Effects of Biodegradable Coating on Barrier Properties of Paperboard Food Packaging

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Abstract

Biodegradable substances with a combination of stearic acid in hydrophobic starch matrix were prepared and coated on paperboard surface. Water resistance by the Cobb test method and grease barrier properties was investigated. According to the results, water and grease resistance properties of coated paperboard were significantly improved. However, the barrier level for both water and grease depended on certain coating solution concentrations.

Key words: Starch, Stearic acid, Coating, Paperboards, Food packaging

Introduction

Papers and boards are versatile packaging materials produced from renewable cellulose fibers. It is, therefore, considered an environmental friendly material. Paper packaging is still used substantially in food packaging applications. However, one of the most critical required characteristics of paper packages for food packaging is its strength and its barrier properties especially for water and grease. The packages must be able to protects or hold foods while offering moisture or grease barrier properties. To a limited extent, papers usually have poor gas, moisture and grease resistance. As a consequence, it is often coated to improve its barrier properties especially to water vapor, oxygen, aromas and grease by hydrophobic materials such as paraffin wax and polyethylene. However, the content of the polyethylene and paraffin wax of packaging materials makes it difficult to separate, recycle or compost them after use. In an effort to produce more environmentally friendly materials, renewable and biodegradable biopolymers have been utilized as paper coating substances.

Generally, polysaccharides such as starches are often used as paper coating substances in order to improve roughness and as binding agents for cellulose fibers. The polysaccharides produce films with good mechanical properties. However, they do not offer good barrier against humidity. On the other hand, most single hydrophobic (lipid-based) films have rather poor mechanical properties but high moisture resistance.

For this research, composite polysaccharide-lipid coatings substances were prepared to combine good mechanical properties of polysaccharide with good moisture-barrier characteristics of lipids. The aim of this study was to improve barrier properties and mechanical properties of paperboards intended for food packaging applications. However, this paper will illustrate the results of the research specifically in details for the barrier properties improvement derived from the research setting.

Experimental Procedures and Methods

Coatings Materials and Papers

Duplex board supplied by Thai Union Paper Industry Co., Ltd., Thailand, having a grammage of 300 g/m² with average thickness of 0.36 mm was use as a controlled paperboard for the coating. Commercial hydrophobic starch, trade name Filmkote 370, was obtained from National Starch and Chemical (Thailand) Co., Ltd. Stearic acid used was obtained from Fluka, USA. In the study, Tween 60 was used as an emulsifier and was obtained from ACROS Organics, USA.

Preparation of Coating Solution

The starch coating solution was prepared by gelatinizing 15 % (w/w) of hydrophobic starch at 85°C (Kukiatikulchai, 2007) and maintained at 75°C for 10 minutes.
Coating solutions of 15% (w/w) hydrophobic starch matrix with 1, 2 and 3 % (w/w) stearic acid were also prepared and mixed with Tween 60 (10% (w/w) on total lipid content of stearic acid). Temperature of coating solution was maintained at 75°C before coating.

**Paper Coating**

Coating solutions were coated onto Duplex board (28x42 cm) using the Film coater model PI-1210 (Tester Sangyo Co., Ltd., Japan). 10 ml of coating solution was poured on the paper along the width at one end and the applicator rod was immediately swept the coating solution along the length of the papers. All papers were single-side coated either for the front or for the back side in which the white is the outer side of the paper that printing graphic may be applied. The applicator speed of the coating was set at 3.5 cm/s. The coated papers were dried at room temperature for 24 hours.

**Conditioning**

All the paperboards were cut for property testing and conditioned in a constant-temperature humidity chamber (model WTB Binder KBF 240, Germany). Conditioning was set at 27°C with 65% RH for at least 24 h in accordance with ISO 187.

**Characterization of Coated Paper**

Coated papers were measured for water and grease barrier properties. These properties were measured by Cobb’s test and Contact angle (CA). The Cobb test method is usually conducted for water absorption measurement. For this study, measurement of oil absorption was modified from the Cobb test method. Cobb’s test was based on ASTM D3285-93. The absorptivity (A; g/m²) was determined as

\[ A = (W_2 - W_1) \times 100 \]  

where \( W_1 \) and \( W_2 \) are the weights of the paper before and after water/oil absorption respectively. Initial contact angle of water and oil on the paperboard was measured by the comparatively simple method (modified from ASTM D5946-04). The photographs of the 40 µl water/oil droplets were then transferred to a personal computer and the contact angles were calculated manually with AutoCAD2006 program.

**Results and Discussion**

**Water Barrier Properties**

Water absorption results are displayed in Figure 1(a). According to the results, Cobb values of coated paper are significantly decreased for both front and back sides. For the front side, the values are decreased form 24.98 g/m² to the range between 12.8 to 19.46 g/m². For the back side, the values are decreased from 277.58 g/m² to the range between 27.96 to 177.7 g/m². The results indicate that increasing of stearic acid concentration can reduce water absorptivity. This can be explained by the long chain saturated fatty acid of stearic acid, were most effectively improve the hydrophobicity and moisture barrier properties of hydrophilic films.

Contact angle (CA) results of coated paperboards are shown in Figure 1(b) and 2(a, b). According to the results, CA of coated paperboards are significantly increased. For example, for the front side, CA is increased from 47 degree to the range between 50.33 and 64.33 degree depending on concentration levels of stearic acid. The increase in CA results is in accordance with the Cobb’s test results.

![Figure 1](image.png)

(a) Water absorption  
(b) Water contact angles

**Figure 1.** Cobb’s test and contact angles of uncoated and coated paperboard for water absorption measurement

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Different letter in each column of the same color is significant differences (P ≤ 0.05)

C= Uncoated paperboards.  
H=15% (w/w) Hydrophobic starch film-coated paperboards.  
HL1=hydrophobic starch with 1% (w/w) stearic acid  
HL2= hydrophobic starch with 2% (w/w) stearic acid  
HL3= hydrophobic starch with 3% (w/w) stearic acid
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Figure 2. Water and oil absorption characteristics of uncoated paper (control) and hydrophobic starch with 3% (w/w) stearic acid coated paperboards (HL3) (a) and (b) are water absorption. (c) and (d) are oil absorption.

Grease Barrier Properties

The Cobb values of coated paperboard for oil absorption are shown in Figure 3(a). According to the results, no particular trends in increasing or decreasing of the Cobb values versus concentration of stearic acid can be detected. Average Cobb values for oil absorption of the back side uncoated paperboard is 75.66 g/m². Further, the Cobb value for oil for the back side of the paperboard are decreased and are in the range between 36.62 to 28.9 g/m² depending concentration levels of stearic acid. This might due to the fact that, during coating, starch penetrated and filled up into the paper structure and this prevent further absorption of oil into the paperboards.\(^{[4]}\)

Figure 2(c, d) and 3(b) displays results of the initial CA of oil on uncoated and coated paperboard. The increase in CA can be observed similar to the water CA results. The oil CA of back side coated paperboard is approximately 30 to 52.5 degree, while oil CA of back side uncoated paperboard is approximately only 22 degree.

(a) Oil absorption

(b) Oil contact angles

Figure 3. Oil absorption and oil contact angles of uncoated and coated paperboard

\(^{abcde}\) Different letter in each column of the same color is significant differences (P \(\leq 0.05\))

C = Uncoated paperboards.
H = 15% (w/w) Hydrophobic starch film-coated paperboards.
HL1 = hydrophobic starch with 1% (w/w) stearic acid
HL2 = hydrophobic starch with 2% (w/w) stearic acid
HL3 = hydrophobic starch with 3% (w/w) stearic acid

Conclusions

Water and oil absorption of paperboards were decreased by starch and stearic acid coating. However, the barrier levels for both water and oil still depend on the concentration of stearic acid in the coating solution.

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References


