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Synthesis and Characterization of Sucrose - Melamine - Formaldehyde Adhesives

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Abstract. Due to the limitation of the petroleum resources and the unstable fossil fuel prices, there is more demand on the development of bio-based adhesives synthesized from the renewable bio-resources. Sucrose, rich in hydroxyl groups, is a class of renewable and biodegradable biomaterials which can be used as a substitute for the synthetic polymers like lactose. In this paper, sucrose–melamine-formaldehyde (SMF) resin was synthesized in a base condition. The wet bonding strength, shelf life, and formaldehyde emission of the SMF resin were determined. It was found that the shelf life of SMF resin increased as the sucrose content increased. As the sucrose content, the wet bonding strength decreased, while the formaldehyde emission also reduced. A sucrose to melamine mole ratio of 0.4:1 was suggested. Fourier Transform-Infrared Spectroscopy (FT-IR) and Mass Spectrum (MS) were employed to analyze the chemical structure of the SMF resin. The spectrogram of FT-IR and MS cleared revealed the structures of sucrose, melamine and formaldehyde in the SMF. Thechemical reaction of SMF resins occurred between the three primary hydroxyl groups of sucrose and methylolmelamine

Keywords: Sucrose-melamine-formaldehyde (SMF) Adhesive; Synthesis; Characterization;

Introduction

Melamine-Formaldehyde (MF) resins are synthesized from formaldehyde and melamine through polymeric condensation reaction (Park et al 2009). MF resins have been common materials used in paper laminates (Roberts et al 2005) attributed to some advantages, such as high bonding strength, good boiling-water resistance and low curing temperature (Gu 1999). However, due the short shelf-life and high cost of melamine (Hansmann et al 2006), the applications of the MF resins have been limited. Therefore, there is a demand on the modification of MF resins for the use in wood industries. The MF resin can be used for the performance enhancement of other adhesives and through modification by renewable biomaterials (Jett et al 1983) in order to increase the biodegradability of the adhesive and reduce the production costs. Ma et al (2013) conducted the fire retardancy study on the melamine-modified urea-formaldehyde resin using intumescent fire-retardant ammonium polyphosphate. Cakić et al (2012) studied the properties of coatings based on alkyd resin improved via blending with epoxy resins and melamine resins, and the results showed that the samples with 30wt% of melamine resin had a higher hardness of baked enamels then that with 20wt%. The resin system with alkyd/melamine ratio of 70:30 and 30wt% of epoxy resin had the lowest apparent activation energy of 141.5kJ/mol. Liu et al (2014) investigated the formaldehyde and VOCs emissions from wood-based panels coated with nanomaterial-modified melamine impregnate. Tseng et al (2015) studied the CO_2 adsorption capabilities at atmospheric pressure on the activated carbons prepared from melamine-modified phenol-formaldehyde resins.

The development of world economy has driven new government initiatives for using the renewable energy for the replacement of the fossil energy. There is an increased demand on using the renewable resources for the bioproducts to replace the petroleum-based products. As a result, the MF resin modified by tannin (Gangi et al 2013 and조재민 et al 2010) and carbohydrate (Holmberg 1982 and Kohlmayr et al 2012) have a potential in wood adhesives for using the bio-resources sufficiently. Sucrose is a renewable, biodegradable, abundant with low cost, and readily available. Sucrose is rich in hydroxyl groups, which can react with amino or formaldehyde (Costa et al 2013). Technically, sucrose can be a good modifier for MF resin to reduce the condensation time attributing to the hydroxyl group of sucrose obtaining some covalent bonds with the MF resin (Gindl et al 2004 , He et al 2009, Chen et al 2007 and Song et al 2010).

The objective of this paper is to investigate the synthesis process on the sucrose modified MF (SMF) resin, and to evaluate the performance of the SMF resin as affected by the sucrose content.

Materials & Methods

Sucrose (Chemical Purity), Melamine (Chemical Purity) and Formaldehyde (Chemical Purity) were obtained from Sinopharm Chemical Reagent Co., Ltd, Shanghai, China; Borax (Analytical Reagent) was obtained from Xingdong Chemical Co., Ltd, Yingkou, China; Sodium hydroxide (Analytical Reagent) was obtained from Tianjin Kemiou Chemical Reagent Co., Ltd, Tianjin, China; Starch (food grade) was purchased from Wuming Guiquan Starch Chemical Plant, Nanning, China; The Eucalyptus veneer with a moisture content of 8%~12% was obtained from Guangxi Zhenshuo Wood Co., Ltd, Nanning, China.

The resin synthesis and specimen preparation/analyzing equipment include:
Digital cantilever electric mixer (GZ120-S，Baoli Scientific Research Apparatuses co., Ltd, Jiangyin, China);
Heating magnetic stirrer (ZNCL-G/190*90mL, shanghai yike Co., Ltd, Shanghai, China);
NDJ-9 Rotational Viscometer (Shanghai Changji geological instrument Co., Ltd, Shanghai, China);

Hot press (XLB100-D), Zhejiang shuangli Groups Co., Ltd, Huzhou, China;

Electric blast oven (101A-2B, Shanghai Jinghong laboratory instrument Co., Ltd, Shanghai, China);

Microcomputer controlled electronic universal testing machine (CMT5504, Shenzhen Sans Material Test Instrument Co., Ltd, Shenzhen, China);

Electronic balance (JM-B20002, Chaozhe Hengqi Instrument Co., Ltd, Zhuji, China;

Electronic Balance (FA224, Shanghai shunyu hengping scientific instrument Co., Ltd, Shanghai, China);

722 Grating spectrophotometry (Shanghai fine instrument Co., Ltd, Shanghai, China);

Fourier Transform-Infrared Spectroscopy (660 FT-IR, Varian, Inc. Palo Alto, America);

Mass Spectrometer (REFLEXⅢ, Bruker, Inc. Germany).

For the preparation of the SMF resin, 178 g of formaldehyde solution (37% wt %) and 1.3 g of borax (0.3 wt %) were put into a four-necked round-bottom flask with a mechanical stirrer, reflux condenser and a thermometer. The mixture went through a constant stirring until a complete dissolution was achieved. The pH of mixture was adjusted to 8.5 by sodium hydroxide solution (0.1 mol/L). Then, 126 g of melamine and 138 g of sucrose were added into the mixture. The temperature was increased to 90℃, and kept for 150 min. The solution was cooled to room temperature. 192 g of water was added when water tolerance of 2. Finally, sodium hydroxide solution (0.1mol/L) was added to adjust the pH to 7.5-8.5.

Characterizations of FT-IR and MS

SMF resins were purified by silica gel column chromatography with methanol-acetic acid ethyl ester as eluent. And the structure of SMF resin was characterized by Fourier Transform-Infrared Spectroscopy and Mass Spectrum. For the FTIR characterization, the extracted samples were coated with ZnSe crystal and each sample was scanned 64 times over a region of 4000-650 cm^{-1} at a resolution of 4 cm^{-1}. For the MS characterization, the spectrum of SMF resin was obtained from Matrix Assisted Laser Desorption Ionization/Time of Flight MS with a nitrogen laser and a wavenumber of 337 nm.

Bonding Strength Test

The bonding strength for the adhesive was tested in accordance with the procedure described in Chinese standard GB/T 17657-1999 (1999). Plywood (Eucalyptus, 8% water content, $340g/m^3$) with nominal dimensions of 425 mm × 425 mm were glued with the SMF adhesive under a pressure of 0.9 MPa at 150℃ for 7 min and the specimens with nominal dimensions of 25mm × 100mm were made from bonded plywood. The specimens were immersed in the boiling water for 3 hours, and tested in tension using a CMT5504 testing machine. The bonding strength of the specimens was calculated as following:

$$X=P_{max}/A \qquad \text{Eq. (1)}$$

where X is the shear strength, P_{max} is the maximum failing load, and A is the bonding surface of the specimen.

Shelf-Life of Adhesive

The SMF adhesive in an iodine flask was placed in box with a constant temperature of 23±2℃. During the conditioning, the viscosity of sample was measured by rotational viscometer every 5 days until the sample was gelled.

Formaldehyde Emission

The formaldehyde emission of SMF bonded plywood at different sucrose content was measured in accordance with the procedure described in Chinese Standard GB/T 17657-1999. Ten samples (150 mm × 50 mm) were placed in a desiccator with a dish container of 300 mL water in the bottom for 24h at the room temperature of 20℃. The water samples in the dish were tested by a 722 Grating spectrophotometry.

Results and Discussion

Fourier Transform-Infrared Spectroscopy Analysis

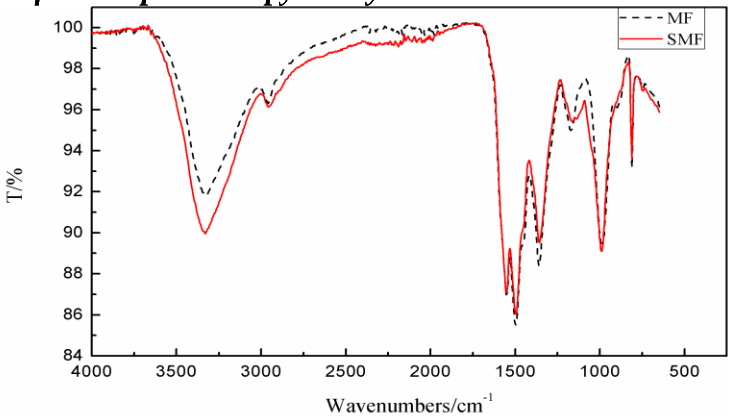


Figure 1 FTIR spectrum of SMF resin and MF resin

The FTIR technique was used to determine the characteristic groups of the resin and to confirm the condensation of sucrose, melamine and formaldehyde. The spectrum results of SMF and MF are shown in Fig. 1. The peak at 3349 cm^{-1} is assigned to the stretching vibration of the N-H and O-H bonds, while the peak at 1069cm^{-1} to that of the C-O-C bonds. The absorption peaks at 2957cm^{-1} and 1457cm^{-1} are assigned to the stretching vibration and the flexural vibration of C-H in the alkane, respectively. The peaks at 1553 cm^{-1} and 1495 cm^{-1} are both attributed to the stretching vibration of C=N in the heterocyclic nitrogen. The peak at 814 cm^{-1} is assigned to the characteristic absorption peak of thiotriazinone. As shown in Fig. 1, the SMF shows enhanced characteristic peaks at 3349cm^{-1} and 1160cm^{-1}, compared to MF, indicating the effect of sucrose groups on the structure of SMF resin.

Mass Spectrum Analysis

The Mass Spectrum of SMF resin is shown in Fig. 2.

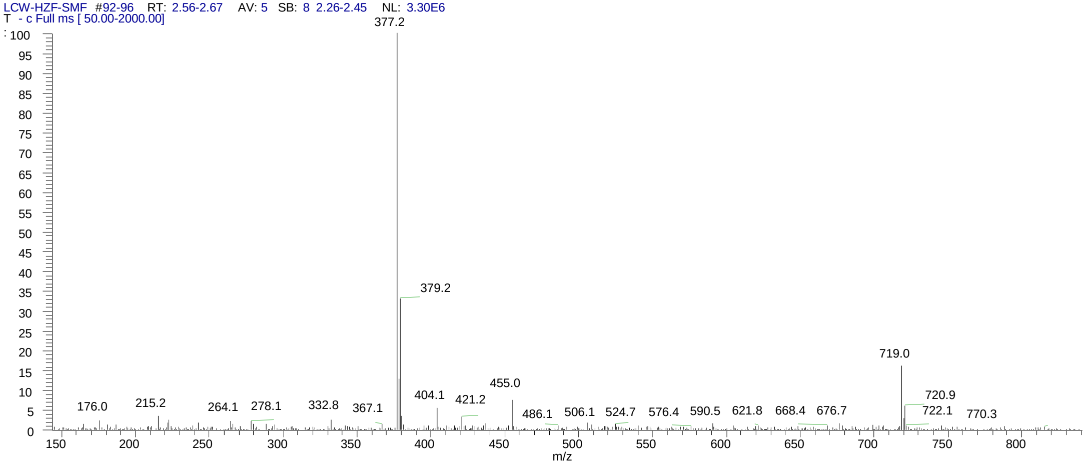
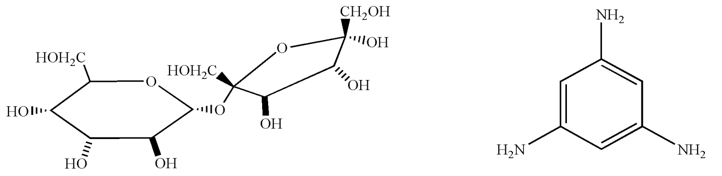
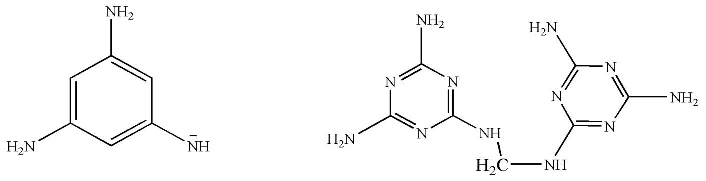


Figure 2 ESI-MS spectrum of SMF resin

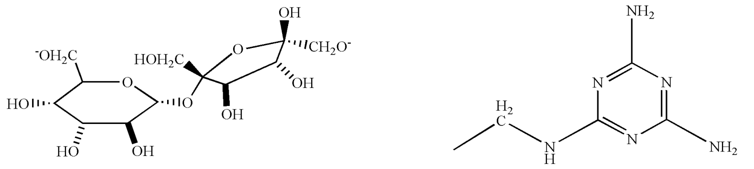
It is very useful for Mass spectrum to know the weight of molecule and fragment of samples (Mclafferty and Choi 1993). As shown in Fig. 2, the molecular structure of sucrose (molecular weight of 342, Fig. 3) can be obtained from the change of fragment from 719 (m/z) to 377 (m/z). The molecular structure of melamine (molecular weight of 126, Fig. 3) can be obtained from the change of fragment from 234 (m/z) to 108 (m/z). The structure of melamine which lost a hydrogen atom (molecular weight of 125, Fig. 3) can be obtained from the change of fragment from 206 (m/z) to 79 (m/z). The change of fragment from 719 (m/z) to 455 (m/z) is assigned to a chemical structure (molecular weight of 264) shown in Fig. 3. The fragment between 719 (m/z) to 379 (m/z) is assigned to a chemical structure (molecule weight of 340) shown in Fig. 3. The fragment from 218 (m/z) to 79 (m/z) is assigned a chemical structure (molecule weight of 139) shown in Fig. 3.



The fragment from 719(m/z) to 377(m/z) The fragment from 234(m/z) to 108(m/z)



The fragment from 206(m/z) to 79(m/z) The fragment from 719 (m/z) to 455 (m/z)



The fragment from 719(m/z) to 379(m/z) The fragment from 218 (m/z) to 79(m/z)

Figure 3 Structure of fragment speculated from the change of mass-to-charge ratios

The above analysis suggested that the SMF resin was synthesized by the chemical condensation of melamine, formaldehyde and sucrose. In addition, the main covalent linkages between the monomers were ether group and methylene group.

Bonding Strength Test

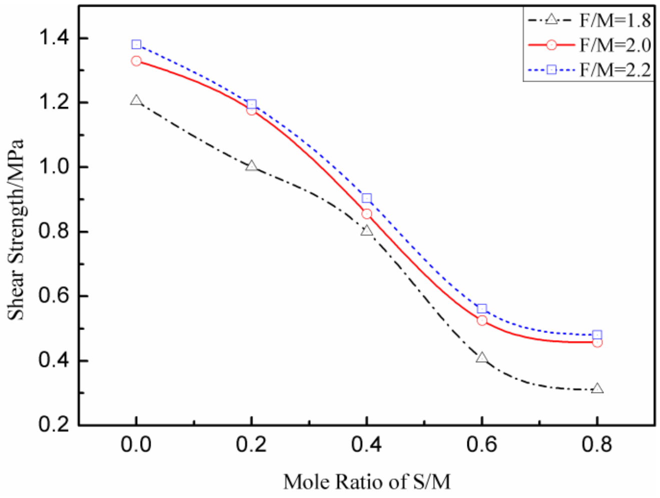


Figure 4 Effect of sucrose content on bonding strength of SMF bonded plywood

Table 1 Wood Failure Percentage (%) of SMF bonded Plywood in Bonding Strength Test

		Mole ratio of S/M				
		0	0.2	0.4	0.6	0.8
F/M	1.8	80	60	60	30	10
	2.0	80	50	60	40	10
	2.2	100	80	70	40	20

- ✧ *The mole ratio of F/M is 1.8, 2.0, 2.2 and the wood failure percentage is speculated according to Chinese standard of GB/T 17657-1999.*

The bonding strength results of SMF bonded plywood using the SMF resins with different formulations (S/M ratios and F/M ratios) are shown in Fig. 4 and wood failure percentage (%) of SMF bonded Plywood in Bonding Strength Test are shown in Tab. 1. Compared to the MF adhesive (S/M ratio = 0), the bonding strength of the resins was reduced. As the S/M ratio increases, the bonding strength of plywood decreases. A turning point which meet the requirement of Chinese standard of GB/T 17657-1999 (≥0.7MPa) of 0.4 S/M mole ratio, 0.80MPa, 0.86MPa and 0.90MPa, is shown in Fig. 4. The incorporation of sucrose reduced the water resistant (especially in boiling water) of the resin because of the hydroxyl group of sucrose.

Shelf-Life test

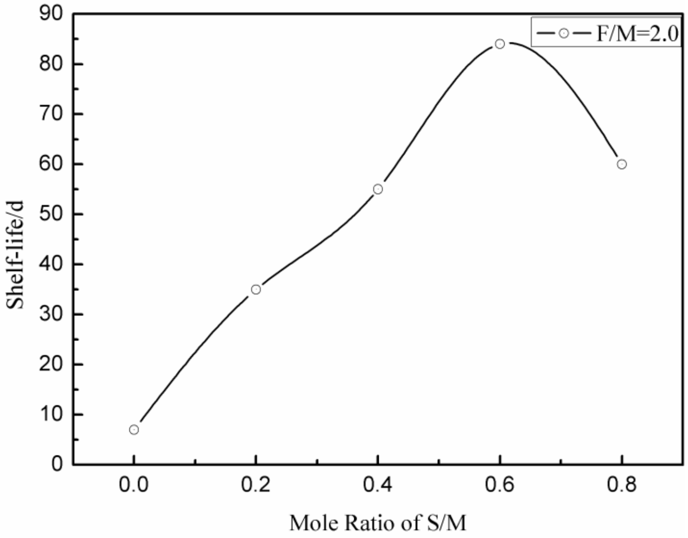


Figure 5 Effect of sucrose content on shelf-life of SMF resin

Shelf life is an important parameter for the wood adhesive. The shelf life of SMF resin as a function of sucrose content is shown in Fig. 5. It was very unstable for MF adhesive to stockpile especially in the environment with low temperature (Gu 1999). As it is shown in Fig. 5 that there was only seven days of shelf-life for the pure MF adhesive, which affect the commercialization of the MF adhesive. The shelf life of SMF adhesive is shown much longer than that if the MF (Fig. 5). As the sucrose content increases, the shelf life increases when the mole ratio of sucrose and melamine is between 0 and 0.6. The longer shelf life of SMF may be due to the efficient reaction of hydroxyl (Wang et al 2012) of sucrose and the active groups-methylol of resin, so that the crosslinking reaction of active groups of resin is reduced***Formaldehyde Emission test***

Figure 6 shows the effect of sucrose content on the formaldehyde emission of the SMF resin.

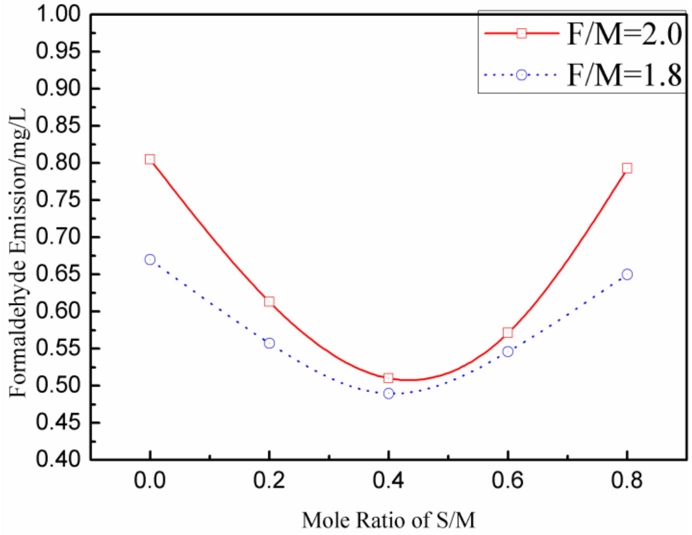


Figure 6 Effect of sucrose content on formaldehyde emission of plywood

The formaldehyde emissions of SMF resins formulated at two different mole ratios of sucrose to melamine were measured. It was found that the formaldehyde emissions of the SMF bonded plywood were in between 0.5 mg/L and 0.8 mg/L when the mole ratios of sucrose to melamine were 0~0.8, which had met the requirement of E_1(≤1.5mg/L) in the Chinese standard of GB 18580-2001 (2001). It is also shown that different trends on the formaldehyde emission vs. S/M ratios between the F/M 2.0 and F/M 1.8. For the both F/M ratios, when the S/M ratio bellows 0.4, increasing the sucrose content is beneficial to reducing the formaldehyde emission. As the sucrose content continues to increase, the formaldehyde emission increases. A turning point of 0.4 S/M mole ratio, 0.49mg/L and 0.53mg/L, is shown in Fig. 6. It is equivalent to acknowledge an efficient reaction can be coming true as the mole ratio of sucrose and melamine, 0.4. Increased sucrose content could promote reaction of MF resin and sucrose which will enhance the stability of chemical bond of SMF resin to reduce the formaldehyde emission from the degradation of ether.

Summary and Conclusions

A SMF adhesive was synthesized by a condensation of sucrose, melamine and formaldehyde. An optimum sucrose to melamine mole ratio was found as 0.4:1, with a wet bonding strength of 0.90 MPa, formaldehyde emission of 0.49 mg/L. Compared with the MF adhesive, an improved performance of shelf life was achieved. SMF adhesives can be a potential alternative for environment-friendly wood adhesive.

Acknowledgments

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Drying Cellulose-Based Materials Containing Copper Nanoparticles

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Abstract

Cellulose nanostructures are produced in aqueous solutions and even though there are some applications that do not require a drying process to use them there are many others that demand the material to be dried. Today, drying cellulose nanomaterials remains as an essential and latent challenge for obtaining properties for specific applications. In this research carboxymethyl cellulose and TEMPO nanofibrillated cellulose were used as substrates to synthesize copper nanoparticles from copper sulfate and they were subsequently dried using spray-, freeze- and modified freeze drying processes. Morphological characterization, particle size distribution, copper quantification and the oxidation state of copper were evaluated. Plate-like structures of cellulose and cellulose-copper nanoparticles were formed after the freeze-drying process, with length and width over hundreds of microns. Most of the spray dried materials exhibited spherical shapes with the particle size ranging from around 300 nm to several microns. The spray drying process caused more copper loss compared with freeze drying, most probably because of the additional steps required to perform the spray drying. XPS results showed that the state of oxidation of the final dried material depends on the specific substrate. CMC surfaces exhibit mostly Cu0 and/or Cu+. On the contrary TNFC surfaces present mostly Cu2+. The differences in the state of oxidation will presumably affect the antimicrobial properties of the hybrid material. Solvent exchange process using ethanol and butanol creates more porous structures on the CMC substrates. A solvent exchange process using ethanol and tert-butanol sequence facilitates the formation of a more porous structure on TEMPO nanofibrillated cellulose.

CLT Adoption in the U.S.: Perceptions, Market Potential, and Resource Assessment

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Abstract

Recent research by the authors (Laguarda Mallo and Espinoza) has shown that the level of awareness about Cross Laminated Timber (CLT) among U.S. architects is low, and perceptions and barriers to adoption were also uncovered. This research builds on this experience and expands the scope to include other decision makers in the CLT supply chain. Perceptions are critical in the production adoption process and research is needed to provide entrepreneurs and potential adopters with information about this promising construction technology. The purpose of this research is to investigate, identify, and disseminate opportunities and barriers to the adoption of cross-laminated timber (CLT) in the U.S. Two nationwide surveys and two sets of interviews are being conducted among structural engineering firms, construction firms, and developers. A new product diffusion model is used to assess market potential in the U.S., in absolute terms and over a period. Based on market potential, the impact on U.S. forest resources is quantified, using parameters obtained from industry. The information generated by this study benefits entrepreneurs, industry support organizations, government agencies, and specifiers of structural materials.

Soybean meal-based wood adhesive enhanced by ethylene glycol diglycidyl ether and diethylenetriamine

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Abstract

The objective of this study was to improve performance of the soybean meal-based adhesive by an ethylene glycol diglycidyl ether (EGDE) and diethylenetriamine (DETA). Three-ply plywood was fabricated to measure wet shear strength. The functional groups, cross section, crystallinity, thermal behavior, and physical properties of the resultant adhesives were characterized in detail. Results show that DETA reacted with EGDE to form a long chain structure with epoxy groups, which cross-linked the soy protein molecules to form a denser cured adhesive layer to improve the water resistance of the resultant adhesive. In addition, the long chain structure formed an interpenetrating network with the soy protein molecules, which further improved the water resistance of the adhesive. Incorporating EGDE/DETA, the wet shear strength of the plywood bonded by the resultant adhesive was improved by 30.7% to 1.15 MPa, which met the interior use plywood requirement. Additionally, compared with the soybean meal-based control adhesives, the viscosity of the cured adhesive decreased by 39.4%-50.3%, that made the resultant adhesive practical for plywood industrial application.

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Activated Carbon Monolith Derived From Bio-char

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Abstract

Activated carbon monoliths were fabricated using powered bio-char as a raw material and bio-oil phenol-formaldehyde (BPF) resin as a binder. The effect of the preparation condition on the physical and mechanical properties (compressive strength, iodine adsorption value, methylene blue adsorption value) of the resultant form was investigated. Using N_2 adsorption, the adsorption performance under different conditions was observed. The results showed that the binder ratio and molding pressure had a significant effect on the the adsorption capacity and mechanical strength of activated carbon monoliths. It was found that an increase in the binder ratio would reduce the iodine and methylene blue adsorption value first and then enhance and strengthened the compressive strength of the carbon first and then reduced. The activated carbon monoliths prepared from the high molding pressures exhibited lower adsorption value and higher compressive strength than those of the activated carbon monoliths prepared from low molding pressures. Using the scanning electron microscopy (SEM), the microstructure characteristics of activated carbon monolith was examined. The optimum conditions to obtain the highest properties were the 20% BPF resin binder and 20 MPa molding pressure.

***Keywords*:** Activated carbon monoliths; Binder ratio; Molding pressure; Adsorption property; Compressive strength.

Introduction

Activated carbons have been widely used in industrialized societies to remove odor, taste and color and other impurities from drinking water through adsorption from liquid/gases or as advanced catalyst support and electrode material (Carvalho 2006). This is result of unique surface properties and physico-chemical properties of activated carbon, such as large surface area, suitable pore volume, along with adjustable particular surface chemistry (Qiao 2001). As a special class of activated carbon, the activated carbon monolith received a considerable attention in the last decade due to its high strength and bulk density, dust free, and high adsorption capacity per unit volume. (Jiang 2013) Activated carbons are traditionally made from coal and petroleum coke(Ruth 2006). Biochar is one of the most proficiency raw materials because of its high carbon content, particle uniformity, low ash content and certain pore structure (Lozano-Castello´ 2002).

In this study, the activated carbon monoliths were pressed into pillars using Bio-oil Phenol-formaldehyde resin as a binder. The effect of the binder ratio and molding pressure on properties of activated carbons monoliths in pillars, such as the mechanical strength, iodine adsorption value and methylene blue adsorption value, were investigated. Consequently, it was found that the optimal manufacturing condition was the 20% binder content and 20 MPa molding pressure.

Materials and Methods

Materials. The bio-char was a type of wood-based carbon obtained by the fast pyrolysis of pine sawdust. Table 1 presents the proximate analyses results of the bio-char used in this study.

Table.1 Proximate analysis of Bio-char

Materials	M_{ad}[a]	V_{ad}	FC_{ad}	A_{ad}
Bio-char	5.86	18.25	67.38	8.51

[a] Subscript “ad” stands for air-dried condition.

Bio-oil Phenol-formaldehyde resin was supplied by the Institute of Wood Based Material, Beijing Forestry University, China. Bio-oil Phenol-formaldehyde resin showed black sticky appearance with a viscosity of 388 mPa•s and a solid content of 50.8%.

Methods.

Preparation of the activated carbon from bio-char and BPF

The powder bio-char was obtained from a series of high temperature pyrolysis treatments using mongolica sawdust as the raw material. The bio-oil phenol-formaldehyde (BPF) resin was added to the bio-char and then mixed mechanically at room temperature. The mixture of bio-char and BPF resin was molded under a pressure of 10–50 MPa into a monolith at 120℃(The BPF resin curing temperature).Then the monolith was activated with steam to obtain activated carbon monolith. The activation temperature, activation time and activation medium flow were selected according to the results obtained in our preliminary experiments to produce monolith with the most suitable porous texture and mechanical properties. The monolith was carbonized at 800℃for 1h in a H_2O flow (600ml/min) with a heating rate of 10℃/min.

Compressive strength
The compressive strength of the activated carbon monolith was measured using a universal material testing machine (Zwick/Roell, Z005) under a loading speed of 1mm/min. The compressive strength, P, was calculated by the equation, $P= F/S$, where F is the load at failure, S is the cross sectional area of monolith. The data presented in this paper were typically an average of three measurements.

Iodine and methylene blue adsorption performance analysis
The iodine adsorption value and methylene blue adsorption value were determined according to the national standard of China (GB/T12496.8-1999 and GB/T12496.10-1999)

Scanning electron microscope (SEM)
The microstructure of the activated carbon monoliths were observed under a scanning electron microscope (SEM) using a Hitachi SU8010 microscope. Images were obtained at an excitation energy of 5000V.

Results and Discussion

Effect of the molding pressure

The molding procedure significantly influenced on the adsorption capacity and mechanical properties of the activated carbon monolith. Fig. 1 shows the effects of the molding pressure on the compressive strength of the activated carbon monolith.

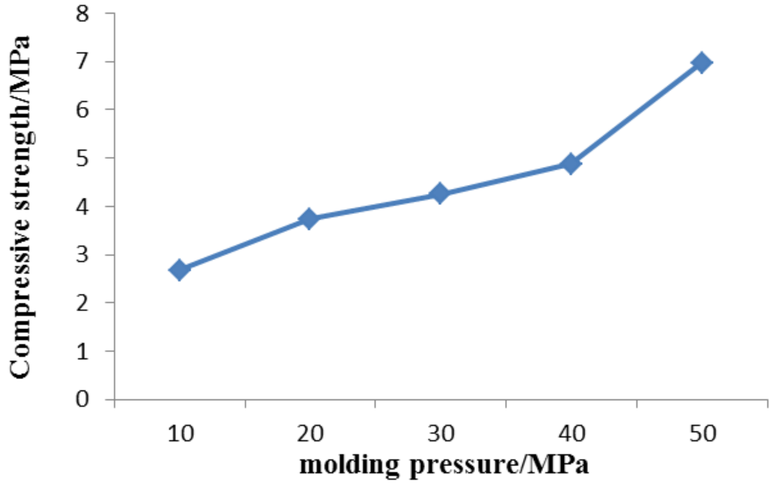


Fig. 1 The effect of the molding pressure on the compressive strength of activated carbon monolith.

As shown in Fig. 1, the increase in the molding pressure improved the compression strength of the products. The compression strengths of activated carbon monoliths molded at 10MPa and 50MPa were 2.68 and 6.98MPa, respectively. Thus, the higher the molding pressure produced higher strength of the molded monolith.

Fig. 2 shows the effects of the molding pressure on the iodine adsorption value and methylene blue adsorption value of the activated carbon monolith.

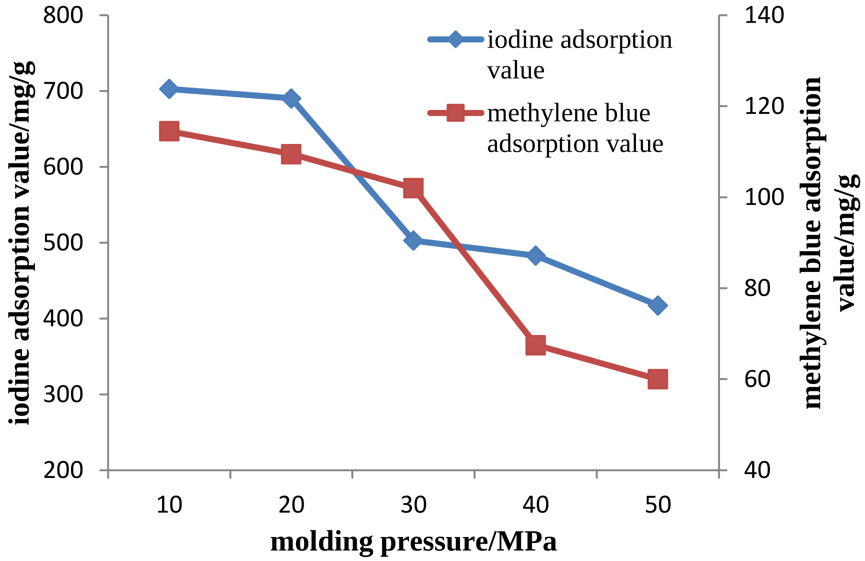
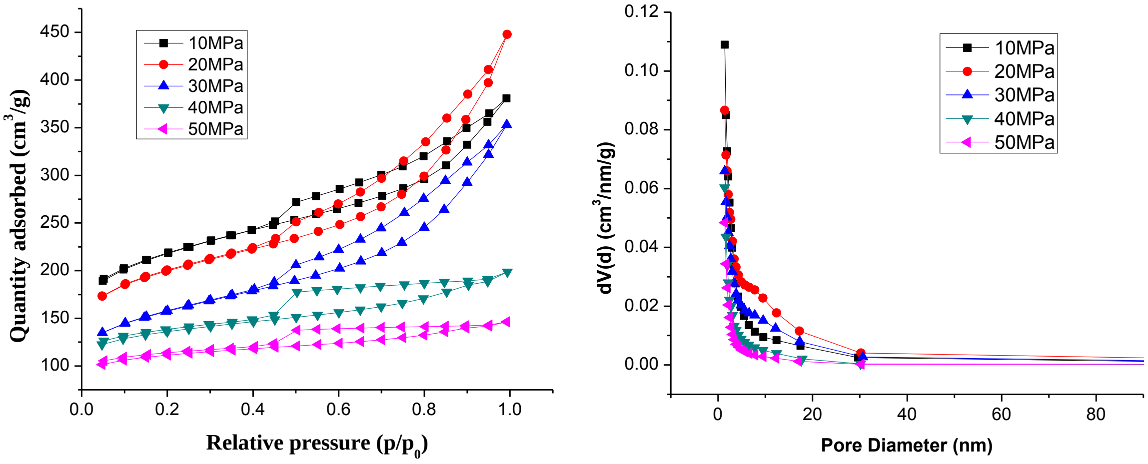


Fig. 2 The effect of the molding pressure on the iodine adsorption value and methylene blue adsorption value of activated carbon monolith.

The variation of iodine and methylene blue adsorption value against the molding pressure used in the molding procedure is depicted in Fig. 2. It is shown that, as the molding pressure increases, the iodine and methylene blue adsorption capacity of activated carbon monolith reduces. The iodine and methylene blue adsorption value do not reduce significantly when the molding pressure increases from 20 MPa to 30 MPa. Over these molding pressures, the reduction in iodine and methylene blue adsorption value is markedly. Therefore, the molding pressure of 20 MPa was selected for preparing the activated carbons monoliths.



(A) (B)

Fig. 3 (A) N_2 adsorption-desorption isotherms and (B) mesopore size distribution of the samples

Fig. 3 (A) shows different N_2 adsorption isotherms of the activated carbon monoliths prepared with different molding pressures. The four samples demonstrated the typical characteristics of IV-type adsorption isotherms. When the relative pressure was high, the adsorption isotherms of the samples exhibited a sharply upturned appearance, which indicated the existence of mesopores or macropores. For these samples, a decrease in the molding pressure gave an increase in the amount of nitrogen adsorbed together with a slight widening of the knee at low pressures. This meant that an increase in the molding pressure would result in a decrease in the number of pores.

The mesopore size distribution is shown in Fig. 3 (B). Theoretically, pores can be sorted by diameter into micropores (pore diameter less than 2 nm), mesopores (pore diameter between 2 and 50 nm), and macropores (pore diameter greater than 50 nm). The mesopore distribution decreased with the increasing molding pressure. It can be inferred that molding pressure had a direct impact on the pore size distribution. When the mechanical properties and adsorption properties are taken into account, the best molding pressure seems to be 20MPa

Effect of the percentage of binder

In order to understand the reasons of adsorption and mechanical properties were affected by the amount of binder, activated carbon monoliths with a different percentage of BPF (10,20,30,40 and 50w% at the end of the preparation) were prepared. Fig. 4 shows the effects of binder ratio on the compressive strength of the activated carbon monoliths.

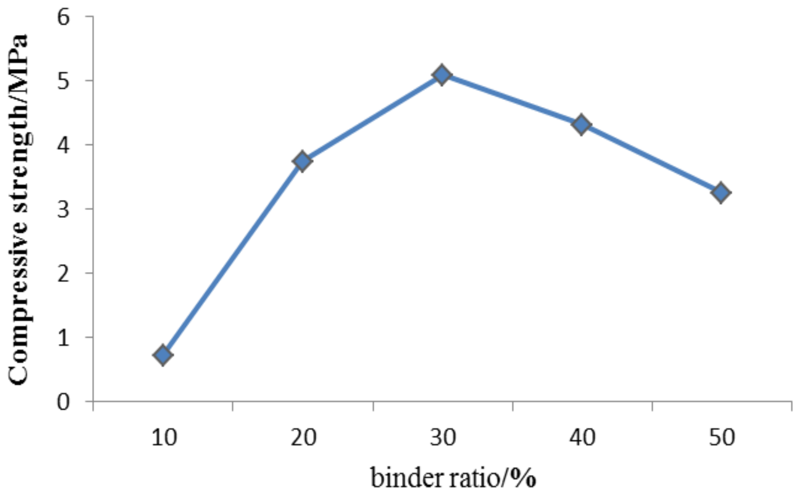


Fig. 4 The effect of the binder ratio on the compressive strength of activated carbon monolith.

Fig.4 shows that, as the binder ratio increased, the compression strength presented a tendency to enhance first and then reduce. It was observed that an increase in the amount of binder from 10 to 30 wt% produced an increase in the compressive strength. The compressive strength reached its highest values at the binder ratio of 30w%. Above this binder ratio, the higher the binder content in the monolith, the lower the compression strength were obtained.

Fig. 5 shows the effects of the binder ratio on the iodine adsorption value and methylene blue adsorption value of the activated carbon monoliths.

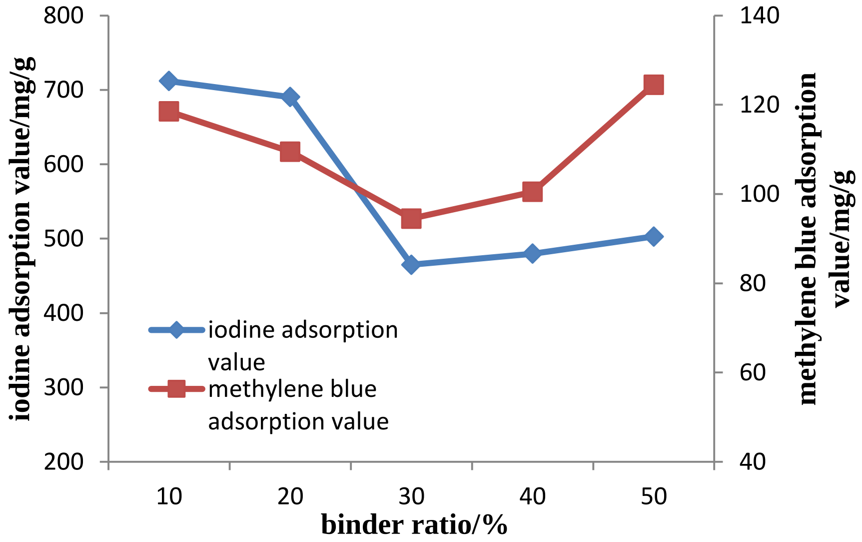
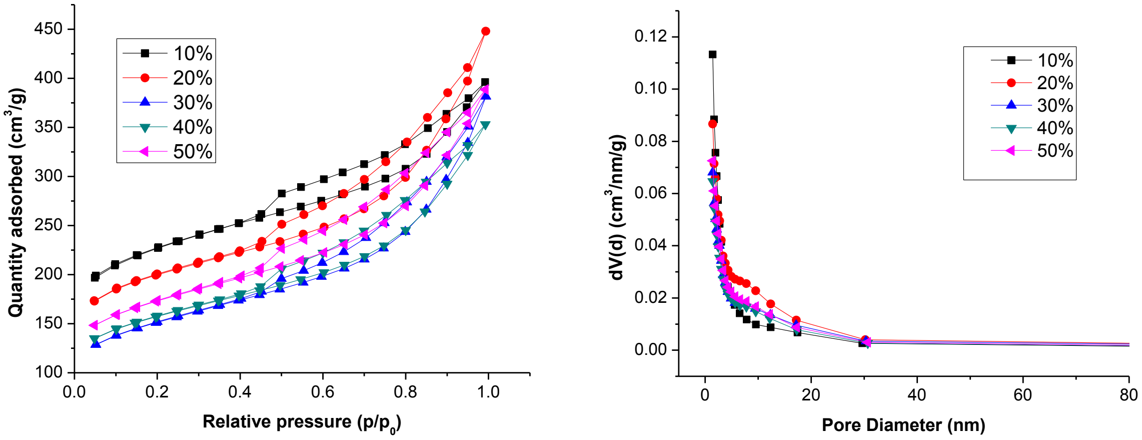


Fig. 5 The effect of the binder ratio on the iodine adsorption value and methylene blue adsorption value of activated carbon monolith.

Fig.5 shows that the adsorption capacity changed with the amount of binder significantly. As the binder ratio increased, the adsorption capacity showed a tendency to reduce first and then enhance. The minimum adsorption value was obtained at binder ratio of 30w%.



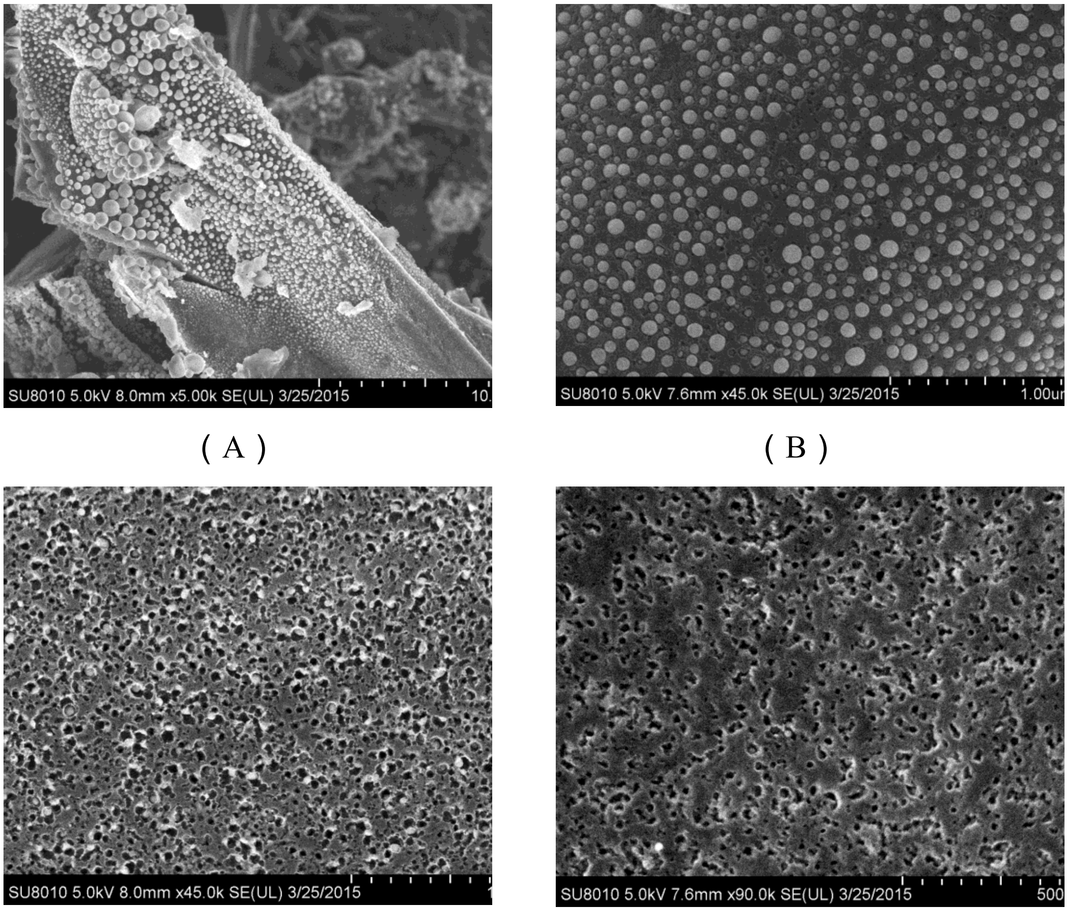
(A) (B)

Fig. 6 (A) N_2 adsorption-desorption isotherms and (B) mesopore size distribution of the samples

Fig. 6 (A) presents the nitrogen adsorption isotherms of the activated carbon monoliths prepared with different binder ratios. The figure shows a trend whereby the adsorption capacity of the samples first decreased and then increased with the increasing ratio of binder. This means that adding binder to the bio-char is adverse to forming pores in the preparation process. On the other hand, as the further increase of binder will result in an increase in the number of pores. The mesopore size distribution is shown in Fig. 6 (B). The mesopore distribution decreased first and then increased with the increasing ratio of the binder. When the mechanical properties and adsorption properties are taken into account, the best condition of binder ratio seems to be 20%.

SEM Analysis

Fig 7 shows SEM images of the activated carbon monoliths molded under 20 MPa and binder ratio of 20%. Figs. (A), (B), (C) and (D) were presented in the cases of 5.00k, 45.00k, 45.00k and 90.00k magnification, respectively.



(A) (B)

(C) (D)

Fig.7 Scanning electron microscope photograph of activated carbon monolith.

The existence state of BPF in the structure of activated carbon monolith are shown in Fig.7 (A) and (B). As seen in these images, the carbonized BPF resin attached on the surface of activated carbon particles. The presence of pores in large size played an important role in adsorption. In Fig.7(C) and (D), it can be observed that a large number of mesopores and macropores on the particle surface can be appreciated.

Conclusions

Using BPF resin as a binder, different activated carbon monoliths were obtained by the H_2O-activation of bio-char with different molding pressures and binder ratios. The molding pressure and percent of binder in the monoliths had a great influence on the mechanical and adsorption properties. As the molding pressure increased, the compression strength of the products enhanced, and the iodine and methylene blue adsorption capacity reduced. As the binder ratio increased, the compression strength presented a tendency to enhance first and then reduce and the adsorption capacity showed a tendency to reduce first and then enhance. It was found that the best mechanical and adsorption properties characteristics could be obtained with a binder ratio of 20% and a molding pressure of 20MPa.

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Bio-Based Energy in the Southeast US: A Stakeholder Perception Study

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Abstract

A sample of consumers in North Carolina (NC) and Tennessee (TN) were surveyed in the fall of 2013 and spring 2014 to examine their perceptions and concerns about bioenergy. Approximately, 586 consumers completed the survey electronically (376 in NC, 210 in TN). The initial data was weighted to represent the adult population of NC and TN. The respondents recognized solar and wind energy sources mostly as renewable compared to all other energy sources including biomass-based energy. Respondents reported that the price of biofuels and compatibility of biomass-based fuels with their cars were the most important factors that influence their choice of biofuels versus gasoline at a pump. Results show that the acceptance of bioenergy, and specifically biofuels from the consumer’s perspective, depend on the extent of knowledge and available information about the energy source. A principal component analysis (PCA) of bioenergy statements indicate seven distinct dimensions of consumer perceptions and attitudes towards bioenergy including bioenergy benefits to society, risks of bioenergy use, government support for bioenergy, increase in food cost, conditional use of trees as feedstocks, support low-cost biofuel alternative to current energy, and market attribute-based purchase. The findings from

this study highlight not only educational needs and outreach efforts but also reflects the need for trustworthy channels of communication, helpful policy, market, and institutional support for bioenergy success in NC and TN.