Industrial Crops and Products 60 (2014) 45–51

Contents lists available at ScienceDirect

Industrial Crops and Products

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

Rheological property of reconstituted tobacco coatings

Wenhua Gao[a,b], Kefu Chen[a], Rendang Yang[a], Fei Yang[a,*]

[a] State Key Laboratory of Pulp and Paper Engineering, South China University of Technology, Guangzhou 510640, China
[b] Key Laboratory of Pulp and Paper Science & Technology of Ministry of Education of China, Qilu University of Technology, Jinan 250353, China

ARTICLE INFO

Article history:
Received 21 January 2014
Received in revised form 31 May 2014
Accepted 3 June 2014
Available online 24 June 2014

Keywords:
Reconstituted tobacco sheet
Reconstituted tobacco coating
Rheological property
Low–medium shear rate
High shear rate
SEM analysis

ABSTRACT

Reconstituted tobacco sheets are widely used in the tobacco industries to reduce the harm of cigarettes and considered as a comprehensive utilization method for tobacco wastes. Reconstituted tobacco coating is one of the core technologies determining the reconstituted tobacco sheet quality. The main component of reconstituted tobacco coating is water extracts from tobacco wastes. The effects of different dosages (0.1%, 0.3% and 0.5%) of carboxymethyl cellulose (CMC) and cationic guar gum (CGG) on the properties of coatings were studied. Reconstituted tobacco coating exhibited a prominent shear-thinning property at the condition of low–medium and high shear rates. Classical flow models Herschel–Bulkley (H–B), Power-law and Cross models were used to analyze the coating rheological properties. At the condition of low–medium and high shear rates, H–B and Power-law model were more satisfactory to describe the flow behavior than Cross model. SEM analysis showed that when the dosage of rheological agent (CMC) was 0.1%, reconstituted tobacco sheet obtained good coating surface structure.

1. Introduction

Reconstituted tobacco sheet is a product made of tobacco waste, including tobacco stems, mid-ribs, leaf scraps, and tobacco dust, which cannot be incorporated directly into cigarettes. It is widely used by tobacco industry to blend with natural tobacco leaves to make cigarettes with lower tar content (Zhou et al., 2013a,b; Zhong et al., 2010), which minimize the harm to human body (Wang et al., 2011). Additionally, utilizing reconstituted tobacco sheet could extract the maximum values out of a tobacco plant and offer tobacco industries a formula to improve cigarette qualities and flavors.

In recent years, reconstituted tobacco sheet is broadly produced by paper making technology (Ashok and Joao, 2001), which includes the following steps (Gellatly, 1983; Selke, 1980; Strubel and Sanford, 1987): (1) extracting tobacco wastes with water or organic solvents to obtain water/organic extracts (sugars, nitrogenous compounds, alkaloid, etc.) and extraction residues; (2) concentrating of water/organic extracts, which is the main component of reconstituted tobacco coating; (3) making reconstituted tobacco sheet base paper from extraction residues (bleached pulps are usually added to assist the base paper forming and improve the paper strength); (4) making reconstituted tobacco coatings for the base paper; (5) drying and slitting process. Compared to natural tobacco leaves, reconstituted tobacco sheet lacks some special tobacco components and might give the cigarettes with poor smell or flavors and some other inferior physical properties. As a consequence, some flavors and other functional additives are mixed in the coatings to overcome the defects of reconstituted tobacco sheet. Therefore, the coating technology is considered as an important process to improve properties of reconstituted tobacco sheet, such as bulk property, softening property, liquid penetration performance, mainstream smoke release quantity, etc. (Zhou et al., 2013a,b).

Reconstituted tobacco coating constituted of water extracts, rheological agents (such as natural gums, methylcellulose, sodium carboxymethylcellulose) (Strubel and Sanford, 1987), and other additives such as volatile flavorant, sugars, calcium carbonate, magnesium oxide, magnesium carbonate (Mua, 2007; Yang et al., 2009, 2010). The coating is considered as a suspending and stable multiphase system. The properties of the coating obviously, especially rheological property, affect the coating distribution on the base paper, coating weight, gas permeability property, etc. Rheological agents together with water extracts form cross-linking structures causing different viscosities that would influence the coating structures on the reconstituted tobacco sheet (Du and Zang, 2011).

Rheological property of reconstituted tobacco coating is concerned with how all the components respond to applied forces and deformations, particularly their behaviors in the transient area

Abbreviations: CMC, carboxymethyl cellulose; CGG, cationic guar gum.

* Corresponding author. Tel.: +86 20 87110084.
E-mail address: xzyocean@hotmail.com (F. Yang).

http://dx.doi.org/10.1016/j.indcrop.2014.06.002
0926-6690/

between solids and fluids. Basic concepts of stress (force per area) and strain (deformation per length) are used to conduct all rheological evaluations (Tabilo-Munizaga and Barbosa-Cánovas, 2005). In this paper, rheological properties of reconstituted tobacco coating were studied at low–medium shear rate and high shear rate with the aid of different flow models. The coating structure on actual reconstituted tobacco sheet was also investigated. This study might be able to improve coating technology in the manufacturing of reconstituted tobacco sheet by paper making technology and offer theoretical foundation for realizing comprehensive utilization of tobacco wastes.

2. Experimental

2.1. Raw materials

The tobacco stems and tobacco leaf scraps were obtained from a plant in Guangdong, China. The contents of water-soluble sugars, total alkaloid, total nitrogen and total chlorides were tested according to China Tobacco Standards (YCT 159-2002, YCT 160-2002, YCT 161-2002, YCT162-2002) by a continuous flow analytical instrument (AA3, SEAL Analytical Co., UK). The carboxymethyl cellulose (CMC) and cationic guar gum (CGG) were obtained from Danisco Corporation.

2.2. Methods

The water soluble substances in tobacco were used to make reconstituted tobacco coating. The tobacco stems were extracted by distilled water with a solid to liquid weight ratio of 1:7 at 60 °C for 100 min. Tobacco leaf scraps were extracted by a solid to liquid weight ratio of 1:10 at 70 °C for 60 min. After the extraction, the tobacco stems and tobacco leaf scraps were then separated into liquid part of water extracts and solid part of extraction residues, respectively. The chemical compositions of water extracts were analyzed by the AA3 instrument. The reconstituted tobacco sheet base paper was obtained from a plant in Guangdong, China with a basis weight of 70 g/m^2. The base paper constituted of 50% tobacco stem fibers and 50% tobacco leaf scraps fibers, respectively. In the base paper forming process, 6% bleached softwood pulp and 20% precipitated calcium carbonate (based on dried tobacco stem and leaf scraps fibers) were added.

To prepare reconstituted tobacco coating, water extracts from tobacco stems and leaf scraps were mixed with a volume ratio of 5:3 and concentrated by a rotary evaporator at 55 °C to the solid content about 48%. Then 0.1%, 0.3% and 0.5% (based on the weight of concentrated tobacco extracts) of carboxymethyl cellulose or cationic guar gum were added to the concentrated water extracts, respectively. Additional distilled water was blended in each mixture to reach the coating solid content of about 39%. In order to make the coating homogeneous, it was stirred by a high-speed dispersion machine at a speed of 2000 r/min for 40 min.

The viscosity and pH value of the prepared reconstituted tobacco coatings were tested by a Brookfield DV-Viscometer and a pH-meter (H14221), respectively at 25 °C. The coating rheological properties at different shear rates were measured by AR550 Rheometer (TA Instrument, USA). The coating rheological properties at low–medium shear rate was measured through a 40 mm stainless steel plate at the mode of continuous ramp flow with 1000 μm measuring distance. The coating rheological properties at high shear rate was measured through a 25 mm stainless steel cone plate (0.5° taper) at the mode of continuous ramp flow with 12 μm measuring distance (lamina tip distance).

The prepared coating was coated on the reconstituted tobacco sheet base paper by a K-Control Coater at the speed of 5 m/s. The coating weight was 36 g/m^2. The coated base paper was then dried in an oven at 105 °C overnight. After drying, the coated based paper was equilibrated at 23 °C and 50% RH for 48 h. After that the reconstituted tobacco sheet was obtained.

A scanning electron microscope (SEM, S3700 Hitachi Ltd. Japan) was used to investigate the pore structure on the reconstituted tobacco sheet coated surface. The accelerating voltage was 10 kV and working distance was 11 mm.

3. Results and discussion

3.1. Analysis of the compositions of water extracts

In order to discuss the properties of reconstituted tobacco coating, the chemical compositions of water extracts were analyzed. The yields of water extracted total solids and main chemicals components were listed in Table 1 and the values were consistent with the study of Zeng et al. (2012) about a three-stage extraction of tobacco stem and dust. The yield of total solids for tobacco leaf scraps (44.1%) was higher than tobacco stem (40.2%). As for the extracting yields of the individual chemical components, water-soluble sugars and total alkaloid had relative high values for both tobacco stems and leaf scraps, while total nitrogen was much lower. The reason could be that most of the nitrogen in tobacco was within some organic macromolecular compounds, such as protein, and thus was hard to dissolve in the polar solvent. Conversely, water-soluble sugars and alkaloid belong to small polar molecules and are much more easily dissolved in the extractant. In the tobacco stems and leaf scraps, chloride generally existed in the form of ions (Cl^-) with strong mobility and thus was also likely extracted by water. Overall, the high water extract yields became the important premise for making high quality reconstituted tobacco coatings.

3.2. The effects of rheological agents on the viscosity of reconstituted tobacco coating

After concentrated water extracts was obtained, rheological agents were added to improve its viscosity, to endow the coating with shear thinning properties, and to finally make reconstituted

Table 1
The chemical compositions and the water extracting yields of total solids and individual chemical components (based on the original contents of those components in the raw material) for tobacco stems and tobacco leaf scraps.

Weight percent of individual chemical components in the raw materials				
	Water-soluble sugars (%)	Total alkaloid (%)	Total nitrogen (%)	Total chlorides (%)
Tobacco stems	15.80	0.63	1.90	2.06
Tobacco leaf scraps	25.36	2.23	2.54	0.90

Extracting yields of total solids and individual chemical components					
	Total solids (%)	Water-soluble sugars (%)	Total alkaloid (%)	Total nitrogen (%)	Total chlorides (%)
Tobacco stems	40.2	50.6	52.5	19.7	64.3
Tobacco leaf scraps	44.1	73.1	64.6	7.90	72.0