Effects of Pressure and Heat on the Hardening of Japanese Radish

Midori Kasai, Ayako Yamamoto, Keiko Hatae and Atsuko Shimada

School of Human Life and Environmental Science,
Ochanomizu University, Bunkyo-ku, Tokyo 112-0012, Japan

The effects of pressure and heat treatments on the hardening of Japanese radish were compared. Cubic samples of 1 cm³ were pressurized at 400 MPa and room temperature for 2 h or were heated at 60°C and atmospheric pressure for 2 h. Heat treatment increased the fracture load and fracture strain of Japanese radish more than pressure treatment. The rate constant for softening at 99.5°C was decreased to 52 and 24% by pressure and heat treatments, respectively. Both treatments decreased the degree of pectin esterification, and the amounts of water-soluble pectin and water-soluble calcium ions. Both treatments increased hexametaphosphate-soluble pectin, while sodium chloride-soluble calcium ions were slightly increased by the pressure treatment, and significantly by preheating.

(Received August 4, 1997; Accepted in revised form December 15, 1997)

Keywords: pressure treatment, preheating, hardening, Japanese radish, pectin.

INTRODUCTION

Food processing operations for vegetables and fruits include hardening by low-temperature blanching to prevent excessive softening during high-temperature sterilization (LaBelle 1971). The hardening can also be brought about by drying (Fuchigami 1986), adding of calcium salt (LaBelle 1971), storage (Liu et al. 1992) and pressure treatment (Yamamoto et al. 1992). In this study, the effects of pressure and heat treatments on the hardening of Japanese radish were comparatively studied.

It has been reported that the hardening of Japanese radish increased with increasing preheating time (Konishi et al. 1975; Fuchigami and Konishi, 1978; Manabe, 1980b) and with increasing pressurizing time (Kasai et al. 1995). The similar effects of the pressure and temperature treatments on vegetable hardening are of great interest to investigate the mechanism for controlling the vegetable hardness. We focus on the difference in rheological properties and pectic changes between heated and pressure-treated samples.

MATERIALS AND METHODS

Sample preparation

The middle parts of Japanese radish roots for use as samples were cut into cubes of 1 cm X 1 cm X 1 cm. Sample preparation was the same as that described in the previous paper (Yamamoto et al. 1992).

Pressure and heat treatments

About 40 g of cubic samples was put into a polyethylene bag (0.01 mm thickness) and packed with a vacuum sealer (SQ-202, Sharp Co.). The packed samples were either pressurized at 400 MPa and room temperature for 2 h with a high-pressure equipment (R7k-3-10-5, Yamamoto Suiatsu Co.) or heated at 60°C and atmospheric pressure for 2 h in a water bath (Yamato Science Co.). After each pretreatment, the samples were cooked at 99.5°C for 0–60 min.

Measurement of rheological properties

The fracture load (g) and fracture strain (mm) of the pretreated samples were measured by a rheonner (RE-3005, Yamaden Co.) under the following conditions: plunger, V-type; load, 20 kg; sample table speed, 0.5 mm/s; chart speed, 480 mm/min; voltage, 0.5 or 1 V. The hardness of each sample after cooking was measured by a texturometer (GTX-2, Zenken Co.) in the manner reported in the previous paper (Kasai et al. 1994).

Determination of pectin

Alcohol was added to the samples before homogenizing for 5 min. An alcohol-insoluble solid (AIS) was obtained from 40 g of the samples. AIS of 0.4 g was fractionated into three portions: water-
soluble pectin (WP), 4% hexametaphosphate-soluble pectin (PP), and 1 M hydrochloric acid-soluble pectin (HP). The pectin content of each portion was measured by the carbazole method (McComb and McCready 1952) with a spectrophotometer (UV-2000, Shimadzu Co.) at 520 nm.

**Measurement of PE activity**

The activity of pectinesterase (PE) was measured by Manabe's method (Manabe 1980b).

**Measurement of different forms of calcium ions**

Minamide's method (Minamide et al. 1986) was applied to fractionate the calcium ions into the following forms: water-soluble calcium (mainly water-soluble organic acid salts and calcium ions), 1 M NaCl-soluble calcium (calcium pectate, calcium-bound protein, and calcium carbohydrate), 2% acetic acid-soluble calcium (calcium phosphate), and 5% hydrochloric acid soluble calcium (calcium oxalate). In this work, the samples were put into vessels (3 cm × 10 cm) with deionized water during the pressure treatment and preheating.

**RESULTS AND DISCUSSION**

**Changes in rheological properties**

First of all, we examined the time dependence of the rheological properties of the samples in order to clarify the effects of pressure and preheating on hardening. As shown in Fig. 1, the fracture load and fracture strain increased with increasing time for the pressure and heat treatments. The changes in these parameters for the same treating time were greater in the preheated sample than in the pressure-treated one. This difference suggests that such processes as mass transfer and enzymic reactions after the cell membranes have collapsed proceed more slowly in the pressure-treated samples than in the preheated samples. The mass transfer process is considered to cause the hardening by activating pectinesterase (Bartolome and Hoff 1972) and inducing interactions among the tissue components (Kasai et al. 1997).

Figure 2 illustrates the variation in the hardness of preheated or pressurized Japanese radish during cooking.

**Fig. 2. Changes in the hardness of pressurized or preheated Japanese radish during cooking**

○, non-treated; ●, pressurized at 400 MPa and room temperature for 2 h; ■, preheated at 60°C and atmospheric pressure for 2 h; The non-treated and pretreated samples were subsequently cooked at 99.5°C.
Effects of Pressure and Heat on the Hardening of Japanese Radish

the pretreated samples during cooking. Softening of the sample was more restrained by preheating at 60°C for 2 h than by pressure treating at 400 MPa for 2 h. To compare this difference quantitatively, we calculated the rate constants for softening at 99.5°C on the basis of a first order rate law analysis as in the previous report (Kasai et al. 1994). The results are summarized in Table 1. The softening rate constant was decreased to 48 and 76% by pressure treating and preheating, respectively, in comparison with the rate constant of the non-treated sample.

**Changes in pectins**

Pectin is a key component for understanding the hardening mechanism for vegetables (Bartolome and Hoff 1972). It has been reported that pectin was changed by preheating (Manabe 1980b; Bartolome and Hoff 1972; Fuchigami, 1986) and pressure treatment (Yamamoto et al. 1992; Kasai et al. 1997; Kato et al. 1997). The degree of esterification of pectin and the amount of each pectin fraction in the samples after pressure treating and preheating were compared.

As shown in Table 2, the decrease in the degree of pectin esterification of the pressure-treated sample was similar to that of the preheated sample. Although the optimum temperature for the pectinesterase activity of Japanese radish is around 60°C (Manabe 1980b), the effect of temperature on the degree of pectin esterification was not much greater with preheating than with pressurizing. It has been proposed that the decrease in the degree of pectin esterification is the main cause of the heat-induced hardening of chestnuts (Manabe 1980a). However, our data do not corroborate this proposal. Some other factors, therefore, are also suggested to cause the hardening.

The amounts of each pectin fraction in the pressure-treated and preheated samples are compared in Fig. 3. With both treatments, water-soluble pectin (WP) was decreased and hexametaphosphate-soluble pectin (PP) was increased. The decrease in WP for the preheated samples was more marked than that for the pressure-treated ones, due to effusion to the outside of the tissue in the preheated samples.

It can be seen that the amount of PP was almost the same with both treatments, although the hardening was more apparent with the preheated sample as already mentioned. Bartolome and Hoff (1972) have reported that the formation of bridge bonds between pectin and divalent metal ions was the main factor in the hardening. However, this is not supported by our results. We consider some interactions occurred among the tissue components other than bridge bonds between metal ions and pectins, as was the case with the pressure-induced hardening (Kasai et al. 1997).

**Changes in the form of calcium ions**

The form of calcium ions, whether free or bound, is

---

**Table 1. Apparent softening rate constants for pressure-treated or preheated Japanese radish**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>$k_{99.5}$ (min⁻¹) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-treated</td>
<td>0.089</td>
</tr>
<tr>
<td>Pressure-treated</td>
<td>0.046</td>
</tr>
<tr>
<td>Preheated</td>
<td>0.021</td>
</tr>
</tbody>
</table>

* The apparent softening rate constant at 99.5°C was calculated by using the first-order rate law analysis in the previous paper (Kasai et al. 1994).

**Table 2. Degree of pectin esterification in pressure-treated or preheated Japanese radish**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Degree of pectin esterification (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-treated</td>
<td>53.4±5.5</td>
</tr>
<tr>
<td>Pressure-treated*</td>
<td>30.6±3.5</td>
</tr>
<tr>
<td>Preheated**</td>
<td>27.6±3.9</td>
</tr>
</tbody>
</table>

* Pressurized at 400 MPa and room temperature for 2 h.
** Preheated at 60°C and atmospheric pressure for 2 h.

**Fig. 3. Pectin fractions of pressurized or preheated Japanese radish**

WP, water-soluble pectin; PP, hexametaphosphate-soluble pectin; HP, hydrochloric acid-soluble pectin. ■, non-treated; □, pressurized at 400 MPa and room temperature for 2 h; ■, preheated at 60°C and atmospheric pressure for 2 h.
important for understanding its role in the hardening. The amount of calcium ions effused was increased by both treatments as shown in Fig. 4. This means that the collapse of the cell membranes by the pressure and heat treatments caused intra- and intercellular diffusion of water molecules and ions. The decrease in water-soluble calcium ions can be seen in both B and C samples in Fig. 4. On the other hand, the NaCl-soluble calcium ions were unaffected by the pressure treatment, but significantly increased by preheating. It is suggested that an increase in the bound type of calcium ion by binding with such components as pectin and protein caused the heat-induced hardening.

It was found that temperature had a greater influence on the hardening than did pressure. It is suggested that the difference between pressure- and heat-induced hardening is caused by an increase in the interaction among components concerned with the tissue strength rather than by pectic changes.

REFERENCES


ダイコンの硬化に及ぼす圧力および温度効果

香西みどり，山本文子，畑江敬子，島田淳子
（お茶の水女子大学生活科学部）

原稿受付平成9年8月4日；原稿受理平成9年12月15日

ダイコンの硬化現象に及ぼす圧力および温度効果を比較検討した。1cm角のダイコンに室温で400 MPa，2hの加圧処理あるいは60℃，2hの加熱処理を行った。加熱処理の方が破壊荷重，破断距離のいずれも変化が大きく，処理後の加熱による軟化の99.5℃における速度定数は加圧処理では未処理の約52％，加熱処理では約24％に低下した。ベクチンのエステル化度の低下はいずれの処理においてもほぼ同程度であった。いずれの前処理によっても水溶性ベクチンおよび水溶性カルシウムイオン減少し，ヘキサメタリン酸可溶性ベクチンは増加した。食塩可溶性カルシウムイオンは加圧処理によってわずかに増加しただけであったが，加熱処理では有意に増加がみられた。

キーワード：圧力処理，予備加熱，硬化，ダイコン，ベクチン。

Effects of Pressure and Heat on the Hardening of Japanese Radish

(287) 65