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# Enhancing moisture resistance of starch-coated paper by improving the film forming capability of starch film

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ABSTRACT

Starch-coated paper is widely used in packaging, printing, writing, and so on. However, achieving starch-coated paper with excellent moisture resistance remains a challenge for its end uses. To overcome this challenge, we hypothesize that the film-forming ability of starch plays a pivotal role in the moisture resistance of starch-coated paper. Polyvinyl alcohol (PVA) is used to enhance the film-forming capability of starch film and the moisture resistance of PVA/CS coated paper is evaluated in terms of moisture absorption, tensile index, and stiffness. A PVA/CS film with only a coating weight of 4.0 g/m$^2$ can fully cover the porous structure of paper that leads to a higher moisture resistance than CS-coated paper with a similar loading weight. However, as the coating weight continues to increase, the decline of the mechanical properties of PVA/CS coated paper is almost unchanged. Furthermore, the moisture resistance of PVA/CS coated paper (coating weight is larger than 4.0 g/m$^2$) is further improved by using glyoxal as moisture proof agent (MPA). Only 4.8% and 6.3% losses in the tensile index and stiffness at a coating weight of 4.0 g/m$^2$ are achieved before and after moisture treatment, respectively. These results may shed light on exploring new method to enhance moisture resistance of starch-coated paper.



## 1. Introduction

Paper is an indispensable part of human society that is widely used in packaging, printing, writing, etc. However, because of the hygroscopic cellulose and the porous fiber network, the mechanical properties of paper are easily reduced or even lost when exposed to moisture during storage and transportation process (Andersson, 2008; Bandyopadhyay, 2002; Zhang et al., 2014). Starch, a natural, renewable, and biodegradable polysaccharide produced by many plants such as plant roots, stalks, crop seeds and staple corps (rice, corn, wheat, tapioca, and potato), has been widely applied to coat on the surface of paper to improve its moisture resistance (Buléon et al., 1998; Le et al., 2010; Lee et al., 2002; Rhim et al., 2007). However, with increasing demand in the moisture resistance of paper, the hydrophilicity and poor film-forming ability of starch film are problematic for starch-coated paper (Lopez et al., 2008; Yun and Yoon, 2010).

To overcome this challenge, several strategies have been presented in order to improve the hydrophobicity of starch film using moisture proof agents (MPAs) or introducing hydrophobic parts into the molecular structure of starch (Doelle et al., 2014). Examples of MPAs which have been used as additives in combination with starch solution are alkyl ketene dimmer (AKD), styrene-maleic anhydride (SMA), styrene acrylic acid (SAA), styrene acrylate emulsion (SAE), citric, boric acid, glyoxal and so on (Reddy and Yang, 2010; Yin et al., 2005; Yoon et al., 2007). Unfortunately, the moisture resistance of starch-coated paper using the aforementioned approaches remains unsatisfactory (Xu and Hu, 2012); especially when it is exposed to moisture for a long time, the paper's mechanical strength will dramatically decrease (Linvill and Östlund, 2014).

In this study, we hypothesize that the film forming ability of starch film plays a predominant role in promoting the moisture resistance of starch-coated paper. To confirm this hypothesis, a simple, straightforward approach was proposed. First, abundant and biodegradable corn starch (CS) was selected as a major component for surface sizing. Second, polyvinyl alcohol (PVA) was added into the starch solution to improve the film-forming capability of starch-coated paper. The moisture resistance of PVA/CS-coated paper was evaluated according to the moisture absorption, ten-

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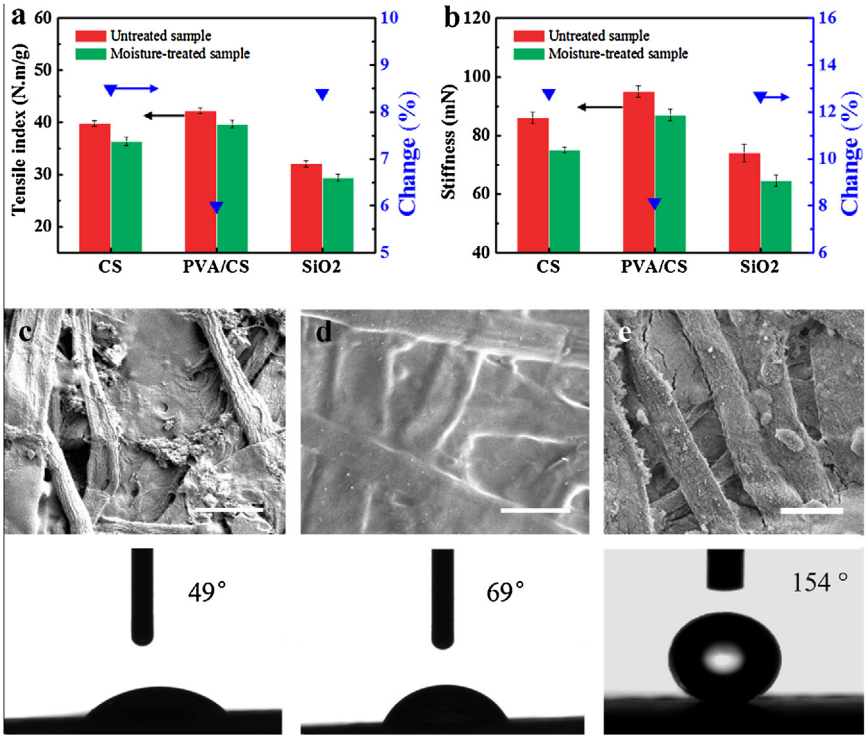


**Fig. 1.** (a) Stiffness and (b) tensile index of three types of coated papers before and after moisture treatment. Top view – SEM images (upper) and contact angle (bottom) of paper coated with (c) CS, (d) PVA/CS, and (e) hexamethyl disilazane treated $SiO_2$ at a coating weight of approximate 4.0 g/m$^2$. The scale bar is 10 μm.

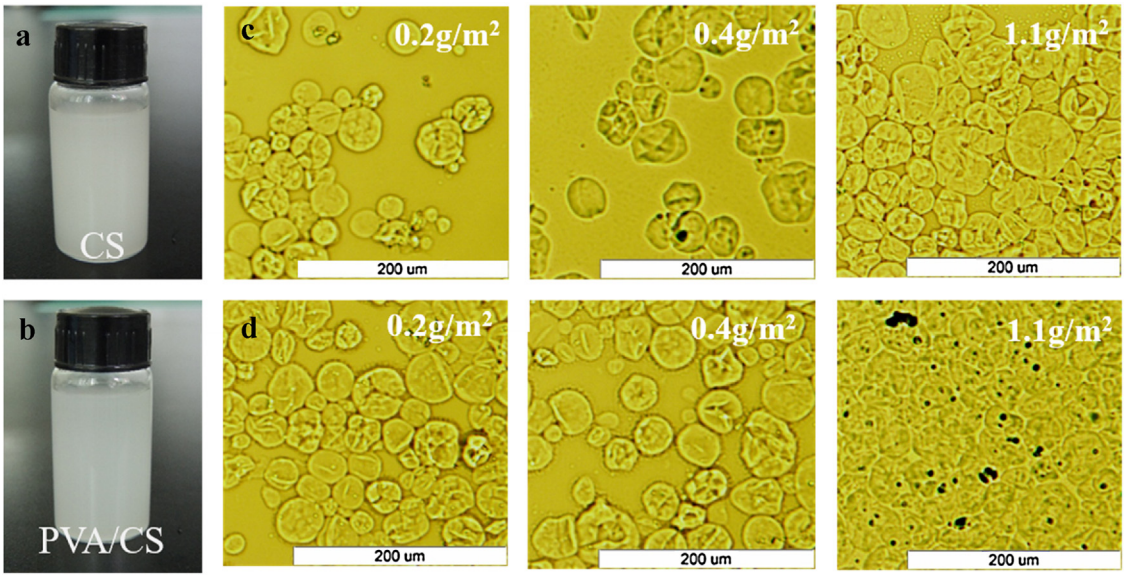


**Fig. 2.** Photographs of (a) CS and (b) PVA/CS solutions (solid content: 10%). Optical microscopic images of (c) CS and (d) PVA/CS films on a glass slide at different coating weights (0.2, 0.4, and 1.1 g/m$^2$).

sile index, and stiffness with increased coating weight. Finally, a MPA was added into PVA/CS coating solution to further enhance the moisture resistance of starch-coated paper with excellent barrier properties. Through reasonable design of a formula for surface sizing agent in this experiment, we aimed to deeply understand the relationship between the film forming ability of starch film and moisture resistance of starch-coated paper.

## 2. Materials and methods

### 2.1. Materials

Corn starch (CS, amylose content 27.65%) was supplied by Guangzhou Jianke Biological Technology Co., Ltd (Guangzhou, China). Polyvinyl alcohol (PVA, MW = 89–98 kDa, 99+% hydrolyzed) was obtained from Shanghai Huihu Industry Co., Ltd (Shanghai,