外 国 語 要 旨

学位論文題目　Study on preparation and cooking property of thermostable vegetable gel

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In general, gels are eaten without heating. However, the restructured vegetables for cooking foodstuff, made of vegetable puree and thermostable gelling agent expressed as "vegetable gel" were used in this study. The objectives of this research were to investigate the preparation and cooking applicability of "vegetable gels". The gels were as hard as vegetables and stable in heated seasoning solution. Carrot and thermostable gelling agents, curdlan and gellan gum were used in this work.

Firstly, to determine the formulation of vegetable gel, optimal concentration levels of carrot puree, carrot juice, RO water and gelling agent (curdlan and gellan gum) were investigated. The level of calcium lactate, required for gelation of gellan gum was also determined in vegetable gels with gellan gum. Hardness and texture was the basis of the formulation. The optical hardness of boiled carrot (ca. $2x10^5$ N/m^2) and hardness of foods for patients with mastication difficulty ($0.5x10^5$ N/m^2) served as reference of hardness for vegetable gels. The vegetable gels with 6% curdlan, 50% carrot puree and 44% carrot juice, as well as the vegetable gel with 1-2% gellan gum, 0.6% calcium lactate, 50% carrot puree and 37.4-38.4% carrot juice was within the reference of hardness for vegetable gels. As gellan gum can form gel at lower concentration than curdlan, the texture of vegetable gels with gellan gum was less rough than that with curdlan. As a consequence, the recommended formulation of vegetable gels was 1-2% gellan gum 0.6% calcium lactate, 50% carrot puree and 37.4-38.4% carrot juice.

Subsequently, the behaviors of vegetable gels in heated seasoning solution were elucidated. Gellan gum used in the vegetable gels can form gel by calcium ion, which crosslinks between pairs of carboxylate groups. The strength of gels in heated seasoning solution with sodium ion were predicted to decrease because of ion exchange between sodium ion in the solution and calcium ion in gels. On the other hand, the strength of gels may be reinforced by highly concentrated sodium ion, which suppresses electrostatic repulsion between carboxylate groups. Reduction pH of solution by seasoning, such as vinegar and soy sauce, was also considered to reinforce the strength of gels by promoting elution of calcium ions which ionically bound with carboxylate groups and hydrogen bonding between carboxylate groups.

Then, the behavior of the vegetable gels heated at various concentrations of NaCl was examined. Cylindrical shaped vegetable gels (1.6 cm diameter and 1.5 cm height) were heated in 0.5~4% NaCl or consommé soup (0.79% NaCl) at 90 or 100°C for 30~90 min. Result showed that vegetable gels boiled in 0.5% NaCl collapsed, however, higher concentration of NaCl prevented the collapse of the gels. At 90°C, the vegetable gels slightly collapsed in every solutions even after heating for 90 min. In 1% NaCl, commonly used as seasoning solution for cooking, the edge of gels slightly collapsed and hardness of the gels remained at 75% of the initial gels after

30 min boiling, while they became round and the height decreased by 10~20% of the initial gels after 90mim boiling.

To further eliminate the above phenomenon, 1 and 2% gellan gum gels heated in RO water, 0.5-2% NaCl, vinegar (pH 2.7), 7% soy sauce solution (1% NaCl, pH 5) for 10-30 minutes at 95 and 100°C, and vegetable gels with 1 and 2 % gellan gum were done in the same way. Hardness and weight of samples, elution of metal ions from gels and pH of each solution were measured. High concentration of NaCl in the solutions promoted elution of calcium ions in vegetable gels and prevented the decrease in gel weight and hardness. The results suggested that more than 1% NaCl might reinforce the strength of vegetable gels. At 95°C, elution of calcium ions from the gels decreased and the collapse of gels was prevented. These results suggested that Ca^{2+}-Na^{+} exchange reaction were decreased as temperature lowered. In vinegar and 7% soy sauce, the elution of calcium ions from the gels owing to low pH was not observed, while hardness of the gels remained at above 90% of the initial gels. These results indicate that the strength of gels were reinforced by low pH and metal ions in soy sauce.

Collectively, these results demonstrate that the vegetable gels can be boiled within 30 minutes in 1% NaCl owing to reinforcement of gels by sodium ion. The results also showed that the gels did not collapse in 0.5% NaCl heated for 30 minutes at 95°C. Moreover, the gels can be boiled in low pH solution containing vinegar or soy sauce and the strength of gels were reinforced.

Finally, the vegetable gels were cooked based on the above results, such as: vegetable gel cooked in consommé soup, in simmered Japanese vegetables, in stew, in kimpira, and used in salad and sensory evaluated. Vegetable gel with 4% NaCl seasoning solution simmered for 20 min showed slight collapse. Panelists considered that cooking vegetable gels with 1% gellan gum were too soft as carrot, however, the texture was a little rough and possessed a slight unpleasant taste.

These results demonstrate the cooking applicability of vegetable gels in heated seasoning solution, and can be applied to other vegetable gels.