The Effects of Sodium, Potassium, Calcium and Magnesium Chlorides on the Hardening of Japanese Radish During Preheating

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1. INTRODUCTION

Plant foods such as vegetables and fruits are hardened by the preheating around 60 ^{0}C, and the preheating suppresses their softening during cooking near the boiling point [1],[2]. The hardening by the preheating can avoid overcooking and shape destruction. As the main causes of the hardening the following two phenomena are considered: (1) the activation of pectin esterase (PE) by intracellular electrolytes brought about by the collapse of the cell membrane, and (2) the binding between divalent metal ions and pectins [1]. In both cases, metal ions play a key role in controlling the hardening. In the plant tissue, mainly metal ions as sodium, potassium, calcium and magnesium are contained. For a better understanding of the hardening mechanism, it is of great importance to investigate the role of these metal ions.

In this study, we investigated the effects of the mono- and divalent metal ions on the hardening of Japanese radish preheated at 60 ^{0}C. We examined the effects of metal ions on the PE activity by using crude enzyme extract and the hardness of the samples preheated in the aqueous solutions of sodium, potassium, calcium and magnesium chlorides.

2. MATERIALS AND METHODS

Japanese radish was cut into segments of (1×1×1) cm^3. The activity of pectin esterase (PE) was measured by the titration method. The sample was preheated at 60 ^{0}C for 2 hours in an aqueous solutions of sodium, potassium, calcium and magnesium chlorides. The ionic strength (I) of the various chloride salt solutions was adjusted to 0.15 mol/kg. After the preheating, the sample was cooked at 99.5 ^{0}C for 10 min in deionized water. The hardness of samples was measured by a texturometer (GTX-2, Zenken Co., Ltd.). Each sample was soaked in chelating agents, 0.07 M (mol/L) EGTA and EDTA, at 5 ^{0}C for 24 h.

3. RESULTS AND DISCUSSION

3.1. Effect of metal ions on the PE activity

First, we examined the effect of metal ions on the PE activity. The crude enzyme extract was dialyzed by deionized water to remove the metal ions and the PE activity of the extract was decreased by this treatment. The PE activity of the dialyzed crude enzyme extract was increased by the addition of any kind of chloride salts. The dependence of the PE activity increase can be described more simply in terms of the ionic strength than the molality. The PE activity increased with increasing ionic strength. The PE activity became similar around 0.2 mol/kg, whereas the divalent metal ions had a larger effect on the PE activity than monovalent metal ions at the ionic strength of 0.1 and 0.3 mol/kg. The solute concentration of the cellular tissue corresponds to 0.15 M NaCl and its ionic strength is equal to 0.15 mol/kg. The solute concentration of the various chloride salts was adjusted to this ionic strength.

3.2. Effect of mono- and divalent metal ions on the hardness of preheated samples

It is well known that the hardening is caused by preheating in water. In our experiment, there was a small difference in hardness of the preheated samples between in the presence and the absence of the metal ions. This can be ascribed to the fact that the tissue already contained comparable amounts of the metal ions. The sample preheated in water containing the monovalent metal ions was slightly less hardened than the one preheated in deionized water. On the other hand, the divalent metal ions had a slightly larger effect on the hardening than deionized water. This suggests that the calcium ions bound to the pectins are replaced by the sodium ions and that the hardness decreases by the elimination of cross linkage.

3.3. Effect of mono- and divalent metal ions on the pH value

Demethylation of pectins by PE is expected to cause a decrease in pH value due to the production of the acid form of pectin. The pH value of the various chloride salt solutions was measured before and after preheating. For all the cases, the pH value was decreased by the preheating. The magnesium ions had a slightly larger effect on the decrease of pH value than the other metal ions.

3.4. Effect of calcium and magnesium ions on the hardness of the preheated samples

We examined to what extent the calcium and magnesium ions contributed to the hardening by their binding with the tissue components. We measured the hardness of the preheated samples soaked with or without chelating agents as shown in Table 1. EGTA is a chelator specific to the calcium ions and EDTA is a chelator for all polyvalent metal ions.
As can be seen in Table 1, when the calcium ions were removed, the hardness of the sample decreases by about 80 % compared with the samples without soaking in EGTA. On the other hand, when both the calcium and magnesium ions were removed, the hardness of the sample decreased drastically. The solutions containing the monovalent metal ions show a greater decrease in the hardness than those containing the divalent metal ions. This indicates that the existence of divalent metal ions causes some interactions among the tissue components, such as polysaccharides and proteins in the cell walls, and the interactions are not associated with polyvalent metal ions.
We conclude that the effect of divalent metal ions on the hardening is to promote some interactions among the tissue components, the activation of the PE and the binding with pectins, and that monovalent metal ions contribute mainly to the activation of PE.

REFERENCES

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2. M. Kasai, A. Yamamoto, K. Hatae and A. Shimada, J.Home Econ. Jpn. 49(1998) 283.

Solutions	I	Hardness(N)		
	(mol/kg)	non-chelated	chelated by EGTA	chelated by EDTA
H20	0	34.0±1.8	31.5±2.9	2.1±0.9
NaCl	0.15	30.7±3.1	24.7±3.9	5.1±1.8
KCl	0.15	30.9±3.6	26.6±0.7	1.4±0.9
$CaCl_2$	0.15	40.1±2.5	32.0±4.8	12.8±2.9
$MgCl_2$	0.15	36.6±1.7	29.2±1.1	13.4±2.4

Table 1: Effects of calcium and magnesium ions on the hardness of Japanese radish preheated at 60 ^{0}C for2 h and then soaked in the chelating agents