

Effect of Pickling Methods on the Quality and Flavor of Umeboshi

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ABSTRACT

Umeboshi is made by pickling plums in salt. The quality of umeboshi varies depending on the pickling method and additives used. In the present study, we compared the quality of plums pickled in salt, brine, and Ca-supplemented brine. Quality determinants of the pickled plums included hardness, moisture content, pH, Brix value, fruit color, and malic acid, citric acid, and salt concentrations. We also performed a microbiological evaluation of the umeboshi. Additionally, using a questionnaire, we surveyed consumer preferences for umeboshi pickled using different additives. Salt-pickled umeboshi had a high pH and low citric acid content, resulting in a mild flavor, whereas umeboshi pickled in brine had a high malic acid content. After soaking in various salts, the acidity of pickled plums increased. Moreover, umeboshi pickled in Ca-supplemented brine exhibited high L- and a-values. Our results suggest that malic acid contributes to the flavor and appeal of umeboshi and that Ca supplementation in the brine results in bright-colored umeboshi.

Keywords: Brine, pickling, plums, salt.

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1. INTRODUCTION

Umeboshi, a traditional Japanese food consumed since ancient times, is made by washing raw plums, draining excess water, and pickling them in a container with salt, equivalent to 18% of the weight of the plums, for approximately one month [1]. However, plums pickled using this technique take longer to become evenly pickled as the water exuded from the plums dissolves the salt. Therefore, plums are often pickled in a brine solution to make umeboshi. A previous study reported that the salinity of dried fish pickled in brine remains constant after approximately 40 min, whereas that of dried fish pickled by other methods requires more than 90 min to reach a constant value [2]. This result suggests that brine could be used to produce umeboshi in a shorter period. In addition, dried fish pickled in a brine solution have a higher moisture content and lower salt concentration than those pickled using the salting method [2]. During the desalting process of umeboshi preparation, components derived from plums are exuded when the plums are pickled in water or low-salt concentration seasoning solutions [3]. Therefore, umeboshi prepared using salt and brine pickling has different qualities. Furthermore, citric acid content varies with the pickling period, with a previous study reporting a citric acid content of 3.0%–3.5% and 1.5%–2.0% after

7 and 14 day of pickling, respectively [4]. This suggests that the quality of umeboshi may also vary depending on the pickling period. In addition, Ca is sometimes added during the preparation of umeboshi to prevent softening [5]; however, the addition of excessive Ca can result in a bitter taste and poor coloration [6], [7], affecting the taste and quality of umeboshi. Furthermore, the composition of umeboshi varies depending on the soaking period. During the production process of umeboshi, the citric acid content of plums soaked for 7 day was approximately 0%–1%, which increased to 2%–3% in those soaked for 20 day [4]. Moreover, the moisture content of umeboshi pickled for 7 day was 50%–60%, which decreased to approximately 25% after 20 day [8]. Overall, these findings suggest that the quality of umeboshi varies depending on the salting conditions, additives used, and duration of pickling.

The overall quality of umeboshi should be comprehensively evaluated based on the number of microorganisms, salt concentration, organic acid content, hardness, and color. In umeboshi pickled at a salt concentration of approximately 11%, the number of general viable bacteria was 10^4 bacteria/g at the beginning of the storage period at 20 °C, increasing to approximately 10^5 bacteria/g on day 15, followed by a slight decrease to 10^2 – 10^3 bacteria/g on day 30 [9]. In contrast, the number of general viable



bacteria in umeboshi pickled at a salt concentration of approximately 19% (seasoning liquid umeboshi) changed from approximately 60 bacteria/g at the beginning of storage at 20 °C to less than 30 bacteria/g after day 15 [9]. As the number of microorganisms decreases with increasing salinity, salinity likely affects the quality of umeboshi. While microbiological testing is essential for evaluating the quality of umeboshi, salinity measurement is equally necessary due to the distinctive strong salty taste characterizing umeboshi and the impact of salinity on its quality. Moreover, given the characteristic acidity and texture of umeboshi, it is essential to assess malic and citric acid contents and pH, as indicators of acidity [10], and moisture and hardness as indicators of texture [8]. In addition, with increasing ripeness, the Brix value of plums increases, and their color changes [11]. Thus, the Brix value and fruit color are also factors that affect the quality of umeboshi. Overall, changes in the number of microorganisms and various factors, such as malic and citric acid contents, pH, moisture, firmness, Brix value, and fruit color, play a role in determining the quality of umeboshi.

In the present study, we prepared umeboshi using different pickling periods and methods, including salt, brine, and Ca-supplemented brine and compared their quality. We first determined the quality of the raw materials and frozen plums. To investigate the effects of different pickling methods and periods on quality, we determined the quality of salt- and brine-pickled umeboshi pickled for 7 or 10 day. We also assessed the quality of umeboshi pickled for 7 day in brine supplemented with 0.15% Ca [5] to investigate the effects of this supplementation on umeboshi quality. Finally, we surveyed how different people perceived the saltiness, sourness, hardness, reddish color, flavor, and overall desirability of umeboshi using a questionnaire to clarify the effects of different pickling methods on the quality of umeboshi from the perspective of consumers.

2. MATERIALS AND METHODS

2.1. Materials

Frozen plums (from Wakayama prefecture) were purchased online (Sugi-lemonhouse, Wakayama, Japan) and transported to the laboratory in a frozen state. Salted umeboshi was pickled for 7 and 10 day in an amount of salt equivalent to 10% of the weight of plums, referring to Hashimoto [12]. To prepare umeboshi soaked for 7 and 10 day in saturated brine, salt was added to maintain saturation. To pickle plums in the Ca-supplemented brine, calcium hydroxide (Fujii Pharmaceutical Co., Ltd., Tokyo, Japan) was added to saturated brine in an amount equivalent to 0.15% of the weight of plums and pickled for 7 day, referring to Odake and Otoguro [5]. To measure hardness, moisture, pH, and fruit color, three umeboshi samples were used and designated as A, B, and C. To assess the Brix value, malic and citric acid contents, and salinity, the three umeboshi samples were ground using a mortar and pestle to prepare samples for analysis.

2.2. Measurement of Hardness, Moisture, pH, Brix Value, and Number of Microorganisms

Hardness measurements were performed using a rheometer (Yamaden Co., Ltd., Tokyo, Japan). Each dried plum was placed on a sample stand, and a cylindrical plunger (3 mm diameter) was lowered at a speed of 1 mm/s while manually holding the sample to measure the breaking load (N). The strain rate was set at 60%.

To measure moisture content, 1 g of the sample was accurately weighed into a weighted bottle previously heated to 105 °C and allowed to cool. The bottle was then heated again to 105 °C and retained at that temperature for 120 min, after which it was allowed to cool and was weighed. Moisture content was calculated as the difference in weight before and after heating.

To measure pH, a pH meter (Sato Shouji Inc., Kanagawa, Japan) was inserted into the sample.

To determine the Brix value, approximately 10 g of each sample was weighed and mixed with an equal amount of pure water. The Brix value of this solution was then measured using a Brix meter (Shanghai Siwei Instrument Manufacturing Co., Ltd., Shanghai, China).

To determine the number of microorganisms, 2 g of the sample was weighed and diluted to 20 mL with 0.9% sterile saline. This solution was further diluted with 0.9% sterile saline, and 100 μ L was applied to a standard agar medium and a standard agar medium containing 0.9% NaCl, followed by incubation at 35 °C for 48 h. The colonies were then counted.

2.3. Color Assessment

A colorimeter (Shenzhen ThreeNH Technology Co., Ltd., Guangzhou, China) was used to evaluate the fruit color of three random regions of each umeboshi sample.

2.4. Measurement of Organic Acid Contents and Salinity

To determine the malic and citric acid contents, 1 g of the sample was weighed and placed in a 50-mL centrifuge tube; the volume was then adjusted to 50 mL using pure water. After mixing well and removing the precipitate via centrifugation (1956 $\times$ g, 25 °C, 3 min), the supernatant was analyzed using high-performance liquid chromatography. The parameters were set as follows: detector, UV; column, 5C18-PAQ 4.6ID $\times$ 150 mm; mobile phase, 200 mM NaH_2PO_4 (pH 2.8); column temperature: 40 °C; flow rate, 0.5 mL/min; injection volume, 20 μ L; and detection wavelength, 210 nm.

To determine the salinity, 1 g of the sample was weighed, the volume was adjusted to 50 mL using pure water, and the concentration was measured using a sodium ion meter (LAQUA twin Na-11: HORIBA Ltd., Kyoto, Japan). The salt content was estimated as $2.54 \times$ the value measured.

2.5. Questionnaire Survey

A questionnaire was used to determine how different people ranked the saltiness, sourness, hardness, redness, flavor, and overall desirability of each pickled plum, excluding frozen plums, on a scale of 1–3, with 1 indicating first place (favorite), 2 indicating second place, and 3 indicating third place (least favorite). This study was

TABLE I: HARDNESS, MOISTURE, pH, AND BRIX VALUES OF THE VARIOUS UMEBOSHI PICKLING METHODS AND FROZEN PLUMS

Methods	Hardness (N)	Moisture (%)	pH	Brix (%)
Salted (7 day)	0.943 (0.395)	74.0 (3.42)	2.04 (0.0373)	19.2 (3.96)
Salted (10 day)	0.654 (0.259)	77.4 (1.22)	1.77 (0.0619)	18.7 (1.12)
Brine-soaked (7 day)	0.938 (0.630)	72.4 (1.22)	1.77 (0.0687)	25.8 (0.441)
Brine-soaked (10 day)	0.842 (0.247)	69.7 (0.107)	1.62 (0.0307)	28.4 (1.42)
Ca-supplemented brine (7 day)	0.967 (0.388)	62.1 (0.107)	1.78 (0.0237)	39.9 (0.928)
Frozen plums	7.01 (4.71)	88.5 (0.107)	2.49 (0.0101)	6.00 (0.707)

Note: Hardness was measured using $n = 6$ samples and the moisture, pH, and Brix values were measured using $n = 3$ samples. Values inside parentheses () indicate the standard deviation.

approved by the Ethics Committee of the Tokyo University of Technology (No. E22BS-022).

2.6. Statistical Analysis

Data were obtained according to Fisher's three principles, differences in means were analyzed using Student's *t*-test, and differences in population distributions were analyzed using the Wilcoxon signed-rank test, all at a 5% significance level. The *t*-tests were performed using Microsoft Excel (2019), and the Wilcoxon signed-rank test was performed using R computing software.

3. RESULTS

3.1. Measurement of Hardness, Moisture, pH, Brix Value, and Number of Microorganisms

Table I shows the hardness, moisture, pH, and Brix values of the salted, brine-soaked, Ca-supplemented, and frozen plums. The breaking load was 7.01 N for frozen plums, which was significantly higher ($p < 0.05$) than that of umeboshi. For the umeboshi samples, the values were 0.938 N for 7 day in brine, 0.967 N for 7 day in Ca-supplemented brine, 0.943 N for 7 day in salt, 0.842 N for 10 day in brine, and 0.654 N for 10 day in salt, with no significant differences ($p > 0.05$).

Moisture content was 88.5% in frozen plums, which was higher than that in the umeboshi samples ($p < 0.05$). In umeboshi, the moisture content was 77.4% after 10 day of salting, which was higher than that in umeboshi pickled using other methods ($p < 0.05$). The moisture content was not significantly different between 7 day of pickling in salt or brine (74.0% vs. 72.4%; $p > 0.05$) but was significantly ($p < 0.05$) lower in samples pickled in Ca-supplemented brine for 7 day (62.1%). However, the moisture content was higher in samples pickled in brine for 7 day ($p < 0.05$) than in those pickled in brine for 10 day (69.7%) and in Ca-supplemented brine for 7 day ($p < 0.05$).

The pH of the frozen plums was 2.49, which was significantly higher ($p < 0.05$) than that of the umeboshi samples. For umeboshi, the pH was 2.04 after 7 day of salt pickling, which was not significantly different ($p > 0.05$) from that after 10 day of salt pickling and 7 day of Ca-supplemented pickling (pH 1.77 and 1.78, respectively). Moreover, the pH of samples pickled in brine was higher after 7 day of pickling than after 10 day (pH 1.77 vs. 1.62, respectively, $p < 0.05$).

The Brix value of frozen plums (6.00%) was significantly lower ($p < 0.05$) than that of the umeboshi samples. The

Brix value was not significantly different between umeboshi plums pickled in salt for 7 or 10 day, with values of 19.2% and 18.7%, respectively ($p > 0.05$). However, the Brix value of plums after 7 day of Ca-supplemented pickling (39.9%) was significantly higher than that after 7 day of either brine (25.8%) or salt pickling (25.8%) ($p < 0.05$). The Brix value was also significantly higher in plums pickled in brine for 10 day (28.4%) than in those pickled in salt for 10 day (18.7%) or in brine for 7 day (25.8%) ($p < 0.05$).

Colonies were not detected on either the standard agar medium or the standard agar medium containing 0.9% NaCl.

3.2. Color Assessment

Table II shows the L-, a-, and b-values of the salted, brine-pickled, Ca-supplemented, and frozen plums. The L-value of plums after 7 day of pickling in brine was significantly lower than that of frozen plums and plums pickled in Ca-supplemented brine for 7 day (42.8, 46.4, and 48.9, respectively, $p < 0.05$). However, it was not significantly different between plums pickled for 10 day in either brine or salt (44.5 vs. 44.6, respectively, $p > 0.05$).

The a-value was 1.49 for frozen plums, which was significantly lower than that of the umeboshi samples ($p < 0.05$). For umeboshi samples, the a-value was 7.37 after 7 day of pickling in Ca-supplemented brine, which was significantly higher ($p < 0.05$) than that after 7 day of salt pickling and 7 day of brine soaking (4.50 and 3.56, respectively). However, it was not significantly different between plums pickled for 10 day in either salt or brine (4.83 vs. 5.56, respectively, $p > 0.05$).

The b-value of frozen plums was significantly ($p < 0.05$) higher than that of plums pickled for 7 day in either brine or Ca-supplemented brine (25.1 vs. 20.2 and 19.3, respectively). The b-value was 22.5, 21.8, and 21.9 at 7 and 10 day of salt pickling and 10 day of brine soaking, respectively, showing no significant differences ($p > 0.05$).

3.3. Measurement of Organic Acids and Salinity

Table III shows the malic and citric acid concentrations and salinity of the salted, brine-soaked, Ca-supplemented, and frozen plums. The malic acid content was 0.514 g/100 g in frozen plums and 0.440 g/100 g in plums pickled for 10 day in brine, which were significantly higher ($p < 0.05$) than those of all other tested umeboshi, but showed no significant difference ($p > 0.05$). After 7 day in brine, the malic acid content (0.705 g/100 g) was significantly higher ($p < 0.05$) than that of all other umeboshi samples. After 7

TABLE II: L-, A-, AND B-VALUES OF THE VARIOUS UMEBOSHI PICKLING METHODS AND FROZEN PLUMS

Methods	L-value	a-value	b-value
Salted (7 day)	44.6 (1.65)	4.50 (1.30)	22.5 (4.31)
Salted (10 day)	44.5 (2.40)	4.83 (1.73)	21.8 (4.60)
Brine-soaked (7 day)	42.8 (2.64)	3.56 (0.970)	20.2 (2.44)
Brine-soaked (10 day)	44.6 (4.74)	5.56 (1.69)	21.9 (5.03)
Ca-supplemented brine (7 day)	48.9 (3.13)	7.37 (2.94)	19.3 (2.91)
Frozen plums	46.4 (2.56)	1.49 (1.17)	25.1 (2.05)

Note: L-, a-, and b-values were measured using $n = 3$ samples. Values inside parentheses () indicate the standard deviation.

TABLE III: ORGANIC ACID AND SALINITY CONCENTRATIONS OF VARIOUS UMEBOSHI PICKLING METHODS AND FROZEN PLUMS

Methods	Malic acid (g/100 g)	Citric acid (g/100 g)	Salinity (g/100 g)
Salted (7 day)	0.229 (0.00662)	2.46 (0.0648)	11.1 (0.147)
Salted (10 day)	0.308 (0.0320)	2.62 (0.0813)	10.9 (0.254)
Brine-soaked (7 day)	0.705 (0.00681)	4.58 (0.118)	17.5 (0.153)
Brine-soaked (10 day)	0.440 (0.0373)	4.37 (0.152)	20.6 (0.239)
Ca-supplemented brine (7 day)	0.275 (0.00361)	4.08 (0.0700)	22.2 (0.404)
Frozen plums	0.514 (0.00325)	3.82 (0.0645)	0.0135 (0.00147)

Note: The organic acid and salinity concentrations were measured using $n = 5$ samples. Values inside parentheses () indicate the standard deviation.

day of salt pickling, the malic acid content was significantly lower (0.229 g/100 g) than that of plums pickled for 10 day in salt (0.308 g/100 g) and 7 day in Ca-supplemented brine (0.275 g/100 g) ($p < 0.05$).

Citric acid content was 3.82 g/100 g in frozen plums, which was not significantly different ($p > 0.05$) compared to that of plums pickled for 7 day in Ca-supplemented brine (4.08 g/100 g), whereas it was higher than that pickled in salt for 7 day (2.46 g/100 g) and 10 day (2.62 g/100 g). However, the citric acid content in plums pickled in salt for 7 and 10 day (2.46 and 2.62 g/100 g, respectively) was significantly ($p < 0.05$) lower than that of plums pickled in brine for 7 and 10 day (4.58 g/100 g and 4.37 g/100 g, respectively), as well as those pickled in Ca-supplemented brine for 7 day. The umeboshi pickled for 7 day in brine showed a higher citric acid content ($p < 0.05$) than those pickled for 10 day in brine, 7 day in salt, or 7 day in Ca-supplemented brine. Notably, 10 day of salting resulted in a lower citric acid content ($p < 0.05$) than 10 day of brine soaking.

Salinity was 0.0135 g/100 g in frozen plums, which was significantly lower ($p < 0.05$) than that in the umeboshi samples. After 7 day of pickling in Ca-supplemented brine, salinity was significantly higher (22.2 g/100 g; $p < 0.05$) than that of the other umeboshi samples. Salinity was not significantly different between 7 and 10 day of pickling in salt (11.1 g/100 g vs. 10.9 g/100 g, respectively, $p > 0.05$) but was significantly lower than that at 7 and 10 day of pickling in brine and 7 day of pickling in Ca-supplemented brine (17.5, 20.6, and 22.2 g/100 g, respectively, $p < 0.05$). Notably, the level of salinity at 10 day of brine pickling was approximately twice that at 10 day of pickling in salt (20.6 vs. 10.9 g/100 g, respectively, $p < 0.05$).

3.4. Questionnaire Survey

Table IV shows how people scored the different characteristics of umeboshi in salt, brine, and Ca-supplemented brine. The Wilcoxon signed-rank analysis of the data for sensory test scores showed no differences among salted, brine-pickled, and Ca-supplemented umeboshi ($p > 0.05$).

4. DISCUSSION

4.1. Measurement of Hardness, Moisture, pH, and Brix Values

In the present study, the hardness of the umeboshi was 0.654–0.967 N, which is similar to that reported for umeboshi made from Juro-ume (1–2 N) [8]. However, it was lower than reported for Koshu ko-ume, which was 5–6 N [5]. As freezing breaks down the cell walls in vegetables [13], and because the structure of fruits is similar to that of vegetables, the frozen plums in this study had lower hardness values than fresh plums. Moreover, we observed no difference in the hardness of Ca-supplemented umeboshi compared to that of plums pickled in salt or brine. A previous study reported that hardness is compromised if the hardener concentration is insufficient; to achieve satisfactory hardness and a crunchy texture in umeboshi, the hardener concentration should be higher than 0.30% of the weight of the plums [5]. In the present study, 0.15% calcium hydroxide was added, a concentration reported to permeate only the skin and not the pulp [5]. Thus, the hardness of plums pickled in Ca-supplemented brine was similar to that of the other umeboshi samples.

In the present study, the moisture content of umeboshi ranged from 62.1% to 77.4%. Ishihara *et al.* [14] and Takiguchi *et al.* [15] reported a moisture content of 76.3% and 68.8% for Nanko-ume and Kishu-grown umeboshi, respectively. The moisture content of frozen plums in our study was 88.5%, whereas that of Nanko-ume was reported to be 91.8% [14], indicating that the fresh plums had a slightly higher moisture content. As the freezing process accelerates dehydration [16], the frozen plums in the present study may have exhibited a lower moisture content.

In the present study, the salinity of umeboshi tended to be higher when the moisture content was low, and lower when the moisture content was high, as shown in Table III. This result is consistent with those previously reported; when the moisture content of commercial umeboshi was 68.8%, the salt concentration was 20.2% [15], and for another commercial dried plum, when the moisture

TABLE IV: NUMBER OF PERSONS WHO RANKED SALTED, BRINE-SOAKED, AND CA-SUPPLEMENTED UMEBOSHI AT FIRST, SECOND, AND THIRD POSITIONS BASED ON DIFFERENT CHARACTERISTICS

		Umeboshi								
		Salted			Brine-soaked			Ca-supplemented brine		
	Rank*	1	2	3	1	2	3	1	2	3
Questionnaire	Saltiness*	1	4	5	6	1	3	3	5	2
	Sourness*	5	2	3	3	2	5	2	6	2
	Hardness*	3	4	3	3	3	4	4	3	3
	Reddish color*	5	1	4	4	5	1	1	4	5
	Flavor*	4	3	3	2	4	4	4	3	3
	Overall desirability*	4	3	3	4	3	3	2	4	4

Note: *No significant differences were observed among salted, brine-soaked, and Ca-supplemented umeboshi.

content was 74.9%, the salt concentration was 17.4% [17]. These previous studies and our results suggest an inverse relationship between salt concentration and moisture content.

In this study, a comparison of umeboshi pickled in salt and brine showed that brine-soaked umeboshi had lower NaCl concentrations. In a previous study, when the difference in NaCl concentration between plums and the pickling solution was large, the amount of moisture loss and NaCl concentration in the plums increased [4]. In the present study, plums were pickled in a saturated saline solution, whereas in the study by Nakayama and Hasegawa [4], plums were pickled in a 10% NaCl salt solution. This discrepancy likely enhances the difference in NaCl concentration between plums and pickling liquid, resulting in a lower moisture content than that in salt pickling. In addition, in our study, Ca-supplemented brine pickling resulted in lower salinity than did brine pickling. Calcium acts on the cell wall, causing the pectin fraction to bind to the cellulose fraction by cross-linking [5]. Thus, Ca that permeates from the pickling solution may remain in the pericarp. However, the higher ion concentration of the pickling solution enables NaCl to permeate the pulp owing to osmotic pressure, likely resulting in the lower moisture content in Ca-supplemented umeboshi than that in brined umeboshi.

In the present study, the pH of umeboshi ranged from 1.62 to 2.04, whereas that of frozen plums was 2.49. The pH of commercial umeboshi made from plums and salt has been reported to be 1.7 [15], which is similar to the pH values observed in our study. Moreover, the pH of Umego-ume was reported to be 2.27–2.70 [14], which was similar to the pH of the frozen plums in this study.

Fig. 1 shows the correlation between pH and citric acid concentration in this study. Sekine *et al.* [17] and Takiguchi *et al.* [15] also observed no correlation between pH and citric acid, indicating that the effect of citric acid content on the pH of umeboshi is limited and that other factors are likely involved.

In the present study, the Brix value of frozen plums was 6.00%, which is similar to that reported for Ume-go (5.4%) and Nanko-ume (6.8%) [14]. In this study, the highest Brix value observed was 39.9% for Ca-supplemented umeboshi and the lowest was for frozen plums. The Brix value of umeboshi increases with increasing salinity, with commercially available umeboshi having a Brix value of 24% at a salinity of 8.0%, and a Brix value of 33% at a salinity

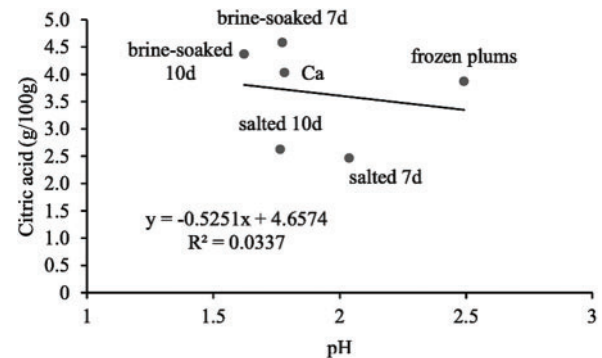


Fig. 1. Correlation between pH and citric acid content.

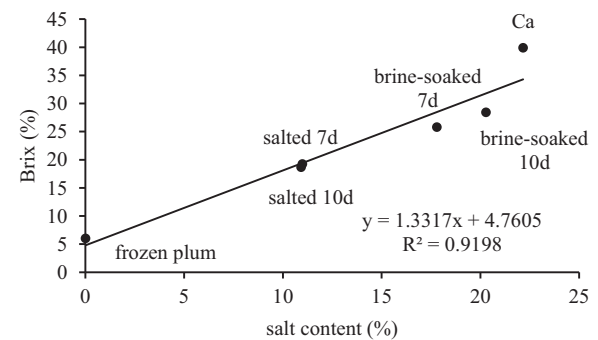


Fig. 2. Correlation between the brix value and salinity.

of 19.6% [12]. Fig. 2 shows the high correlation between salinity and Brix values observed in this study, indicating that the salt concentration has a significant effect on the Brix value of umeboshi.

In addition, we observed that the Brix value of Ca-supplemented umeboshi was approximately 40%, which is considerably high compared to that of the salt- and brine-umeboshi. In a previous study, when the solution contained dissolved solids other than sucrose, the Brix value was an approximation of the dissolved solids [18], suggesting that the Ca-supplemented umeboshi had a higher Brix value. Fig. 2 also shows higher Brix values for umeboshi pickled for 7 days in Ca-supplemented brine.

4.2. Color Assessment

In the present study, the L-values of umeboshi ranged from 42.8 to 48.9, a-values from 3.56 to 7.37, and b-values from 19.3 to 22.5, whereas those of frozen plums were 46.4, 1.49, and 25.1, respectively. The color of umeboshi

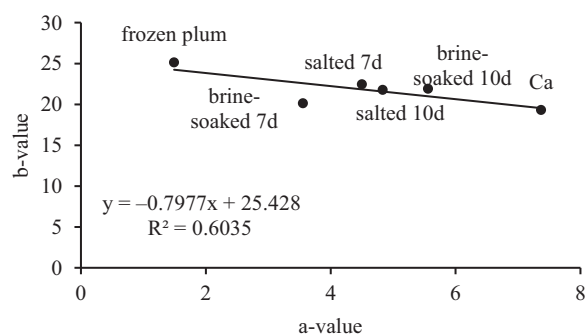


Fig. 3. Correlation between the a- and b-values.

made from Odawara Juro-ume was reported to have L-values of 40–45, an a-value of 5, and a b-value of 25, whereas the color of Juro-ume was reported to have L-values of 65–70, an a-value of 0, and a b-value of 35–40 [8]. These studies reported higher L- and b-values but similar a-values compared to those observed in our study for salt-pickled, brine-pickled, and Ca-supplemented umeboshi.

In the present study, the L-values were higher for frozen plums and plums pickled in a Ca-supplemented brine for 7 day. After salting, the L-values decrease, whereas the a-values increase [5]. Therefore, it is likely that the frozen plums in the present study also showed higher values before pickling. In addition, in a previous study, the L-values increased after salting Ca-supplemented umeboshi [6], which is similar to the trend observed in this study.

The highest a-value in the present study was observed after 7 day of soaking in Ca-supplemented brine. The red color value increases with increasing calcium hydroxide concentration in dried plum production [6]. Consistent with this finding, in our study, the highest a-value was obtained for Ca-supplemented umeboshi. In addition, the comparison between 7 and 10 day of salt-and brine pickling of umeboshi revealed that plums pickled for 10 day showed higher a-values than those pickled for 7 day. Consistent with this finding, a previous study reported increased a-values approximately 14 day after the start of the pickling process [8]. Furthermore, anthocyanin, the red pigment of plums, is reported to increase with additional ripening [11], which is in agreement with the results of the present study reporting higher values than those of frozen plums due to additional ripening that occurred while soaking in salt.

In addition, the b-value was higher in frozen plums and lower in Ca-supplemented umeboshi in this study. The anthocyanin content of frozen mulberry fruit has been reported to have a strong negative correlation with a-and b-values [19]. Fig. 3 shows the negative correlation observed between the a-and b-values observed in the present study. Consistent with our findings, a previous study reported an increase in the a-value and decrease in the b-value over 10 day for umeboshi soaked in calcium hydroxide [6]. Moreover, a decrease in the b-value was reported along with an increase in the a-value when Juro-ume was soaked for 3 months [20].

4.3. Measurement of Organic Acid Contents and Salinity

The malic and citric acid contents of frozen plums in this study were 0.514% and 3.82%, whereas those of umeboshi were 0.229%–0.705% and 2.46%–4.58%, respectively (Table III). Similar to our findings, the malic and citric acid contents of Nanko-ume and Juro-ume were reported to be 0.4% and 1.7% [14] and 1.0% and 4.0%, respectively [1]. In addition, the malic and citric acid contents of the umeboshi were higher when pickled in brine than when pickled in salt.

In this study, the malic and citric acid contents tended to increase when the salt concentration was high, as reported previously in commercially available umeboshi made with plums and salt [15]. This result suggests that there is a relationship between salt concentration and malic and citric acid contents. In the present study, a decrease in malic acid content was observed in umeboshi pickled for 7 day in Ca-supplemented brine. Malic acid is present in wine during production, and to reduce acidity, malic acid is often removed using Ca components [21]. In our study, umeboshi pickled in Ca-supplemented brine for 7 day showed lower malic acid content than that pickled in brine. Malic acid content is reported to significantly contribute to the flavor of umeboshi [15]. Consistently, in this study, brine-soaking resulted in a better-flavored umeboshi.

The salt concentration of the umeboshi in this study ranged from 10.9% to 22.2%. The salinity of umeboshi made from Nanko-ume was reported to be 14.5% [14], which was higher than that of the salted umeboshi observed in the present study and lower than that of the brined umeboshi. In addition, when comparing the salt-and brine-pickled umeboshi, the brine-pickled variety showed higher salinity. This result may be because salt is not added to the initial 10% of the weight of the plums in salt pickling, whereas in brine pickling, additional salt is added to the saturated brine. Moreover, higher salt content was observed in Ca-supplemented brine. A previous study has reported that when plums are pickled with salt containing more magnesium chloride, NaCl tends to move less. This suggests that magnesium chloride and other salts may have higher osmotic pressures than NaCl at the same weight concentration and that the osmotic pressure of the pickling liquid after the salt is dissolved is higher [4]. Therefore, the salt containing magnesium chloride may have penetrated the umeboshi instead of NaCl, resulting in a lower salt concentration.

4.4. Questionnaire Survey

In the present study, the difference in salt concentration is thought to be the reason umeboshi in brine and Ca-supplemented brine was rated as saltier than that pickled in salt. In the “sourness” category, the brined umeboshi received the lowest rating, suggesting that brine pickling reduces sourness, which is a commonly cited reason for disliking umeboshi. These results were also consistent with the pH results of this study. In the “hardness” category, the Ca-supplemented umeboshi received the highest scores, although by a small margin, suggesting that harder plums are preferred to soft plums. In the “dark red” category, Ca-supplemented umeboshi received the lowest evaluation, which was not consistent with the a-value results of this

study. In the “overall desirability” category, salt-and brine-pickled umeboshi had similar scores.

The results of this study showed no significant differences in how people perceived the characteristics of the different umeboshi, indicating that sensory differences among salted, brined, and Ca-supplemented umeboshi were barely discernible.

5. CONCLUSION

To determine the optimal conditions for producing umeboshi using brine, we compared the quality of plums pickled in conventional salt to those pickled in brine and Ca-supplemented brine. No change in hardness was observed among salt-pickled, brine-pickled, and Ca-supplemented umeboshi. Moisture content did not change between salted and brined umeboshi but was lower in Ca-supplemented umeboshi. Fruit color did not change in terms of the L-, a-, and b-values between the salting and brining processes, but the L- and a-values were higher in Ca-supplemented umeboshi. The pH was higher during salt pickling and lower during brine and Ca-supplemented brine pickling. The malic and citric acid contents were the highest in brined umeboshi. The questionnaire survey revealed no significant differences in how people perceived the umeboshi characteristics and that these differences were barely discernible from a sensory point of view. Overall, these results suggest that salt-pickled umeboshi has a mellow flavor due to its high pH and low citric acid content; brine-pickled umeboshi has a good flavor due to its high malic acid content; and Ca-supplemented umeboshi has a bright appearance due to its high L- and a-values. The results of this study clarify the effect of production conditions on the quality of pickled plums and can contribute to their production.

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CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

REFERENCES

- [1] Yoshida M. The processing method and quality of Ume products. *Bull Soc Sea Water Sci Jpn*. 2013;67(4):196–201. Available from: https://www.jstage.jst.go.jp/article/swsj/67/4/67_196/_pdf/-char/ja.
- [2] Shimosaka C, Ishida Y, Shimomura M. Effect of dry salting method and brine salting method on texture of salted dried horse mackerel. *J Home Eco Jpn*. 1990;41(12):1159–67. Available from: https://www.jstage.jst.go.jp/article/jhej/1987/41/12/41_12_1159/_pdf/-char/en.
- [3] Ogata-Saito M, Higuchi K, Kojima M, Naganuma K, Kimura H, Komatsu M. Quality improvement and development of processed agricultural products from Yamanashi Prefecture (2nd Report)-changes in composition of salted Ume by removing salt. *Report Yamanashi Ind Technol Center*. 2019;(2):11–3. Available from: https://www.pref.yamanashi.jp/documents/101631/report_h30_03.pdf.
- [4] Nakayama Y, Hasegawa M. Study of a method to control the amount of sodium chloride and citric acid in pickled fruit products. *Bull Soc Sea Water Sci Jpn*. 2013;67(4):202–7. Available from: https://www.jstage.jst.go.jp/article/swsj/67/4/67_202/_pdf.
- [5] Odake S, Otaguro C. Influence of calcium component on crispy texture of brined ume fruit product “Kari-Kari Ume”. *Bull Soc Sea Water Sci Jpn*. 2013;67(4):212–8. Available from: https://www.jstage.jst.go.jp/article/swsj/67/4/67_212/_pdf.
- [6] Odake S, Otaguro C, Kaneko K. Effect of calcium hydroxide concentration on the bitterness of salted Ume. *J Home Econ Jpn*. 1996;47(1):13–20. Available from: https://www.jstage.jst.go.jp/article/jhej/1987/47/1/47_1_13/_pdf.
- [7] Otaguro C, Kaneko K, Odake S, Hihara M. Effect of Ashed seaweeds on the various characteristics of brined Mume fruit. *Rep Yamanashi Ind Technol Center*. 1995;(9):71–5. Available from: https://www.pref.yamanashi.jp/documents/79575/report_h06_15.pdf.
- [8] Nakayama Y. *Results of Tests Requested at Odawara Juro Plum Brand Improvement Meeting—Influence of Plum’s Degree of Ripeness on Quality of Pickled Plum Product*. Report of Research Institute of Salt and Sea Water Science; 2017. pp. 36–40. No. 18. Available from: https://www.shiojigyo.com/institute/upload/papers_18_36-40.pdf.
- [9] Otaguro C, Hikawa Y. Studies on the improvements of quality of Ume. *Rep Inst Wine Food Technol Yamanashi Prefect*. 1981;(13):27–34.
- [10] Katayama N, Hachiya N. Research on Ume. *J Japan Soc Taste Technol*. 2008;11:7–13. Available from: https://www.jstage.jst.go.jp/article/bimi2002/2008/11/2008_11_7/_pdf/-char/ja.
- [11] Kitazume M. Change in the quality by post-harvest ripening in Mume “Beninmai” fruits. *Bull Gunma Agric Technol Center*. 2012;9:81–2. Available from: <https://agriknowledge.affrc.go.jp/RN/2010831630.pdf>.
- [12] Hashimoto T. Repression on the growth of *Pichia anomala* and the production of low-salted Umeboshi. *Nippon Shokuhin Kagaku Kogaku Kaishi*. 1999;46(6):416–21. Available from: https://www.jstage.jst.go.jp/article/nskkk/1995/46/6/46_6_416/_pdf.
- [13] Nakai Y, Takagi S. Changes of tissues and degradations of pectic substance in heated, frozen vegetables—Carrot and pumpkin. *Bull Mukogawa Women’s Univ*. 1988;35:391–6.
- [14] Ishihara S, Koshihara M, Kitazume M. Effects of maturity of *Prunus Mume* ‘Baigou’ on Umeboshi quality. *Bull Gunma Agric Technol Center*. 2013;10:9–12. Available from: <https://agriknowledge.affrc.go.jp/RN/2010852160.pdf>.
- [15] Takiguchi T, Igarashi A, Yoshino I, Kibe S. A short survey on qualities of commercial Ume-boshi. *Rep Gunma Prefect Ind Technol Res Lab*. 1996;1996:51–7.
- [16] Ohisa N, Suzuki T, Mohri S. A salt-free Umeboshi made by using freeze-dehydration. *Quest Tradit Food*. 2020;47:31–3.
- [17] Sekine Y, Kiyota M, Koizumi N, Oka M. Studies on the chemical components of Ume fruit. Part II. Studies on the chemical components of the pickled Ume, especially of the reduced salt contents. *J Sagami Women’s Univ Nat Sci*. 1994;57B:75–83.
- [18] Xylem Japan. Sugar content/Brix [Internet]. 2022. Available from: <https://www.xylem-analytics.jp/parameters/sugar-brix>. [Accessed 04 January 2024].
- [19] Fujikawa M, Sato A, Kubo K, Ueeda K. Management of anthocyanin content in frozen mulberry fruits by using fruit color. *Kagawa Prefect Ind Technol Res Center*. 2017;17:57–8. Available from: <https://agriknowledge.affrc.go.jp/RN/2010920255.pdf>.
- [20] Yoshida M, Soga A, Nakayama Y, Makabe Y. Influence of inorganic salts species on the quality of pickled Japanese apricot. *Bull Kanagawa Agric Technol Center*. 2010;153:61–4. Available from: <https://www.pref.kanagawa.jp/documents/27459/530379.pdf>.
- [21] National Research Institute of Brewing. *Wine deacids and major organic acids in wine, summary statement for revision of specifications and standards for calcium carbonate containing L(+)-tartaric acid and L(-)-malic acid calcium duplex salt* [Internet]. 2019. Available from: <https://www.fsc.go.jp/fscis/attachedFile/download?retrieveId=kai20191211tel&fileId=110>. [Accessed 04 January 2024].