Carbohydrate Polymers 117 (2015) 78–82

Contents lists available at ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Short communication

Starch/rosin complexes for improving the interaction of mineral filler particles with cellulosic fibers

Xiujie Huang[a], Xueren Qian[a], Jinsong Li[b], Shuang Lou[a], Jing Shen[a,*]

[a] Key Laboratory of Bio-based Material Science and Technology of Ministry of Education, Northeast Forestry University, Harbin 150040, China
[b] Mudanjiang Hengfeng Paper Co., Ltd, No.11 Hengfeng Road, Yangming District, Mudanjiang 157013, China

ARTICLE INFO

Article history:
Received 24 July 2014
Received in revised form 2 September 2014
Accepted 4 September 2014
Available online 28 September 2014

Keywords:
Starch/rosin complexes
Filler particles
Papermaking

ABSTRACT

On the basis of inclusion complex formation of starch with small guest molecules, the concept of filler modification for papermaking by calcium-ion-induced deposition of starch/rosin complexes in the presence of filer particles was demonstrated. The rosin amount of 3% (on the basis of the dry weight of starch) induced effective starch deposition. Due to the cellulose-bondable nature of starch/rosin complexes, filler modification resulted in improved interaction of precipitated calcium carbonate particles with cellulosic fibers, leading to reduced negative impact of filler addition on paper strength. The efficiency of alkyl ketene dimer emulsion as an internal sizing agent for cellulosic paper was also improved as a result of filler modification. The concept demonstrated in this study may provide a useful alternative to the improvement of the use of mineral fillers in the paper industry.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

As a biopolymer, starch can form inclusion complexes with small molecules (Byars, Fanta, & Kenar, 2013; Heinemann, Escher, & Conde-Petit, 2003; Kenar, Eller, Felker, Jackson, & Fanta, 2014). In this regard, small guest molecules are constrained in the structure of starch, leading to the encapsulation of the guest molecules with starch based on host–guest interactions.

Since starch is chemically similar to cellulosic fibers, encapsulation of filler particles for papermaking applications with starch can improve their bondabilities with cellulosic fibers, allowing for increasing the filler content of paper products while maintaining their critical properties (Yan, Liu, & Deng, 2005; Zhao, Hu, Ragauskas, & Deng, 2005). This increase in filler content can provide cost/energy savings associated with the use of mineral fillers less costly than cellulosic fibers (Deng, Jones, McLain, & Ragauskas, 2010). Interestingly, the combination of starch with a fatty acid can induce the effective deposition of cooked starch on filler particles in an aqueous medium, due to the decrease in water-solubility (and also the increase in hydrophobicity) of starch as a result of the inclusion of fatty acid molecules more hydrophobic than starch (Cao, Song, Deng, & Ragauskas, 2011; Deng et al., 2010; Huang, Shen, & Qian, 2013; Yoon & Deng, 2006).

In the current study, the filler modification process concept involving the calcium-ion-induced deposition of starch/rosin complexes in the presence of filler particles was demonstrated. It was hypothesized that such a process concept may provide an alternative to filler bondability improvement. Since rosin-based sizing agents are traditionally used in the paper industry to deliver enhanced hydrophobicity, filler modification with starch/rosin complexes is also likely to enhance the efficiency of internal sizing agents.

2. Materials and methods

2.1. Materials

Powdered corn starch without any chemical treatment was supplied by Shandong Runyin Biochemical Engineering Co., Ltd., China. Rosin was provided by Jinan Changyingda Chemicals Co., Ltd., China. Precipitated calcium carbonate filler with an ISO brightness of 92.4% was sourced from Guangxi Guilin Wuhuan Co., Ltd., China. Softwood-derived bleached chemical pulp (cellulosic fibers) was obtained from MudanjiangHengfeng Paper Co. Ltd., China. This pulp was refined to 31°SR using a Valley refiner. Alkyl ketene dimer emulsion was supplied by MudanjiangHengfeng Paper Co. Ltd., China. Cationic polyacrylamide (Percol® 182) and bentonite (Hydrocol® AP1), commonly used as a microparticle retention system for cellulosic paper stock, were provided by BASF (China)

* Corresponding author. Tel.: +86 130 8998 1727; fax: +86 451 8219 0394.
E-mail address: jingshen.china@hotmail.com (J. Shen).

http://dx.doi.org/10.1016/j.carbpol.2014.09.047
0144-8617/© 2014 Elsevier Ltd. All rights reserved.

Co., Ltd. Sodium hydroxide and calcium chloride were analytical reagents.

2.2. Filler modification by deposition of starch/rosin complexes in the presence of filler particles

To a 250 ml flask, 3 g of starch (on a dry weight basis) was added. Distilled water was added, and the total weight of the mixture was adjusted to 100 g. The mixture was stirred and heated to 95 °C, followed by cooking at this temperature for 1 h. Rosin soap solution (prepared by the reaction of rosin with sodium hydroxide) was added, and the mixture was re-heated to 95 °C and cooked at this temperature for 30 min. The resulting mixture was then cooled down and diluted to 500 ml.

To a 200 ml of 0.2 mol/l calcium chloride solution, 6 g of precipitated calcium carbonate filler was added and sufficiently mixed. Upon heating to 90 °C, 200 ml of the as-prepared mixture containing starch/rosin complexes was added, followed by mixing for 30 min. The mixture was then sufficiently washed by centrifugation to remove the excess calcium ions. It should be noted that the resulting slurry was allowed to stand for 24 h prior to macroscopic optical image observations and turbidity measurement (WGZ-200 turbidity tester (China) with a measuring range of 0 to 200 NTU).

2.3. Paper-sheet preparation and determination of paper properties, filler retention and filler bondability factor

Cellulosic fibers and filler (fibers/filler weight ratio: 4:1, on a dry weight basis) were sufficiently mixed, followed by the sequential addition of alkyl ketene dimer emulsion, cationic polyacrylamide solution, and bentonite slurry. The resulting furnish was made into paper-sheets with a target grammage of 60 g/m^2 by using a ZQJ1-B200 mm sheet former (China). The wet paper-sheets were pressed at 0.4 MPa for 5 min prior to drying (105 °C, 5 min). It should be noted that the dosages of alkyl ketene dimer emulsion, cationic polyacrylamide, and bentonite were 0.11%, 0.05%, and 0.5%, respectively, based on the total dry weight of cellulosic fibers and filler.

After drying, the paper-sheets were conditioned sufficiently in a glass desiccator, and tensile strength was tested by using a ZL-300A tester (China) (Huang, Sun, Qian, Li, & Shen, 2014a). Paper brightness and opacity were determined by using a YQ-Z-48A tester (China). To evaluate the impact of filler modification on sizing, the Stockigt sizing degree of the paper-sheets was tested. Filler retention was determined by following the procedures reported by Shen, Song, Qian, and Yang (2010). Filler bondability factor was calculated based on the following equation (Huang, Sun, Qian, Li, & Shen, 2014a,b):

$$\text{filler bondability factor} = \frac{\text{strength of filled paper}}{\text{strength of unfilled paper}} \times \text{filler content of filled paper} \times 100$$

2.4. SEM observations

SEM observations of filler particles and paper-sheets were conducted using a scanning electron microscope (SEM, QUANTA 200).

3. Results and discussion

Chemically, starch is a mixture of amylose and amylopectin, both of which can form inclusion complexes with certain small

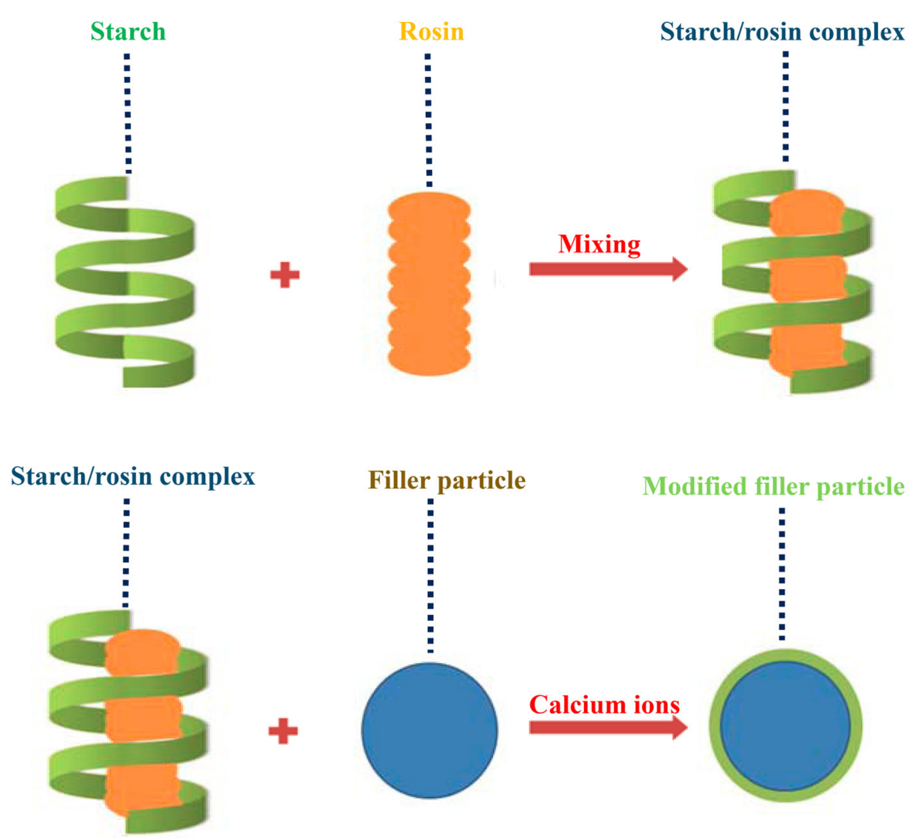

Fig. 1. Schematic illustration of the formation of a starch/rosin complex and its deposition on filler with the aid of calcium ions. Note that the shapes of filler, rosin, and starch as well as the interactions between starch and rosin are for illustration purpose only, and they are not representative of the real shapes of molecules and the concretely defined intermolecular interactions.

Download English Version:

https://daneshyari.com/en/article/7789466

Download Persian Version:

https://daneshyari.com/article/7789466

Daneshyari.com