Effect of the Low Temperature Steam–Heating Process on Taste Components, Amino Acids, Cyanogenic Glycosides, Pectic Substances and Texture of Ume Fruit Removed from Liquor

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To make greater use of ume fruit (Japanese apricot, Prunus mume Sieb. et Zucc.) removed from the liquor, it was investigated whether the low temperature steam–heating process—in which the fruit is heated by steam controlled at temperature intervals between 65 and 80°C, at 90% humidity—is a useful way to prepare the fruit into various processed foods from the constitutional and textural aspect. The analysis of ingredients in fruit samples was carried out on taste components (organic acids and free sugars), amino acids, cyanogenic glycosides and pectic substances before and after the process. Furthermore, the adhesiveness of the paste prepared from the samples was measured in order to examine the effect of the heating process on textural properties of the fruit.

One kg ‘Nanko’ variety of ume fruit contained 1941mg organic acid, 21.8g sugar consisting mainly of glucose and fructose, and 125.7mg amino acid. In the same way, one kg of ‘Ohshuku’ contained 1730mg organic acid, 21.8g sugar and 234.2mg amino acid. These amounts scarcely changed during the low temperature steam–heating process. Water soluble pectin increased markedly along with the ascent of the steam temperature, but hydrochloric acid soluble pectin decreased reversely. One kg ‘Nanko’ fruit contained 3mg amygdalin and 9mg of prunasin. ‘Ohshuku’ fruit contained 10mg/kg of amygdalin and 12mg/kg of prunasin. These cyanogenic compounds exhibited little change throughout the process. The adhesiveness of the flesh paste prepared from the fruit heated by steam showed a trend to increase in accompaniment with the rise of the steam temperature. From these results, it was recognized that the low temperature steam–heating process altered the textural characteristics of the fruit flesh accompanying changes in the solubility of pectic substances, but did not cause resolution or dissolution of taste elements and amino acids. Consequently, it was considered that ume fruit treated by steam can be used as a useful material for various processed foods such as ume caked, seasoned ume pickles and others since the treated fruit is softer than the untreated fruit and contains significant amounts of sugar and organic acids due to material fruit.

(Received Aug. 7, 1997)
Ume fruit has been chiefly used as a material for pickles such as ‘Ume-boshi’ and ‘Ume-zuke’. Increases in production of such pickles has been followed with enhancement of production of the material fruit. In a state of affairs like this, material fruit for ume pickles has been increasingly thrown into a tendency of overproduction. At the same time, the output of ume liquor has increased gradually since 1989, reaching 21,560kl in 1996, an amount ten times the 1985 level of production1). As a result, the amount of ume fruit removed from the liquor also increased. Though some parts of such fruit have been utilized as material of dried ume cake and jam, considerable amounts seem to be in a situation of not being take full advantage of. Accordingly, from the viewpoint of making effective use of food materials, we thought that it was very important to develop a processing method for the use of this fruit.

Although ume fruit removed from the liquor seems to include a large quantity of sugar due to additional sugar used as material during the production process, and organic acids originating in the fruit, studies concerning this do not seem to have been carried out. In an effort to suggest effective usage of the fruit, we tried to make clear the constitutional characteristics present through data obtained by analyzing taste components, amino acids, pectic substances and cyanogenic glycosides thorough examination of fruit removed from the liquor and heated by steam controlled at temperatures between 60 and 80°C5).

**MATERIAL AND METHODS**

**Ume fruit**

Ume fruit used in this experiment were ‘Nanko’ and ‘Ohsuku’ fruit offered from a liquor manufacturing company (Hachiya Yoshu Co., Ltd., Wakayama, Japan) in 1995. The fruit was removed from liquor aged for six months. The combination ratio of material was 1.8 l of 35% white liquor, 0.6kg of superior sugar and 1.0kg of ume fruit.

**The low temperature steam-heating process**

Ume fruit was heated by steam controlled at 65, 75 and 80°C, at 90% humidity for 30 minutes2) using a steam occurring apparatus (Kuriate Japan, Co., Ltd., Kagawa, Japan).

**Analysis of organic acids, sugars, amino acids and cyanogenic glycosides**

Organic acids, sugars and free amino acids in 80 % ethyl alcohol extract prepared from the flesh of ume fruit before and after the low temperature steam-heating process were determined with the same method as that described in a previous paper3). Organic acids and amino acids were also determined using a carboxylic acid analyzer (S-14 model, Tokyo Rika Co., Ltd., Tokyo, Japan) and an amino acids analyzer (L-8500 model, Hitachi Co., Ltd., Tokyo), respectively. Free sugars were determined using a high performance liquid chromatograph (Tosoh Co., Ltd., Tokyo, Japan). Cyanogenic compounds (amygdalin and prunasin) in 50% methyl alcohol extract prepared from the flesh of the ume fruit were determined using a high performance liquid chromatograph4). Analytical conditions were as follows. Column : Zorbax ODS, 4.6mm ID × 250 mm (5μm), (Rockland Technologies, Inc.). Mobil phase : Phosphate buffer : Acetonitrile = 5 : 955), Flow rate : 0.5 ml/min., Temperature : 60°C, Detector : UV (215nm).

**Measurement of pectic substances**

Pectic substances in AIS (Ethyl alcohol insoluble substances) prepared from the fruit before and after the process were determined using the 3, 5-dimethylphenol method6), 7).

**Measurement of hardness and adhesiveness**

The hardness of ume fruit was measured using a rheometer (NRM 2003 J model, Fudo kogyo, Co. Ltd., Tokyo, Japan) in the way described in a previous paper6), and exhibited as maximum strength (N). The adhesiveness of the flesh paste prepared from ume fruit before and after the process was measured by a rheometer. To obtain the paste, fruit with the seeds removed was homogenized by a food processor for 5 minutes, and then was strained out with a stainless steel
strainer to make a pasty flesh. The flesh paste was packed into a styrol vessel (22.5mm i. d × 40 mm) to 25mm in depth, and settled on a sample rack. A plunger for gelatin (15mmφ) was intruded into the sample packed in the vessel until 20mm depth from surface at 20 mm/min. in velocity. After a suspension for 20s, the plunger was pulled up at the same velocity. Adhesiveness was exhibited as energy (μJ) needed for separating the paste adhered to the plunger.

RESULTS AND DISCUSSION

Some characteristics of ume fruit removed from the liquor

Table 1 shows analytical values of pH, ash, total acid, ethyl alcohol and AIS of both ‘Nanko’ and ‘Ohshuku’ fruit removed from the liquor throughout the low temperature steam-heating process. Though ethyl alcohol content appeared to decrease with a rise of temperature, pH and other constituents did not change. Although both kinds of untreated ume fruit had a rather soft texture, the hardness value showed a tendency to become even lower as the temperature of the steam rose. Accordingly, the process was understood to be effective in eliminating ethyl alcohol from the fruit, and in softening the flesh.

Organic acids

Total organic acid content in 100 g untreated samples was 1941mg in ‘Nanko’ and 1730mg in ‘Ohshuku’. Ratio in content of malic acid to citric acid was 0.69 in ‘Nanko’ and 1.71 in ‘Ohshuku’. Such differences in the acid ratio in both the fruits were considered to be followed with the distinction in the maturity of each fruit(9), (10). In addition, the heterogeneity of variety in both fruits may also be enumerated as the reason for the deference of acid ratio. From these matters, it was thought that the ‘Nanko’ fruit might have been a more matured sample than the ‘Ohshuku’. This expectation was also thought from data in which organic acid composition of ume liquor was almost the same as that of the material fruit, and citric acid ratio to total acid exhibited an increase as the harvesting time of the fruit sample for the liquor became later(11). Since a liquor manufacturing company produces many kinds of commodities, some parts of the products seem to be produced from ume fruit differing in maturity in an effort to create manufactured goods holding a striking feature. Consequently, the difference of organic acid composition in the fruits described above appears to originate in variance of the maturity of the material fruit as planned by the producer rather than by accident. With the steam heating-process, organic acid content and composition in the fruit were kept in nearly fixed quantity regardless of steam temperature.

Free sugars

Total sugar in both untreated ‘Nanko’ and ‘Ohshuku’ samples were 21.8 g/100g. Major sugar in both fruits was glucose and fructose. Glucose and fructose in ‘Nanko’ samples occupied 50.9 and 47.2% to total sugar respectively. In the same way, those in ‘Ohshuku’ fruit were 50.5% in glucose and 47.2% in fructose. Sucrose was only about 2% in

<table>
<thead>
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<th>Table 1 Changes in some properties of ume fruit removed from the liquor during the low temperature steam-heating process</th>
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<td>Items</td>
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<tr>
<td></td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Ash (%)</td>
</tr>
<tr>
<td>Total acid (%) as citric acid (%)</td>
</tr>
<tr>
<td>Ethyl alcohol (v/w %)</td>
</tr>
<tr>
<td>Hardness (N, AV±SD)</td>
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<tr>
<td>AIS (%)</td>
</tr>
</tbody>
</table>

‘Nanko’: Ume fruit removed from the liquor which material fruit was ‘Nanko’ variety.
‘Ohshuku’: Ume fruit removed from the liquor which material fruit was ‘Ohshuku’ variety.
AIS: Ethyl alcohol insoluble substance.
ratio to total sugar in both fruits. In addition, sorbitol was also detected in slight quantity in both fruits. The additional sugar in ume liquor is inverted to glucose and fructose by invertase\(^{12,13}\) or acid\(^{14}\) during aging. In addition, the inversion of the sugar is almost finished at 200 days of aging \(^{14}\). Therefore, glucose and fructose will originate from additional sucrose used as material of the liquor. These sugar content and composition in the fruit were constant regardless of steam temperature throughout the process.

**Amino acids**

Total amino acid content in untreated samples was 125.7mg/100g in ‘Nanko’ and 234.2mg/100g in ‘Ohshuku’. The ume fruit was dominated with asparagine which occupied 71.4% (‘Nanko’) and 78.6% (‘Ohshuku’) in ratio to total amino acid. Throughout the development of ume fruit, amino acid content exhibits a trend to increase until the ripe stage, followed by a decrease thereafter\(^6\). In addition, the major amino acid in fresh ume fruit, which occupied 80–91% of total amino acid, was asparagine, regardless of the harvesting time\(^9\). According to this data, the difference in total amino acid content between ‘Nanko’ and ‘Ohshuku’ fruit may originate in the distinction in the maturity of each fruit. Furthermore, the heterogeneity in the variety may also affect the variance in amino acid content in both the samples. From matters described above, it was thought that ‘Nanko’ fruit might have been a more matured sample than ‘Ohshuku’. This speculation will be in agreement with the prediction obtained from the result on organic acids mentioned above. Because the ratio in asparagine to total amino acid was nearly the same as that in fresh ume fruit \(^3\), amino acids in the fruit used in this experiment were thought to have been kept in stable condition during aging of the liquor.

During the low temperature steam-heating process, amino acid content and composition in both fruits remained constant regardless of steam temperature.

**Cyanogenic glycosides**

Table 2 shows amygdalin and prunasin content in ‘Nanko’ and ‘Ohshuku’ fruit. The untreated ‘Nanko’ sample contained 3mg/kg of amygdalin and 9 mg/kg of prunasin. In the same way, ‘Ohshuku’ included 10mg amygdalin and 12mg prunasin.

There is a paper suggesting that ume fruit flesh includes 6–44 ppm prunasin and 7–91 ppm amygdalin\(^{12}\). From this paper and the prediction that cyanogenic glycosides will also dissolve into the liquor in the same way as organic acids and sugars during aging\(^{11}\), the amygdalin and prunasin content detected in each fruit sample will be appropriate levels. In addition, the difference in each cyanogenic glycoside level might be due to the distinction in the maturity in both ume fruits as well as that in ume seeds\(^4\). From these results, it was found that ume fruit removed from ume liquor contained cyanogenic glycosides.

During the process, amygdalin and prunasin content seemed to hardly show any variation.

**Pectic substances**

Fig. 1 and 2 shows changes in pectic substances in AIS prepared from ‘Nanko’ and ‘Ohshuku’ fruit, individually. The untreated ‘Nanko’ sample contained 1333mg/100g of total pectin. It was

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### Table 2 Changes in content of cyanogenic glycosides in ume fruit removed from the liquor during the low temperature steam-heating process (mg/kg)

<table>
<thead>
<tr>
<th>Cyanogenic glycosides</th>
<th>Untreated ume fruit</th>
<th>Treated ume fruit</th>
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<tbody>
<tr>
<td></td>
<td>‘Nanko’</td>
<td>‘Ohshuku’</td>
</tr>
<tr>
<td>Amygdalin</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Prunasin</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>22</td>
</tr>
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</table>

Ume fruit: See Table 1.
Ume removed from the liquor and the steam heating process

Fig. 1 Changes of pectic substance content in AIS prepared from ume fruit ('Nanko' variety) removed from the liquor during the low temperature steam-heating process

AIS: Ethyl alcohol insoluble substance.

Fig. 2 Changes of pectic substance content in AIS prepared from ume fruit ('Ohshuku' variety) removed from the liquor during the low temperature steam-heating process

AIS: See Fig. 1

composed of 805.1mg/100g of water soluble pectin (WSP), 168.0mg/100g of hexametaphosphate soluble pectin (HXSP), 298.6mg/100g of HCl soluble pectin (HSP) and 61.3mg/100g of NaOH soluble pectin (SSP) (Fig. 1). Although total pectin maintained nearly a fixed level during the process, WSP indicated a trend to increase more and more along with a rise of the steam temperature, while HSP showed a tendency to decrease. Pectic substances in the fruit treated at 80°C for 30 minutes was made up of 967.2mg/100g of WSP, 197.4mg/100g of HXSP, 129.4mg/100g of HSP and 40.0mg/100g of SSP. From these results, it was evident that during the steam-heating process total pectin did not change, but WSP and HSP exhibited a tendency to increase and decrease, respectively. Since the variation from HSP to WSP in ume fruit stored in sodium chloride solution under low pressure was considered to be the resolution of pectic substances by acid, and the ume fruit used in this experiment was about 3 in pH (Table 1) and an increment of WSP and a decline of HSP became more noticeable with the steam temperature going up, HSP appears to resolve into WSP throughout the process. If such resolution of pectic substances occurs during the process, it might be chiefly caused by temperature promotion of the acid action for decomposing the substances.

The untreated 'Ohshuku' sample was less in total
pectin and WSP than those in ‘Nanko’, but contained a larger quantity of HSP (Fig. 2). This result will also suggest that ‘Ohshuku’ was a more immature sample than ‘Nanko’. Pectic substances changed with almost the same tendency as that of ‘Nanko’ fruit.

From these consequences, it was understood that pectic substances of the ume fruit removed from the liquor might change from HSP to WSP during the steam-heating process.

**Adhesivness**

Fig. 3 shows change in adhesiveness of the flesh paste prepared from ‘Nanko’ and ‘Ohshuku’ fruit heated by steam. The adhesiveness value of untreated ‘Nanko’ fruit indicated 250μJ following an increase of the value with the steam temperature going up. Such a change was the reverse of the tendency of the variation such as that in the hardness of the fruit (Table 1).

The flesh of ‘Nanko’ fruit included about 20% sugars consisting mainly of glucose and fructose, and was nearly 3 in pH (Table 1). High methoxyl pectin forms gel as sugar concentration reaches 60 ~ 65% at pH 2.0 ~ 3.5[17]. In addition, pectic substances have the ability to form a gel which is the basis of jam and other food preserves. From these data, the increment in adhesiveness of the flesh paste appeared to originate in the gelatinization of pectic substances. Furthermore, such a gelatinization seemed to be followed with a change in properties of pectic substances since WSP as well as the adhesiveness increased with the ascent of the steam temperature.

The paste of the ‘Ohshuku’ samples increased in adhesiveness by almost the same tendency as that of ‘Nanko’, though the value was lower. From the results described above, it was found that the low temperature steam-heating process altered the textural characteristics of the fruit paste, accompanying a change in solubility of pectic substances without resolution or dissolution of organic acids, amino acids and sugars. Consequently, it is considered that since the fruit handled by the steam is softer than the untreated fruit and contains significant amounts of sugar and organic acids, the treated fruit can be a useful material for various processed foods such as ume cake, seasoned ume pickles and ume fruit flesh paste. In addition, because the adhesiveness of the paste increases with the steam temperature going up, various conditions for the process will have to be suitably regulated to fit the feature of the product.

**LITERATURE CITED**

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梅酒を構成する成分

梅酒の成分について、アミノ酸、ベクチン、テクスチャに及ぼす低温蒸気加熱処理の影響

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梅酒から分離した梅（梅酒梅）の有効利用を目的として、梅酒梅を蒸気加熱処理（60～80℃、湿度90%、30分）し、諸成分の分析値とテクスチャーの変化を検討した。その結果、1）蒸気温度が上昇するとエチルアルコールが減少し、硬度が低下した。
2）梅酒梅の主要構成糖は、砂糖に由来するグルコースとフルクトースであった。これらの糖は加熱処理中、安定に保持された。3）有機酸とアミノ酸は失活したが、梅酒梅の種類により異なっていたが、加熱処理後もその量と組成は変わらなかった。
4）蒸気温度が上昇すると、水溶性ベクチンが増加し、塩酸可溶性ベクチンが減少した。
5）‘南高’種にはアミノ酸が3 mg/kg、ベクチンが9 mg/kg検出された。
6）‘南高’種にはアミノ酸が3 mg/kg、ベクチンが9 mg/kg検出された。

(平成9年8月7日受理)