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Abstract of thesis

Minimal processed fruits and vegetables such as fresh-cut products have been gaining popularity among consumers because of convenience and freshness. An example of a fresh-cut product gaining interest from researchers and industries is the fresh-cut lotus root (*Nelumbo nucifera*). Its white color, crisp texture, pleasant aroma, and high nutritional content make this rhizome appealing to consumers. In Japan, the Ministry of Agriculture, Forestry, and Fisheries (2017) reported that the Ibaraki region produces the highest amount of lotus root yearly (39 million kg), which accounts for approximately 49% of the total production.

However, fresh-cut lotus root is prone to enzymatic browning and as a result, deteriorates its quality and shortens its shelf-life. Various strategies from researchers have been employed to improve the shelf-life of fresh-cut lotus root. Most of these strategies are mainly focused on chemical methods such as the use of anti-browning and preservatives and physical methods such as the application of gases and modified atmosphere packaging. However,these methods have limited applications due to safety concerns of some chemicals, as well as the highcosts of equipment needed for modified atmosphere packaging (MAP). The author also reported that the use of acidic treatments led to the cell wall damage of fresh-cut lotus root, hence, resulted to tissue softening.

One of the alternative and promising approaches for the shelf life extension of fresh-cut lotus root is the

application of edible coatings (Chapter 1). These coatings were reported to provide a semi-permeable barrier to gases and water vapor which reduced respiration rates, enzymatic browning, and water loss. Due to the limited information on the application of edible coating systems on fresh-cut lotus root, the author developed an effective and low cost edible coatings from natural sources such as gums and marine polysaccharides and evaluated its effects on quality changes of fresh-cut lotus root such as color, texture, enzymatic activity, total phenols, and microstructural changes during 16 d of storage at 5°C.

In Chapter 2, the author targeted the formulation of polysaccharide-based edible coatings with different ionic charges from natural gum sources, such as guar gum, xanthan gum, and chitosan. The author also compared the effect of single layer coatings versus layer-by-layer (LbL) deposition as edible coating techniques for fresh-cut lotus root. Single layer coatings of xanthan gum, guar gum or chitosan separately, and LbL coatings of xanthan gum + chitosan, or guar gum + chitosan were applied to fresh-cut lotus root (10 slices per treatment) and stored for 16 d at 5°C. The changes in color, texture, weight loss, enzymatic activity, and morphological aspects were monitored during storage. The results have shown that LbL coatings consisting of xanthan gum and chitosan were the most effective among all treatments, thereby reducing whiteness color (L^*) changes and weight loss up to 60% and 86%, respectively. Decreased polyphenol oxidase (PPO) enzymatic activity up to 70% was also observed in coated samples as compared to the non-coated samples. The author also found that morphological analyses proved that edible coatings have maintained cell wall integrity of samples during storage. In this work, it had been proven that the LbL coating technique was more effective than single layer coating, which shows a promising strategy to increase the storage stability of fresh-cut lotus root especially during transport and distribution.

Previously, the author reported in Chapter 2 that xanthan gum-chitosan edible coatings applied through the LbL electrostatic deposition of charges had the highest barrier properties in preventing oxidation during storage of fresh-cut lotus root. The author, then, evaluated the influence of xanthan gum concentration in improving the barrier properties of xanthan gum-chitosan edible coatings on fresh-cut lotus root in Chapter 3. In this study, LbL coatings of xanthan gum + chitosan was applied in fresh-cut lotus root with varying concentrations of xanthan gum concentration (0.5%, 1% and 1.5% w/w). Color and polyphenol oxidase (PPO) enzymatic activity of the fresh-cut lotus root were evaluated during storage at 5°C up to 16 d. The results have shown that LbL coatings of 1.5% xanthan gum and chitosan were the most effective in decreasing the total color changes and enzymatic activity of fresh-cut lotus root during storage for 16 d at 5°C. In this part of the research work, the author concluded that increasing the xanthan gum concentration in xanthan gum-chitosan edible coatings resulted to stronger barrier against oxidation and enzyme activity in fresh-cut lotus root.

Dipping, coacervation and spraying are some reported techniques of edible coating application on food products. In Chapters 2 and 3, the author developed polysaccharide-based edible coatings with different ionic charges from gum sources, such as guar gum, xanthan gum and chitosan and applied to the fresh-cut lotus root through dipping. However, due to the limitations of the dipping process such as uneven thickness of coating layer, the author had been interested in an alternative application technique, which is the spraying method. In Chapter 4, the author evaluated the effect of the spraying method as an application technique for xanthan gum-based edible coatings and investigated its barrier and microbial properties on fresh-cut lotus root. Xanthan gum solutions (0.1%, 0.3%, and 0.5%) were prepared and incorporated with citric acid as an anti-browning agent and 1% (w/w) glycerol as

plasticizer. The coatings were sprayed using a pilot spray system to 5 mm thick slices of fresh-cut lotus root for 20 s, packed in polyethylene bags, stored for 16 d at 5°C and analyzed for color, pH, morphology and microbial counts. It was found that spray-coated fresh-cut lotus root samples had significant reduction in the total color changes as compared to non-coated samples. These results suggest that the spray coating treatments were effective in decreasing the enzymatic browning of fresh-cut lotus root during storage which could potentially increase its shelf-life in the market. In addition, the author also found that the xanthan gum-based spray coated treatments were also effective against inhibiting the growth of *Bacillus subtilis* during 24 h of incubation which were indicated by the lower microbial counts recorded as compared to non-coated fresh-cut lotus root samples. In this part of the work, the author highlighted the spray coating technique of xanthan gum-based edible coatings as a promising strategy in improving the storage stability of fresh-cut lotus root during post-harvest storage.

Dipping and spraying methods of coating applications were also investigated in this work and storage stability parameters were also evaluated. However, based on the obtained results, no significant difference was found between the dipping and spraying method, in terms of the reduction of color changes during storage for 16 d at 5°C. Overall, the application of edible coatings is a promising strategy in extending the shelf life of fresh-cut lotus root. In the future, the author aims to widen the scope of the application of these coatings to other agricultural products which are prone to degradation during storage in the market.

Abstract of assessment result

【Review】

Lotus root has been gaining attention as a popular vegetable in various countries, such as Japan, Korea, China and Vietnam, especially in the form of fresh-cut slices, due to tis convenience as a minimallyprocessed food. However, lotus root is considerably prone to enzymatic browning, which generally deteriorates its quality and shortens the product shelf-life. In these regards, the author has investigated the application of low pH treatment (pH 2 and pH 4), foreseeing enhanced overall quality of fresh-cut lotus root. In addition, the application of polysaccharide-based edible coatings with different ionic charges from natural gum sources, such as guar gum, xanthan gum, and chitosan, was also investigated, for thesame purpose. The experimental results indicated that coatings consisting of xanthan gumand chitosan were the most effective among all treatments, thereby reducing whiteness color changes and weight loss up to 60% and 86%, respectively. Therefore, this study demonstrated that the application of layer-by-layer coating technique aiming to enhance the storage stability of agricultural products seems to be a promising strategy, especially aiming to minimize damages caused during the transport and distribution of thoseproducts.

【Result】

The final examination committee conducted a meeting as a final examination on 17 January, 2020. The applicant provided an overview of dissertation, addressed questions and comments raised during Q&A session. All of the committee members reached a final decision that the applicant has passed the final examination.

【Conclusion】

Therefore, the final examination committee approved that the applicant is qualified to be awarded Doctor of

Philosophy in Food Innovation.