Development of edible films and coatings made from biomaterials to extend the shelf life of fresh fruit

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（果実鮮度保持のための生物由来材料を用いた可食性フィルムとコーティング剤の開発）

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論 文 内 容 の 要 旨

Plastic-free is a worldwide campaign encouraging people to reduce the use of plastics. It is well known and approved that plastic is one of the causes of environmental problems. To overcome such problems, the use of biopolymers has gained increasing attention. Many biopolymers have been introduced to develop food packaging such as polysaccharides and protein; especially those obtained from the by-products of agro-industry. The by-products utilization represents a promising way of recycling wastes into useful products in an eco-friendly way. Thus, the development of the edible films and coatings using biomaterial to extend the shelf life of fresh products was investigate in this study.

Asian Bull Frog (*Rana tigerina*) skin oil (FSO), a by-product of frog industry, was selected to develop the edible films and coatings. Interestingly, the FSO at different concentrations (0-10%, w/v) showed the antifungal effect against *Colletotrichum gloeosporioides*, which is the major fungal pathogen found in mango. The inhibition effect was increased by the influence of FSO concentrations. Thus, the FSO extracted from frog industry wastes could be used as an alternative source of biomaterial to develop edible films and coatings. Moreover, the mathematical models related to quantitative risk-based assessment were applied to predict the growth pattern of *Colletotrichum gloeosporioides* treated by FSO at different concentrations. Among the mathematical models, four models were studied. The modified logistic model consistently produced the best fit for all inactivation at various FSO concentrations, and the first-order kinetics model was the poorest. Thus, the modified logistic model would be recommended to predict mold inhibition as influenced by FSO.

Since the FSO showed a satisfied antifungal property, it was selected to develop edible films and coatings by fortifying into gelatin-based material to create the new formulation. Among coated persimmon fruits with developed formulations (3.5% gelatin (w/v) containing 5%, 25% and 50% FSO, w/w based on gelatin content), the coated fruit showed significant difference ($P<0.05$) in lowering weight loss, pH, total solids (°*Brix*) and firmness loss compared to uncoated sample. Interestingly, no differences in color between uncoated and coated fruit were observed. Lower respiration rate in coated sample confirmed the effectiveness of gelatin-based coating containing frog skin oil (FSO). However, some properties of the developed formulation need further improvement before its application.

As the utilization of by-product (FSO) to develop edible films and coatings is not ready for application and still needs more improvement, commercial substances were used to develop edible films and coatings in order to anticipate for commercialization or licensing in the future. The effects of Good Recognized As Safe (GRAS) substances (sodium benzoate: SB, sodium propionate: SP and sodium dehydroacetate: SD) at different concentrations (0-2.5%, w/v) on mycelium growth of *Botrytis cinerea* were

evaluated. The results indicated that no mycelium growth was found in SD treatment at any concentrations tested throughout the storage period. SP showed the lowest inhibition effect compared to the others. The lowest concentration of SD (0.1%) was recommended to use for developing edible films and coatings.

Moreover, the deterministic models (modified logistic model, modified Gompertz model, and Baranyi and Roberts model) were used to predict the mold, *Botrytis cinerea,* growth behaviors (growth rate and appearance lag time). The modified logistic model showed the best fit model to the observed data. To eliminate the limitation (uncertainly and variability) of deterministic models the probabilistic model was used. A stochastic approach based on the modified logistic model, which had two random kinetic parameters generated by assuming a multivariate normal distribution successfully described the mycelium growth behavior of *B. cinerea* as a probability distribution at various concentrations of SP. It was concluded that, Monte Carlo simulation could be a useful tool in predicting the probability of events based on *Botrytis cinerea* growth behavior variability.

As 0.1% SD (w/v) showed the best antifungal substance, it was used to formulate new edible films and coatings by incorporating into the 4% hydroxypropyl cellulose (HPC) in the presence of plasticizer. The new edible films and coatings formulation (4% HPC (w/v) and 0.1% SD (w/v) containing 20% glycerol (w/v of HPC)) possessed satisfactory film properties (low moisture content, high transparency, and elasticity). Therefore, it is plausible to use it as a commercial edible films and coatings.