Changes in texture, structure and pectin of peach during pressurization, heating or processing of high-pressure-induced and heat-induced jam

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ABSTRACT
The objectives of this study are to research the relationship between pectin and the softening of peach by soaking in citric acid solutions for 24 hrs at 35°C, pressurizing for 30 min at 500 MPa or heating for 10 min. Also, comparing high-pressure-induced jam (HP-jam) and heat-induced jam (H-jam) were evaluated. It was found that firmness of the peach decreased greatly when soaked at pH 2.0 > heated > soaked at pH 2.2 or 2.5 > pressurized, respectively. About 88% of the peach pectin was water-soluble-pectin and high-methoxyl pectin, while low-methoxyl pectin was slight. During pressurization, the pectin did not change. However, pectin degraded through hydrolysis during heating; consequently, the middle lamella separated. Also, eight kinds of peach jam (65% sugar, pH 2.0 or pH 2.2, and 50% or 60% sugar, pH 2.5) were compared. Both color and flavor of HP-jam were better than H-jam. As the pH values were lower, L-, a-, b-values of jam became higher, and the jam became pinker. Raw peach contained about 0.3 ~ 0.4% pectin, therefore an addition of 0.6% pectin was needed for both HP- and H-jams. However, there was no great difference in rheology or sensory evaluation between HP- and H-jams.

Keywords: peach; pectin; high pressure; processing, jam

INTRODUCTION
Jam, marmalade and jelly are prepared by boiling fruit with sugar. Also, boiling should continue until a certain concentration is reached. During boiling, two processes, pectin extraction and jam manufacture, are performed. Heat-induced-jam has some faults such as off-flavor and deterioration of food components, nutrients and especially color. However, high pressure can produce jam without heating because pressurization accelerates hydrogen bonds between pectin macromolecules. It does not greatly change food color during processing [1]. Thus, HP-jam was patented by Meidi-ya Ltd. in Japan in 1990 (Japan patent No. H3-219844), and HP-jam, such as strawberries, blue berries and apples have since been marketed. However, pectin is added to this HP-jam. Citrus peel possesses sufficient pectin and acid to form marmalade. Thus, a processing for citrus yuzu marmalade without the addition of pectin was investigated [2]. During pressurization the peel did not soften because the pectin did not degrade through β-elimination. Therefore, a method for softening yuzu peel without heating should be required for HP-marmalade. In previous papers [3][4], high-methoxyl pectin was extracted by soaking in 0.01N HCl solution (pH 2.0) at 35°C due to the removal of Ca2+, therefore vegetables were softened. This extraction method of pectin was used for softening the peel by using citric acid instead of HCl for yuzu marmalade [2]. Consequently, the peel softened. However, during maturation, the peach flesh became soft due to the solubilization of pectin and polysaccharides by polygalaturonase [5]. Although peach is softer than yuzu peel, soaking in citric acid solution may be useful for the extraction of pectin from peach. Thus, the objectives of this study are to research the relationship between pectin and the softening of peach by soaking in citric acid solution, pressurizing or heating, and to establish a process for HP-jam and compare it with H-jam.

MATERIALS & METHODS
Sample preparation

Peach (*Prunus persica* L, harvested in Okayama, Japan, weight: 369 ± 37g, sugar content: 10.4 ± 1.2%, pH 4.46 ± 0.03) was diced into 1 cm pieces. The vacuum-packed pieces were pressurized for 30 min at 500 MPa at room temperature (about 25°C) using a Dr. Chef high pressure food processor (Kobe Steel Ltd., Kobe, Japan) [6] or boiled in hot water (850 ml) for 10 min. Also, pieces were soaked in about 2%, 1% or 0.3% citric acid solutions (pH 2.0, 2.2 or 2.5, respectively) for 24 hrs at 35°C.

Texture measurement

Changes in texture of peach samples during soaking, pressurizing or heating were measured by a creepmeter (Rheoner, RE-33005, Yamaden Ltd., Tokyo, Japan). The sample was punctured at 1 mm / sec by a plunger (cylindrical shape: 8 mm in diameter, 22 mm long) using a loadcell of 2 kg. The rupture stress and rupture strain (the mean of ten measurements) were indicated.

Structure measurement

Histological structures of the peach samples, which were soaked in citric acid solution at pH 2.5, pressurized or heated, and also peach jam were observed using a cryo-scanning electron microscope (S-4500, Hitachi Ltd., Tokyo, Japan) [7].

Extraction of pectin

An alcohol insoluble solid (AIS) was prepared from raw, pressurized or heated samples. Pectic substances were extracted from AIS, successively into five reagents; distilled water (at 20°C, 24 hrs), 0.01N HCl (at pH 2.0 and 35°C for 24 hrs × 2 ~ 5 times), 0.1M sodium acetate buffer (at pH 4.0 and 35°C for 24 hrs × 1 ~ 2 times), 2% sodium hexametaphosphate solution (at pH 4.0 and 90°C for 3.5 hrs × 2 ~ 6 times), and 0.05N HCl (at 90°C for 3.5 hrs × 3 ~ 8 times) [3][4]. Each extraction was repeated until no sugar was detected. These extracts were designated as WSP, PA, PB, PC and PD, respectively. The amount of galacturonic acid was determined by the carbazole method [8].

Jam preparation

Eight kinds of peach jam were produced. Peach-dices were soaked in citric acid solutions (pH 2.0, 2.2 or 2.5), mixed in a ratio of 2 : 1 with homogenized peach, then 50% (at pH 2.5), 60% (at pH 2.5) or 65% (at pH 2.0 or 2.5) sucrose (Nacalai Tesque, Icn., Kyoto, Japan) of total weight were added. However, sugar content of peach was subtracted from the added sucrose content. They were vacuum-packed, then pressurized for 30 min at 500 MPa (HP-jam) or boiled for 10 min (H-jam), respectively. The sugar contents (brix) of raw peach and peach jam were measured by a digital refractometer (PR-100, PR-200 or PR-300, Atago Ltd., Tokyo, Japan).

Color measurement of jam

The Color of HP- and H-jams was measured using a spectrophotometer (ZE-6000, NDK, Osaka, Japan).

Rheology measurement of jam

The steady-flow viscosity, thixotropy and dynamic-viscoelasticity of jelly in peach jam were measured at 25°C by using a Rhesosol-G3000 (UBM Ltd., Kyoto, Japan).

Sensory evaluation of jam

Sensory evaluation of peach jam was performed using a five point scale (-2 ~ +2). The color (bad ~ excellent), transparency (opaque ~ transparent), flavor (smell) of fruit (weak ~ strong), texture of jam (soft ~ firm), sweetness and sourness (weak ~ strong, not like ~ like), mouthfeel (rough ~ smooth), total taste and preference of jam (not like ~ like) were compared. Samples were evaluated by 10 female students (20 ~ 21 years old). Statistical analysis (significant differences by T-test at P < 0.05) was carried out using software (Edu-STAT, Higashiyama Shobo, Kyoto, Kyoto).

RESULTS & DISCUSSION

Changes in texture of peach during soaking, pressurizing or heating

Changes in rupture stress and rupture strain of peach during soaking in citric acid solutions, pressurizing or heating are shown in Figure 1. Firmness of the peach decreased greatly when soaked at pH 2.0 > heated > soaked at pH 2.2 or 2.5 > pressurized, respectively.
**Changes in histological structure of peach during soaking, pressurizing or heating**

Cryo-scanning electron micrographs of cell walls after soaking at pH 2.5 for 24 hrs, pressurizing or heating are compared in Figure 2. Middle lamella of cell walls, rich in pectic substances, was separated more from heating for 10 min than soaking at pH 2.5. However, they did not separate when pressurized. Cell wall of HP-jam was similar to the raw and pressurized cell walls. Thus, great change was not found. However, the middle lamella of the H-jam was separated.

**Changes in pectin composition of peach during pressurizing and heating**

Changes in pectin composition of peach during pressurizing and heating are shown in Figure 3. The amount of pectin in peach was about 340 mg / 100g and the percentage of WSP, PA, PB, PC and PD of raw peach was 39.8%, 48.3%, 4.3%, 6.0% and 1.6%, respectively. About 88% of the peach pectin was water-soluble-pectin (WSP) of low molecular weight and high-methoxyl-pectin (PA), while low-methoxyl pectin (PB, PC and PD) was slight. Amount and composition of the pectin did not change during pressurization. However, pectin degraded during heating; consequently the middle lamella separated. The pH value of raw peach was 4.46. Since pectin does not degrade through $\beta$-elimination by pressurization [6] or by heating at pH 4 [9][10], it might degrade through hydrolysis by enzyme.

**Changes in rheology of jam**

The final sugar percentages and pH values of jam are shown in Table 1. During processing, the pH values increased and sugar content decreased slightly.

The steady-flow viscosity of jam is shown in Figure 4. The viscosity of H-jam was slightly higher than HP-jam. As the pH value of citric acid solution was higher and sugar content was lower, viscosity decreased. Since the thixotropy and dynamic-viscoelasticity showed a similar tendency, thixotropy and dynamic-viscoelasticity are not shown.

**Changes in color of jam**

L-value (+ brightness), a-value (+ red, - green), b-value (+ yellow, - blue) of jam are shown in Figure 5. As the pH values were lower, L-, a-, b-values of jam became higher and jam became pinker. L-, a-, b-values of HP-jam were higher than H-jam. This suggests that the amount of anthozyan (pigment of peach) was maintained by pressurizing but decreased by heating.

**Sensory evaluation of jam**

Sensory evaluation of jam is shown in Figure 6. Color and flavor of HP-jam were better than the H-jam. However, there was no significant difference in sensory evaluation between HP- and H-jams.

**CONCLUSION**

Firmness of the peach decreased greatly when soaked in citric acid solution for 24 hrs at pH 2.0 > heated for 10 min> soaked at pH 2.2 or 2.5 > pressurized for 30 min at 500 MPa, respectively. Pectin did not change during pressurization but degraded through hydrolysis during heating; consequently, the middle lamella of heated peach separated. Eight kinds of peach jam (65% sugar, pH 2.0 or pH 2.2, and 50% or 60% sugar, pH 2.5) were compared. Color and flavor of HP-jam were better than H-jam. However, there was no great difference in rheology or sensory evaluation between HP- and H-jams. Raw peach contained about 0.3 ~ 0.4% pectin, therefore an addition of 0.6% pectin was needed for pressure-induced jam.

**ACKNOWLEDGEMENTS**

We thank Ms. A. Ogura and Ms. A. Yamamoto for technical assistance. A part of this work was supported by a Grant-in Aid for Scientific Research (C) from the Ministry of Education, Science, Sports and Culture in Japan.

**REFERENCES**

Table 1. The initial and final pH values and sugar contents of jam.

<table>
<thead>
<tr>
<th>Initial pH and sugar</th>
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<tr>
<td>pH</td>
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<td>HP-jam</td>
<td>H-jam</td>
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<tr>
<td>2.00</td>
<td>65.0</td>
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Raw peach: pH 4.46 ±0.03, sugar 10.4 ± 1.2%.

Figure 1. Changes in rupture stress and rupture strain of peach during soaking in citric acid solution, pressurizing or heating.
Figure 2. Cryo-scanning electron micrographs of cell walls of peach.
Soaked in citric acid for 24 hrs at pH 2.5.
Pressurized at 500 MPa for 30 min.
Heated for 10 min in boiling water.
HP-jam: high-pressure-induced jam
H-jam: heat-induced jam

Figure 3. Changes in pectin composition of peach during pressurizing and heating.
- WSP: water-soluble pectin
- PA: 0.01N HCl-soluble pectin
- PB: 0.1M acetate buffer-soluble pectin
- PC: 2% sodium hexymetaphosphate-soluble pectin
- PD: 0.05N HCl-soluble pectin

Figure 4. Steady-flow viscosity of high-pressure-induced and heat-induced peach jams.
- □ High-pressure-induced jam, □ Heat-induced jam

Figure 5. L-, a- and b-values of peach jam.
- High-pressure-induced jam
- Heat-induced jam
Figure 6. Sensory evaluation of peach jam.