Preparation and characterization of foamed urea formaldehyde (UF) adhesive for wood

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Abstract – In this study, urea formaldehyde (UF) resin was foamed using egg white (EW), blood albumin (BA), blood protein (BP) and liquid soap (SP), and the effect of foaming on the adhesive strength (IB), gelling time, density and water absorption (WA) was investigated. Black pine samples were used for the IB analysis. Two 50 mm x 50 mm x 5 mm wood samples were bonded to each other using 1-gram foamed UF and the IB strength was determined. In order to determine the water intake amounts, foamed UF was poured into the mold and allowed to solidify for 7 days. The density and water uptake amounts of the solidified UF were determined by keeping them in water for 24 hours. According to the obtained results, the foaming agents increased the volume of UF 2-3 times after 10 minutes of mechanical mixing and increased the gelation times. EW and BA increased IB strength while SP and BP decreased. No significant change was detected in the densities of the samples. With the foaming process, UF covered more surface area. this increased the gluing efficiency of UF. However, although SP and BP increased the volume of the glue, they decreased the adhesion strength. It has been determined that the gluing efficiency can be increased by foaming the glues. In this way, formaldehyde emission can also be reduced.

Keywords – Adhesive, Urea Formaldehyde, Foaming, Internal Bond, Jell Time

I. INTRODUCTION

Much research are carried out on the foaming of organic and inorganic materials [1]–[3]. Foaming allows the volume of materials to be increased and thus the wood surface to be covered more. This improves both the saving of the adhesive and the adhesion of the adhesive.

UF most abundant adhesive in the wood sector. In addition to being economical, UF glue has advantages such as high reactivity, sufficient hardening with low pressing time, providing a clean glue line and not adding extra flammable properties to the board. Despite these advantages, the biggest disadvantage of UF glue is formaldehyde emission [4].

With foaming, it is possible to reduce the amount of formaldehyde as well as increase the adhesion force. In some studies, on this subject, Bi and Huang. [5] foamed the phenol formaldehyde by azodicarbonamide (AC) under heat and improved mechanical properties. In another study, both the emission amount of UF glue and its adhesion strength were improved by using egg white [6]. The foaming method of glue is also used to reduce the density of wood composites. Wang et al. [7] foamed polyurethane glue and used it in particleboard production and improved mechanical properties without formaldehyde emission.

Boruszewski et al. [8] foamed the UF using blowing agents from the group of hydrazides, dicarboxamides, or tetrazoles and stated that for the production of particleboards with a reduced density (at the assumed level of 520 kg/m^3), the UF resin modifier in the form of p-toluene sulfonyl hydrazide

should be used. Many similar studies have been conducted in the production of low-density wood composites [9]–[13] .

In this study, foaming and characterization of UF glue were studied. Natural foaming agents were used as foaming agents. The effects of foaming agents on volume increase, density, gelation time and adhesion strength were determined.

II. Materials and Method

A. *Materials*

Urea formaldehyde (UF) resin and ammonium sulfate (AS) solution used in the study were obtained from Yıldız Entegre. UF and AS solid concentrations were 65% and 30% respectively. Egg, liquid foaming agents and black pine wood were purchased from local market. Animal blood was obtained from slaughterhouse. In the foaming process, 100-gram UF and 10-gram foaming agent and 15gr 30% AS solution were used. Foaming process were carried out by a mechanical stirring machine for 10 minutes. Foaming levels were given in Fig. 1. The gel times of the foamed UF resins were measured using 5 grams of resin in boiling water at 100 degrees (Fig. 2). Black pine (*Pinus nigra*) were used to determine the adhesion resistance of foamed glues to the wood surface.

B. *Methods*

Mechanical characterization of foamed UF was carried out by internal bond (IB) analysis according to TS EN 319. Black pine was cut 50 mm x 50 mm x 5 mm pieces for IB strength test. The wooden pieces were glued together using 1g glue. The glued parts were compressed by hand torture (4 bar) and kept in the oven at 190 degrees for 30 minutes. Then IB test was carried out by Z*w*ick 2500 test machine.

Physical characterizations were carried out by density and water absorption tests according to TS EN 323 and TS EN 327 respectively. Foamed UF were poured in a (150 mm x 30 mm x 20 mm) cap and were kept for 7days in room temperature. Then, solid UF's were cut 30 mm x 20 mm x 10 mm (Fig.3). solid UF samples were kept in water for 24 hours and calculated WA quantity.

A one-way anova statistical analysis method was used to determine whether there was a significant difference between the samples. The differences were grouped by applying Duncan analysis to the samples with significant differences.

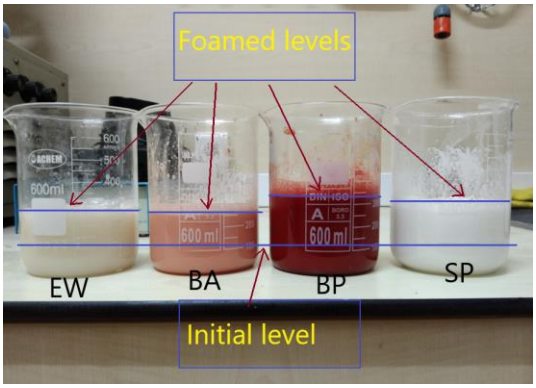

Fig. 1 Foamed UF levels

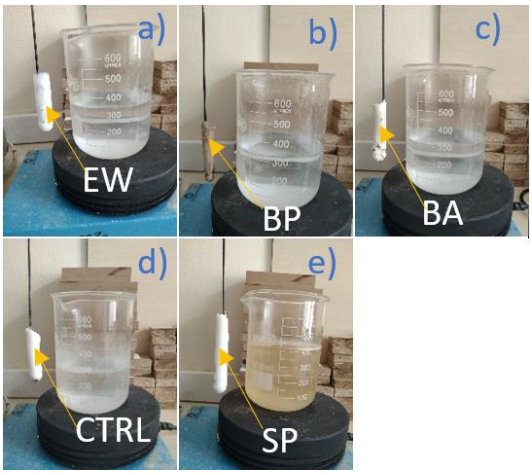

Fig. 2 Jelled urea formaldehyde formations in boiling water a) foamed with egg white, b) foamed with blood protein, c) foamed with blood albumin, d) control sample, e) foamed with liquid soap

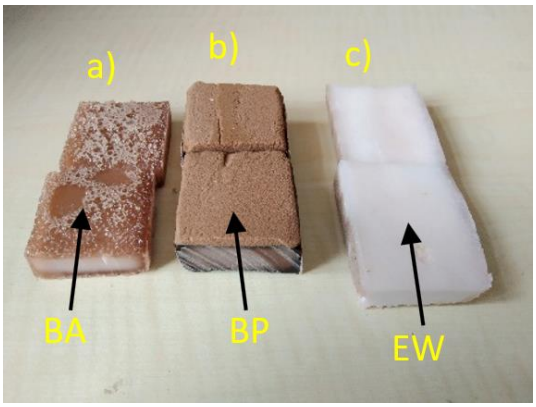

Fig. 3 Foamed solid UF a) blood albumin, b) blood protein, c) egg white added samples.

III. Results

When the IB strength was examined, it was determined that the EW foaming agent was more effective than other foaming agents in terms of improving the adhesive properties. The IB strength of the BA and EW samples is higher than the control sample. However, it was determined that the IB strengths of BP and SP samples were lower than the

control sample (Table 1). When Fig. 4 is examined, it is seen that there is a similarity between gelation times and IB forces. It was determined that the IB strength decreased as the gelation time increased (Fig.4). The oils in SP and BP are thought to prolong the gelling time of UF and reduce the IB strength.

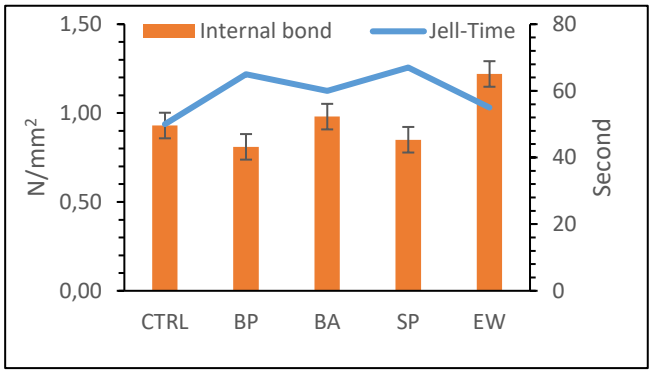

Fig. 4 Foamed UF jell time and bonding strength relations

When Fig. 5 is examined, it is seen that foaming reduces the densities of the samples. Although the densities of the samples decreased, the amount of WA also decreased. It has been found that foaming agents reduce the water absorption of UF.

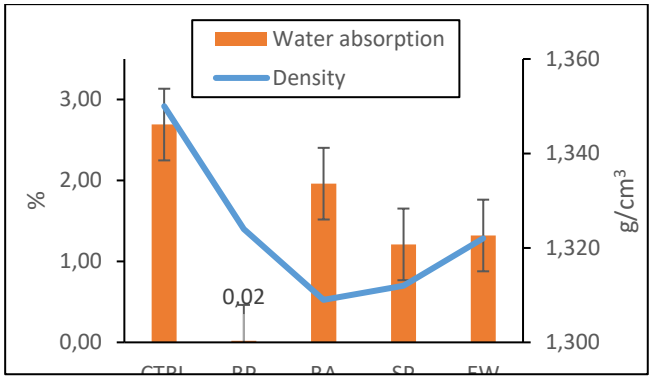

Fig. 5 Foamed UF density and water absorption relations

When the results were statistically examined, it was determined that there were significant differences ($P < 0,05$) except for the densities (Table 2).

Table 1. Analysis (Duncan) results

Samples	Jell-Time (second)	IB (N/mm^2)	DN (g/cm^3)	WA (%)
CTRL	50 A	0,93 C	1,35 B	2,69 D
BP	65 D	0,81 A	1,32 AB	0,02 A
BA	60 C	0,98 D	1,30 A	1,96 C
SP	67 D	0,85 B	1,31 A	1,21 B
EW	55 B	1,22 E	1,32 A	1,32 B

When the foamed UF was kept at room temperature for 7 days, the amount of foam decreased. It has been determined that foaming agents do not provide a stable foaming.

Table 2. One-way Anova results

		Sum of Squares	df	Mean Square	F	Sig.
Jell_time	Between Groups	548,9	4	137,2	66,4	,000
	Within Groups	20,7	10	2,07		
	Total	569,6	14			
WA	Between Groups	11,3	4	2,82	907,0	,000
	Within Groups	,03	10	,003		
	Total	11,3	14			
DN	Between Groups	,003	4	,001	6,7	,007
	Within Groups	,001	10	,000		
	Total	,004	14			
IB	Between Groups	,310	4	,078	776,1	,000
	Within Groups	,001	10	,000		
	Total	,311	14			

The foaming process increased the amount of adhesive acting on the per square meter of the wood surface. In this way, the gluing efficiency has increased. Here, EW and BA foaming agents increased the bonding power of the glue as well as the gluing efficiency. Other foaming agents (SP and BP) have been successful in foaming the glue, increasing the volume, and covering more surfaces. However, they reduced the adhesive strength of the glue. The effects and descriptives results of foaming agents on gelling time, adhesion strength, water absorption strength and densities are given in Table 3.

Table 3. Descriptives results

		Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Jell time	CRTL	50,3	1,5	,9	46,5	54,1
	BP	64,7	1,5	,9	60,9	68,5
	BA	60,3	1,5	,9	56,5	64,1
	SP	66,7	1,5	,9	62,9	70,5
	EW	55,0	1,0	,6	52,5	57,5
	Total	59,4	6,4	1,6	55,9	62,9
WA	CRTL	2,630	,113	,065	2,350	2,910
	BP	,020	,010	,006	-,005	,045
	BA	1,957	,025	,015	1,894	2,019
	SP	1,223	,015	,009	1,185	1,261
	EW	1,300	,044	,025	1,192	1,408

	Total	1,426	,899	,232	,928	1,924
DN	CRTL	1,35	,01	,01	1,33	1,37
	BP	1,33	,02	,01	1,29	1,37
	BA	1,31	,01	,00	1,30	1,33
	SP	1,31	,01	,00	1,30	1,33
	EW	1,32	,01	,01	1,30	1,35
	Total	1,33	,02	,00	1,32	1,34
IB	CRTL	,93	,01	,01	,91	,95
	BP	,81	,01	,01	,79	,83
	BA	,98	,01	,01	,96	1,00
	SP	,85	,01	,01	,83	,87
	EW	1,22	,01	,01	1,20	1,24
	Total	,96	,15	,04	,88	1,04

IV. DISCUSSION

In this study, the effects of foaming process on UF resin were investigated. The purpose of the foaming process is to provide the glue to cover more surface area and thus to reduce the amount of glue to be used. UF glue is an adhesive that releases formaldehyde. Formaldehyde is a poisonous volatile organic compound. Prolonged exposure to formaldehyde gas can cause cancer. For this reason, reducing the amount of formaldehyde in the glue or reducing the amount of glue used in wood is important in terms of protecting human health.

In the study, the mechanical method was successful in foaming the UF glue. The volume of the glue increased 2-3 times with the addition of foaming agents. Chemical foaming agents were also used in the foaming process of glue. However, these chemicals cause the release of different volatile organic compounds. The foaming process can be applied to many organic and inorganic materials. By reducing the density of foamed materials, it is ensured that they can be used more efficiently. In the wood sector, the highest cost is adhesives after the wood cost. More research is needed on the foaming issue.

V. CONCLUSION

In this study, UF resin was foamed using EW, BP, BA and SP and the foamed UF physical and mechanical characterization was carried out. In the foaming process, the biggest increase in volume was in BP, SP, EW and BA, respectively. The best adhesion was obtained from EW and BA samples. Foaming stability decreased after 7 days of waiting. foaming agents increased the gel time of the glue between 5-15 seconds. this increases the curing time of the glue and is not particularly desirable in composite board production. All foaming agents reduced the amount of water uptake of the glue. improved the physical properties of the glue. The mechanical properties were improved by the addition of EW and BA. The addition of SP and BP decreased the adhesion strength.

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