外国語要旨

学位論文題目 Study on effects of vacuum packing on vegetable tissue and new application of vacuum packing

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Vacuum cooking is a cooking method in which raw or pretreated ingredients are vacuum-packed as they are or with seasoning liquid added, and then cooked at an appropriate temperature for an appropriate time. Generally, it is said that food prepared by vacuum cooking is easy to season. Regarding seasoning of vacuum-cooked food, there are studies comparing seasoning concentration and preference with that of the conventional cooking method using a pan. To date, there has been no study that experimentally demonstrates why vacuum-cooked foods are considered easy to season. The seasoning of vegetables is caused by the loss of the semi-permeability of cell membranes followed by the diffusion of the seasoning ingredients into the vegetables. The atmospheric pressure is 10131 hPa and the lowest pressure used in vacuum packing is 100-1000 Pa, and vacuum packing creates a special environment. To date, however, no studies have focused on the effect of vacuum packing on the semi-permeability of cell membranes. Thus, the primary aim of this study is to determine the effect of vacuum packing on the semi-permeability of cell membranes. To facilitate the investigation, samples of Japanese radish were analyzed using two methods. In the first method, the sample was immersed in a 0.5% NaCl solution which was hypotonic than the osmotic pressure of Japanese radish, and the NaCl concentration in the Japanese radish was measured. If the semi-permeability is lost owing to vacuum packing, the concentration of NaCl in the Japanese radish increases when it is immersed in a 0.5% NaCl solution immediately after vacuum packing. The NaCl concentration did not increase, it was suggested that the semi-permeability of cell membranes was not lost as a result of the process. In the other technique, the electrical impedance method, the integrity of the cell membrane function of the Japanese radish that was vacuum-packed was analyzed in terms of changes in impedance, resistance inside and outside the cell, and capacitance of cell membranes. The results showed that although the electric resistance of extracellular space increased within 3 hours of vacuum packing, the integrity of the cell membrane function was almost maintained. Therefore, it is suggested that the ease of taste of vacuum-cooked food is not owing to the loss of semi-permeability of cell membranes by vacuum packing.

Next the reason why vacuum-packed food is considered easy to season was analyzed through

a different approach. Pressure gradient develops in vacuum packing, and the hydrodynamic mechanism referred to in the vacuum impregnation method also applies to vacuum packing. The hydrodynamic mechanism comprises two steps. In the first step, when the food is immersed in the liquid in the chamber and decompressed, the gas in the pores of the food expands and outflows. In the second step, the atmospheric pressure is restored in the chamber, the residual gas in the pores compresses, and the external liquid flows into pores.

Vegetables have vessels, sieve tube and intercellular spaces that can be considered pores. Therefore, when vegetables are vacuum-packed in solution, it is hypothesized that the inflow of the solution into the pores in the food contribute to the seasoning process. Assuming that the pores of vegetables affect the inflow of external liquid, the true porosity and effective porosity of five types of vegetables (Japanese radish, carrot, turnip, sweet potato, and winter melon) were measured. Effective porosity indicates the presence of the pores into which external liquid flows after vacuum packing. For this study, X-ray micro-computed tomography (X-ray μ CT) was used to observe the pore structure. Consequently, the real porosity and the effective porosity differed depending on the kind of vegetables used. For example, there was a difference in the effective porosity of sweet potato and Japanese radish despite the fact that their real porosity was almost at the same level. It was observed that sweet potato has a large effective porosity, which explains why the effect of vacuum packing is great. X-ray μ CT scan results showed that the difference in effective porosity between sweet potato and Japanese radish is attributable to the differences in size, connectivity, and open porosity.

The second aim of this study was to analyze the effect of effective porosity of vegetables on seasoning. There is no previous study on seasoning in vacuum cooking focusing on the porosity of vegetables. 1.5% NaCl solution (300% of sample weight) for conventional cooking and 5% NaCl solution (30% of sample weight) for vacuum cooking were used as a seasoning liquid. The NaCl concentration of the sample and that of the solution were separately measured for the vacuum packing treatment and the subsequent cooking. Consequently, immediately after vacuum packing treatment, the NaCl concentration of vegetables with large effective porosity was higher than that of the non-vacuum-packed sample. Thus, it was found that seasoning is possible even for raw vegetables with semi-permeability of cell membranes by using vacuum packing. In the cooking after vacuum packing, the NaCl concentration of vacuum-packed samples with a particularly large effective porosity (among the samples investigated in this experiment) was higher than that of non-vacuum-packed samples because of the large amount of inflow caused by vacuum packing. However, for the other samples, the effect of diffusion by cooking was greater than the effect of effective porosity, and it was found that the seasoning effect of vacuum packing, which was observed immediately after the packing treatment, was lost. Because the seasoning effect of vacuum packing is clear for raw

vegetables, vacuum packing was considered as a cooking method, and a new application was examined. When the Japanese radish was vacuum-packed in a high-concentration NaCl solution and left as it was, it was observed that although the weight loss was reduced, the NaCl concentration was significantly higher than that of the non- vacuum-packed samples. However, this effect was not observed in carrots, which have a small effective porosity. Therefore, it was suggested that vacuum-packed vegetables with a relatively high effective porosity can be offered as new food products seasoned with the texture of raw vegetables. Based on this premise, new food products developed pickles having a different texture from that of the conventional ones.

None of previous studies on vacuum cooking have separately analyzed the effects of vacuum packing and subsequent cooking. This study focused on the vacuum packing process of vacuum cooking and analyzed the effects of vacuum packing on semi permeability of cell membranes. In addition, the relation between the porosity of vegetables and the seasoning effect of vacuum packing was demonstrated, and a new application of vacuum packing utilizing the pores of vegetables is proposed.

This study is believed to contribute to the provision of favorable vacuum-cooked products and the development of new food products using vacuum packing as a cooking method.