)}	Without calcium H-0	Calcium hydroxide			Calcium gluconate			
				HC-1	HC-2	HC-3	HG-1	HG-2	HG-3	HGP-1
Brining condition	Ume weight (kg)	—	2	2	2	2	2	2	2	500
	Water (ml)	—	1200	1200	1200	1200	1200	1200	1200	300000
	NaCl added first (g)	—	60	60	60	60	60	60	60	15000
	Calcium compound (g) ^{b)}	—	0.00	6.61	9.92	13.22	40.00	60.00	80.00	10000
After salting	Hardness (N) ^{c)}	8.06	0.70	6.87	6.91	7.58	6.91	6.97	7.27	7.74
	NaCl content (%) ^{d)}	—	10.88	10.89	10.00	11.25	11.24	11.19	10.62	11.02
	Total acid content (%) ^{e)}	5.04	2.70	2.35	2.12	1.97	2.37	2.31	2.26	2.40
	Citric acid (%)	2.68	1.46	1.14	0.94	0.78	1.25	1.12	1.02	1.29
	Malic acid (%)	2.36	1.24	1.21	1.18	1.19	1.12	1.19	1.24	1.10
	AIS (%)	3.854	2.908	3.044	3.259	3.361	2.779	3.278	3.263	3.250
	Bound Ca to AIS (mg/100g AIS)	312.0	534.0	1847.6	2699.0	2856.1	1771.2	2544.2	2748.0	1320.5
	Gluconic acid (%)	—	—	—	—	—	0.447	0.673	0.879	0.496
	Color <i>L</i>	47.1	41.5	40.8	42.3	43.4	43.1	42.9	42.1	45.5
	<i>a</i>	−8.82	1.73	4.23	3.18	3.38	2.80	2.88	2.94	1.77
	<i>b</i>	20.0	18	14.2	14.9	15.5	16.1	16.0	15.5	20.2

^{a)}Ume fruit was harvested on May 23 1997 at Yatsushiro in Yamanashi Prefecture.

^{b)}Ca ion content was 0.179% (HC-1, HG-1 and HGP-1), 0.268% (HC-2 and HG-2) and 0.358% (HC-3 and HG-3).

^{c)}Stress against cylindrical plunger with diameter of 1 mm. ^{d)}Mohr method was used to the filtered solution of flesh homogenate.

^{e)}Citric acid content calculated from titratable acidity of the flesh homogenate supernatant.

Sodium chloride and total acid The concentration of sodium chloride of the samples was between 10.00% and 11.25%, and there was no great difference among them. The total acid value decreased after salting in all samples, however, the degree of decrease depended on the concentration of the calcium compounds. The total acid value of the sample salted without calcium was the highest, indicating that less acid eluted without the addition of calcium. In the samples salted with calcium compounds, the total acids decreased as the calcium compounds increased, and indicating that the compounds promoted the elution of acids from the fruit. The total amount of acid of the sample salted with calcium hydroxide was lower than that of the sample salted with calcium gluconate, which meant that calcium hydroxide caused acids to elute more than calcium gluconate. The acids were citric acid and malic acid, and more of the former eluted from the fruit. Of the two calcium compounds, calcium hydroxide promoted the elution of citric acid more than calcium gluconate.

Ca bound to alcohol insoluble solid The amount of calcium bound to AIS increased as the concentration of the calcium compounds increased in both calcium hydroxide and calcium gluconate. Although the amount of AIS of the sample salted with calcium gluconate was less than that salted with calcium hydroxide with the same calcium concentration, the hardness of the sample salted with calcium gluconate was greater than that salted with calcium hydroxide. This indicates that the hardening effect of calcium gluconate was higher than that of calcium hydroxide. The calcium amount bound to AIS of the plant scale sample (HGP-1) was 75% of the amount of the laboratory scale sample (HC-1), however the hardness of the plant scale sample was greater. Furthermore, the small amount of calcium bound to AIS meant that more calcium gluconate existed in a free state, and that this compound can act as a promoter for the growth of *Lactobacillus bifidus* (Asano *et al.*, 1994; 1997).

Gluconic acid Calcium gluconate and gluconic acid were reported as promoters of the proliferation of *Lactobacillus bifidus* (Asano *et al.*, 1994; 1997) and this action is one of the advantages of using calcium gluconate. Therefore, the amount of gluconic acid in hardened ume samples was measured. The content increased to 0.447%, 0.673% and 0.879% when the amount of calcium gluconate added increased. The amount of gluconic acid in the plant scale

sample was 0.496%, which was higher than that in the laboratory scale sample 0.447% at the same concentration of added calcium gluconate. The gluconic acid in this measurement existed in a free state in ume flesh, consequently all the measured gluconic acid had the ability to promote *Lactobacillus bifidus*.

Color The surface color of the sample was investigated by measuring the *L*-, *a*- and *b*-values. The *L*-value of the laboratory scale sample was between 40.8 and 43.3, and there was no big difference among the samples. However, *L*-value of the plant scale sample 45.5 was higher than the laboratory scale sample with the same calcium gluconate concentration. Sun exposure made ume fruit brighter in color (Otake & Otaguro, 1996), and the difference between the laboratory scale sample and the plant scale sample was thought to be caused by exposure to sunlight of the former. The vessel for the laboratory scale sample was made of translucent polystyrene, consequently the sunlight had penetrated through the walls of the vessel; the fiberglass reinforced plastic tank for the plant scale sample, on the other hand, was opaque, so that sunlight was shut out. The *a*-values of the samples salted with calcium hydroxide were between 3.18 and 4.23, and those of calcium gluconate were less at 2.80–2.94. This indicated that the samples salted with calcium gluconate were less red than those salted with calcium hydroxide. In the latter salting, the reddening of the sample surface became a serious problem because consumers dislike a reddened product (Otake & Otaguro, 1996). Calcium gluconate had the advantage of not turning the surface color red. Furthermore, the *a*-value of the plant scale sample was less than that of the laboratory scale sample; this is also believed to be due to the shutting-out of sunlight. The *b*-values of the samples salted with calcium hydroxide were between 14.2 and 15.5, and those of the samples with calcium gluconate were between 15.5 and 16.1, so which meant that the latter were more yellowish. The plant scale sample with a *b*-value of 20.2 was more yellowish than the laboratory scale sample.

Scanning electron microscopy The scanning electron micrographs of the section of the samples salted with the least calcium concentration in the laboratory scale samples, HC-1 and HG-1, and the plant scale sample (HGP-1) are shown in Fig. 1. The cell walls retained their shape and the vacant spaces in the cells could be clearly observed. Round crystalline deposits were also observed in some cells. Sections of the

Fig. 1. Scanning electron micrographs of vertical section of hardened ume product. a, calcium hydroxide (HC-1) $\times 120$; b, calcium gluconate (HG-1) $\times 120$; c, calcium gluconate (HGP-1) $\times 120$. Bar indicates 100 μm and arrows indicate the crystalline deposits in the cells. Preparation conditions of HC-1, HG-1 and HGP-1 are shown in Table 3.

other samples salted with different concentrations of calcium showed this same appearance. These kinds of observations were also reported with the samples salted with different kinds of calcium compounds, which were sufficiently hard (Odake *et al.*, 1995a; b). Consequently, it is concluded from the microscopic results that it is possible for calcium gluconate to be used as a hardener for the hardened ume fruit products.

Sensory evaluation The results described above support the fact that calcium gluconate acted as a hardener for the hardened ume fruit products from the aspect of maintaining the hardness and the structure. However, the addition of calcium hydroxide to maintain the hardness with a concentration of more than 0.45% to fruit weight produced a bitter taste which was unpleasant to consumers (Odake *et al.*, 1996).

Fig. 2. Recognition threshold of bitterness for calcium hydroxide and calcium gluconate. ■, calcium hydroxide; □, calcium gluconate.

Consequently, sensory evaluation was essential and was carried out to verify the advantages of calcium gluconate for taste. The recognition threshold of bitterness was first measured using various concentrations of calcium gluconate seasoning solutions (Fig. 2). The score was higher when the concentration of calcium gluconate in the aqueous solution increased. The scores of the calcium gluconate aqueous solution were lower than those of calcium hydroxide when the concentration of calcium was more than 0.01082%. Seasonings masked the bitterness of both calcium gluconate and calcium hydroxide: that of calcium gluconate was more suppressed and was barely perceptible by assessors at even the highest concentration of the compound. The detection threshold of calcium hydroxide was 0.01082% in the aqueous solution and 0.02164% in the seasoning solution (Table 4), being higher in the latter solution because of its masking by the seasonings. The bitterness of calcium gluconate was not significantly detected in the triangle test to measure the detection threshold; therefore, it can be said there is no

Table 4. Detection threshold of bitterness for calcium hydroxide and calcium gluconate.

Calcium concentration (w/v %)	Aqueous solution		Seasoning solution	
	Calcium hydroxide	Calcium gluconate	Calcium hydroxide	Calcium gluconate
0.08656	**	n.s.	**	n.s.
0.04328	**	n.s.	**	n.s.
0.02164	**	n.s.	*	n.s.
0.01082	**	n.s.	n.s.	n.s.
0.00541	n.s.	n.s.	n.s.	n.s.
0.00271	n.s.	n.s.	n.s.	n.s.
0.00135	n.s.	n.s.	n.s.	n.s.

Triangle tests were undertaken between samples with and without calcium compounds.

**, $p < 0.01$; *, $p < 0.05$; n.s., not significant.

Table 5. Data obtained from fresh, salted, dried and seasoned ume (dried and soft product).

	Fresh ume ^{a)}	Without calcium ^{b)} S-0	Calcium hydroxide ^{b)}			Calcium gluconate		
			SC-1	SC-2	SC-3	SG-1	SG-2	SG-3
Brining condition Ume weight (kg)	—	2	2	2	2	2	2	2
NaCl added (g)	—	350	350	350	350	350	350	350
Calcium compound (g) ^{b)}	—	0.00	1.00	2.00	3.00	6.00	12.00	18.00
After seasoning Yield rate (%) ^{c)}	—	60.02	59.18	59.05	60.52	59.84	59.72	60.04
Damaged rate (%) ^{d)}	—	26.8	16.1	8.1	4.0	17.2	11.3	5.8
Moisture (%) ^{e)}	90.99	75.90	76.53	76.11	76.33	75.63	75.70	75.52
Titrateable acidity (%) ^{f)}	5.28	3.31	3.23	3.24	3.11	3.29	3.30	3.25
Sodium chloride (%) ^{g)}	0	10.06	9.93	10.27	9.78	10.04	10.10	9.88
pH	2.5	2.9	2.9	2.9	3.0	2.9	2.9	3.0
AIS (%)	2.08	3.15	3.04	3.21	3.26	3.21	3.19	3.26
Ca bound to AIS (mg/100g AIS)	119	138	269.0	320.0	846.0	271.0	373.0	815.0
Adhesiveness (μ j)	—	177	196	172	143	194	164	145

^{a)}Ume fruit was harvested on June 12 1997 at Yatsushiro in Yamanashi Prefecture.

^{b)}Ca ion content was 0.027% (SC-1 and SG-1), 0.054% (SC-2 and SG-2) and 0.081% (SC-3 and SG-3).

^{c)}Weight ratio before and after each process to weight of the fresh material.

^{d)}Ratio of the number of squashed or burst damaged fruit to the whole.

^{e)}Change in weight before and after drying at 105°C.

^{f)}Titration with a 0.1 N-NaOH solution.

^{g)}Mohr method after diluting the ashed substances at 550°C for 5 h.

^{h)}Odake *et al.* (1999)

Fig. 3. Scanning electron micrographs of vertical section of salted and sun-dried ume product added with calcium gluconate. a, SG-1 $\times 120$; b, SG-2 $\times 120$; c, SG-3 $\times 120$. Bar indicates 100 μm and arrows indicate the depth of hardened parts. Preparation conditions of SG-1, SG-2 and SG-3 are shown in Table 4.

problem of taste of this compound in the solution samples. Eighty percent of assessors objected to the bitterness of calcium hydroxide in ume samples, however, no one noticed the bitterness of calcium gluconate in these samples. According to the analysis of variance, the bitterness of the samples with calcium hydroxide was found to be significantly greater ($p < 0.01$) than in samples with calcium gluconate.

Salted and sun-dried ume samples The measured properties of salted and sun-dried ume samples are shown in Table 5.

Effect of reduction of damage to product The purpose of adding calcium compound to salted and sun-dried ume samples was to prevent damage to the skin and flesh of the product. However, excessive addition reduces the flesh softness. The quality of salted and sun-dried ume products to which 0.05, 0.10 and 0.15% of calcium hydroxide had been added was improved (SC-1, -2 and -3, Table 4), and the damage rate reduced with increase in the calcium hydroxide concentration (Odake *et al.*, 1999). At that time, there was no difference in yield rate, water content, titratable acidity, sodium chloride content, pH or AIS content. In contrast, the Ca content bound to AIS increased and adhesiveness dropped when the concentration of calcium hydroxide was increased. Calcium gluconate also had the effect of reducing the damage rate of the product, and this rate decreased to 17.2%, 11.3% and 5.8% when the concentration of calcium gluconate was increased to 0.3% (SG-1), 0.6% (SG-2) and 0.9% (SG-3). This result provided evidence that calcium gluconate could be used to reduce the damage to salted and sun-dried ume products. With the exceptions of Ca content bound to AIS and adhesiveness, there was no difference in the measured properties among the samples salted with calcium gluconate. Ca content bound to AIS indicated 271.0 mg/100 g AIS, 373.0 mg/100 g AIS and 815.0 mg/100 g AIS when the concentration of calcium gluconate increased, and these values were almost the same as those for samples salted with calcium hydroxide with the same concentration of calcium. Adhesiveness decreased as the concentration of calcium gluconate increased, and the tendency was the same as in the case of calcium hydroxide.

Scanning electron microscopy The section of the sample flesh salted without calcium was uniform from the skin to the inner part of the flesh, the cells had collapsed completely and the shape of the cell wall could not be identified (Odake *et al.*, 1999). Scanning electron micrographs of the section of the

salted and sun-dried samples to which calcium gluconate had been added are shown in Fig. 3. The area just beneath the skin was found to have a clear cell shape where it had been strengthened by the addition of calcium. These results were the same for the samples salted with calcium hydroxide (Odake *et al.*, 1999). The cell shape was clearer when more calcium gluconate had been added, and the depth became progressively greater: 13.64 μm (SG-1), 29.50 μm (SG-2) and 45.45 μm (SG-3). These depths were greater than in the samples which had been salted with calcium hydroxide with the same concentration of calcium.

Sensory evaluation There were no significant differences in the flesh softness of samples salted with three different concentrations of calcium gluconate. However, the sample salted with 0.15% calcium gluconate, which was the highest concentration, was judged to have a significantly thicker skin ($p < 0.01$). This result was the same as in the samples which had been salted with calcium hydroxide with the same concentration of calcium.

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