Synthesis and Characterization of Sucrose - Melamine - Formaldehyde Adhesive

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MF is common adhesive used in wood industries (paper laminates); maybe replace of PF. **Advantages:** high bonding strength, good boiling-water resistance and low curing temperature; **Defects:** the short shelf-life and higher cost than UF; **Therefore, MF is modified.**

Sucrose is a renewable, biodegradable, abundant with low cost, and readily available. **It** is a good **modifier** for MF because of rich hydroxyl groups (hydroxymethyl groups specially).
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 and Methods

- Sucrose, Melamine and Formaldehyde
- Characterizations of FT-IR and MS
- Bonding Strength Test
- Shelf-Life of Adhesive
- Formaldehyde Emission
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 reactor. 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°C, and kept for 150 min. When water tolerance was 2, the solution was cooled to room temperature and 192 g of water was added. Finally, sodium hydroxide solution (0.1 mol/L) was added to adjust the pH to 7.5-8.5.
Results and Discussion

1. Fourier Transform-Infrared Spectroscopy Analysis

The SMF shows enhanced characteristic peaks at 3349 cm\(^{-1}\) and 1160 cm\(^{-1}\), compared to MF, indicating the effect of sucrose groups on the structure of SMF resin.
Results and Discussion

2. Mass Spectrum Analysis

Fig. 2
Results and Discussion

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

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

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

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

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

The fragment from 218(m/z) to 79(m/z)
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.
Results and Discussion

3. Bonding Strength Test

Fig. 4

[Graph showing shear strength vs. mole ratio of S/M for different F/M ratios (F/M=1.8, F/M=2.0, F/M=2.2).]
Results and Discussion

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

<table>
<thead>
<tr>
<th>Mole ratio of S/M</th>
<th>0</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/M</td>
<td>1.8</td>
<td>80</td>
<td>60</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>80</td>
<td>50</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>100</td>
<td>80</td>
<td>70</td>
<td>40</td>
</tr>
</tbody>
</table>

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 17657-2013.
Results and Discussion

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 17657-2013 (≥0.7MPa) of 0.4 S/M mole ratio, 0.80 MPa, 0.86 MPa and 0.90 MPa, 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.
Results and Discussion

4. Shelf-Life test

![Graph showing shelf-life in days against Mole Ratio of S/M for F/M=2.0.]

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 of sucrose and the active groups-methylol of resin, so that the crosslinking reaction of active groups of resin is reduced.
Fig. 6
It is 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.
Results and Discussion

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.
Conclusions

◆ A SMF adhesive that can be used indoor was synthesized by the 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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Next work

- Investigating the synthesis mechanism of SMF resin by building kinetic model of synthesis process
- Investigating thermostability of SMF resin
- Investigating the curing kinetics of SMF resin
- Researching MMF (Maltose-Melamine-Formaldehyde) resin

蔗糖(左) 和麦芽糖(右) 结构式
The Structure of sucrose (left) and maltose (right)
Thank you

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