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学 位 論 文 内 容 の 要 旨

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学位論文題名

Physico-chemical Properties of Bioplastics and its Application for Fresh-cut Fruits Packaging

（バイオプラスチックの理化学特性とカットフルーツ包装への応用）

1. Introduction

Climate change and energy shortage are currently key global issues. Plastics account for approximately 5% of worldwide oil consumption. Growing demand for more environmental preservation and resource conservation, greater sustainability is taken into consideration. Plastics, mainly derived from crude oil, comprised 37% of food packaging material, which is more than metal, glass and paper as packaging materials. Therefore, the whole doctoral research aimed to study whether bioplastics, such as polylactic acid (PLA) and bio-based polyethylene (PE), could be an appropriate alternative to conventional petroleum-based plastic for food packaging.

2. Physico-chemical properties of bioplastics as a food packaging

Food packaging is expected to deliver high-quality product during distribution. The selection of packaging form and materials should be primarily based on considerations of food safety, followed by quality, cost, etc. Important properties of common packaging materials are generally mechanical, optical and barrier properties. Mechanical properties include tensile elasticity, tensile stress and breaking elongation, optical properties refer to transparency, haze, etc., and barrier properties involve water vapor transmission rate and gas transmission rate. These characteristics are mainly based on the physical properties such as crystallinity, molecular weight, etc. of bioplastics.

Tensile elasticity of petroleum-based low-density PE (LDPE, thickness: 30 μm), bio-based LDPE (30 μm) and PLA (25 μm) were 223.5, 248.4 and 2555.6 MPa, respectively. This meant that PLA possessed highest stiffness among the plastics. Tensile elasticity of bioplastics decreased as thickness decreased and as temperature increased, which meant flexibility of bioplastics increased when temperature increased. As temperature decreased, its effect on mechanical properties of plastics increased. Moreover, machine and transverse direction of a plastic sample also affected its mechanical properties. Bio-based LDPE indicated similar mechanical properties to petroleum-based LDPE.

As thickness of petroleum-based PE increased, transparency decreased. For the same thicknesses of LDPE samples, petroleum-based LDPE with lower crystallinity showed higher transmittance of visible light than that of bio-based LDPE representing in higher transparency. The transmittance of visible light of PLA was the highest among the plastics analyzed in this

study.

At 23°C and 50% relative humidity, water vapor transmission rate of PLA (25 μm) was 54.4 g/m^2·d, in contrast, the water vapor transmission rates of petroleum-based and bio-based LDPE (30 μm) were 7.3 and 3.7 g/m^2·d. The plastic film provided a resistance to water vapor transfer across it, thus the molecular structure of plastics could be a factor, which affects water vapor transferring through plastic material. Compared with PE, hydrophilic molecular structure in PLA material indicated higher water vapor transmission.

Due to these physico-chemical properties, bio-based LDPE could be applied as an alternative to petroleum-based LDPE, while PLA, which was bio-based and biodegradable, was stiff and transparent so that it can be applied as food packaging containers.

3. Application of bioplastics for fresh-cut fruits packaging

The market of the chilled fresh-cut produce has witnessed dramatic growth in recent years, stimulated largely by consumer demand for fresh, healthy, convenient and additive-free foods, which are safe and nutritious. Minimally processed fresh-cut fruits are very perishable and usually have a shelf life of 5-7 days at 1-7°C. In this study, packaging containers made from PLA and polyethylene terephthalate (PET) were examined for their ability to preserve the quality of fresh-cut melon and pineapple under low temperature conditions (<10°C). Changes in quality of fresh-cut melon and pineapple packed in PLA and PET containers, including weight loss, juice leakage, surface color, firmness, soluble solids content (SSC), pH, titratable acidity (TA), vitamin C and sensory quality, were evaluated during the storage. Overall quality of fresh-cut melon and pineapple declined regardless of the packaging material. Melon and pineapple cubes in both packages increased in weight loss, juice leakage and TA and also decreased in surface color (L^*, a^*, b^*), firmness, SSC, pH, vitamin C and sensory evaluation. No significant differences in juice leakage, color, firmness, SSC, pH, TA, vitamin C and sensory evaluation of fresh-cut melon and pineapple were observed in either of the packages stored at 4°C.

Melon and pineapple cubes that were stored at 10°C deteriorated on the 10th and 7th sampling day, respectively. Also a large amount of fungi in both fruit cubes was clearly observed in the PET containers. Significant differences in color (L^*, a^*, b^*, ΔE) between the melon cubes in the two packages were recognized after 7-day storage at 10°C. Significant differences in juice leakage and color (L^*, ΔE) between the pineapple cubes in the two packages were recognized after 5-day storage at 10°C. Due to higher water vapor transmission rate and oxygen permeability, the PLA containers used in this study maintained overall quality of fresh-cut melon and pineapple better than did the PET containers at 10°C during 10 days of storage.

4. General conclusions and recommendations

In this study, bio-based PE showed comparable properties to those of petroleum-based PE. The PLA containers, bio-based and biodegradable, used in this study maintained overall quality of fresh-cut fruits better than did the PET containers during storage. In conclusion, bioplastics would be an appropriate alternative for food packaging material from the viewpoint of the environmental preservation and sustainability.