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## **Process Development of Lentil flour- based Adhesive for Woodworking Industries**

**Tin Sein**

### **Abstract**

The aim of this paper was to develop a quality wood adhesive from readily available renewable resource and to reduce significant amount of petroleum based phenol and formaldehyde with biomass. Quality wood adhesive was prepared on the basis of 15.15 % of defatted lentil flour, 59.4 % of phenol and 25.5 % of formaldehyde. The physicochemical properties of prepared adhesive were measured and compared with standard phenol formaldehyde adhesive. The prepared adhesive was applied successfully in plywood industries, parquet flooring and particleboard preparation. The prepared adhesive bonded 3-ply plywood has nearly the same shear strength as those of standard phenol formaldehyde (PF) and urea formaldehyde (UF) adhesives. A specific study was made on the preparation and physicochemical properties of various types of particleboards by using different raw materials, viz, sawdust (wood flour), coir (coconut fibre), straw fibre and bagasse, and 15% w/w of adhesive.

The produced particleboards were measured for their thickness, modulus of rupture, water absorption, density and hardness. Findings from these measurements indicated that the prepared adhesive do provide proper bonding of particleboard. The prepared adhesive has been used to produce particleboards having tensile strength (modulus of rupture) and water resistance values equal to those obtained using a standard PF adhesive. Thus, the lentil flour based phenol-formaldehyde adhesive is cost effective and can be used as good quality adhesive in plywood industry, parquet flooring and particleboard makings.

**Key words:** Defatted lentil flour, phenol, formaldehyde, adhesive, particleboards, plywood.

### **Introduction**

Wood is a basic material sustaining human living. It is widely used in interior decoration and in the furniture industries. As a result of human population growth, the demand for wood material increases rapidly with the forest product industry. Consequently, it is a key fact in efficient utilization of timber resource and adhesive bonding of wood components has played essential role in the development and growth of the forest products. In fact,



adhesives are required in many wood processing industries such as particleboards, wood panels, fiberboards and plywood etc. (Tiptipakorn, S., 2004). Interest in using biomass-derived adhesives has been strong for both environmental and cost considerations (Keimel, F.A., 2003). The cost of petroleum products has risen faster than many biomass sources, including some agricultural products. Leguminous flour can be substituted in glue compositions comprising aldehyde condensation resins such as phenol formaldehyde resin without loss of bond strength (Aldehyde Condensation of Leguminous flour). This study investigates the possibility of biomass-resources such as lentil flour to replace some part of synthetic resin. The quality assessment of prepared adhesive involves physicochemical and working properties including preparation of particleboards (Tang, J.L., 2001). The results are compared to those of standard phenol formaldehyde adhesive and urea-formaldehyde adhesive (from ply I) qualities. In developing countries, this information is valuable as the synthetic glues are expensive or not available at all, and furthermore, the raw material sources are abundant especially in Myanmar.

Lentil is included in the Leguminosae family. The botanical name of lentil is *len culinaris* Medic and the Myanmar name is Pe-wa-Lay. Lentil like the other cereal grains are grown in almost every part of upper Myanmar. The lentil seed contain 30% of crude protein, 12.4 % moisture, 59.7 % of starch, 0.7% of fat and 2.1% of mineral matter (calcium, sulphur, chlorine, bromine, phosphorus, iron, sodium, potassium and copper) (Muehlbauer, et al., 1985). Among the cold season legume crops, lentil is the richest in the important amino acids (lysine, arginine, leucine and sulphur containing amino acids) (Willams et al; 1994).

### Experimental

Defatted lentil flour 30 or 40 or 50 grams which contains 25% protein, 59.7% carbohydrates, 6% ash, 10% moisture was dissolved in approximately 50 cm<sup>3</sup> of distilled water, and mixed with 11 cm<sup>3</sup> of ammonia solution and 196 g of 90% phenol. Then they are mixed inside a three necked glass round bottom flask. A glass stir rod with a Teflon paddle was inserted in the vertical neck of the flask and connected to an overhead stirrer motor. A water-cooled condenser was inserted into one of the lateral neck on the flask, and an addition funnel was inserted in the remaining neck.

The physicochemical properties of prepared adhesive such as pH, viscosity, solid content, pot life, shelf life, specific gravity, and free formaldehyde content were measured and compared with standard phenol formaldehyde adhesive. The results are described in Table 1.

The wood veneers (150 mm × 150 mm) were dried in an oven at 100°C for 15 minutes. One veneer was used as a core layer and the two veneers were used as face and back veneers. The thicknesses of the core, face and back veneers were 2.4 mm, 1.2 mm and 1.2 mm, respectively. The surfaces were cleaned to be free from dust and oily substances. Prepared adhesives were carefully applied to the inner surfaces of face and back veneers and both surfaces of the core veneer. The veneers were then pressed by a hydraulic pressed machine for 5 min at pressures 2500 psi. The resulting plywood was 4.4 mm thick and 150 mm square 3 ply panel.

Sixteen blocks of teak (7 inch in length, 1.7 inch in width and 0.4 inch thick) were charged with prepared Adhesive (80 g) to make 14 inch square parquet flooring samples. Individual raw samples (Bagasse, Sawdust, coir (coconut fiber) and straw fiber) were grounded by grinding machine and screening to get the fiber with 1.2 cm in size. They were dried in oven at 70-100°C to get the samples with moisture content ≤ 10%. Fibers and prepared adhesive were thoroughly mixed by machine. Individual raw materials (120 g) and prepared Adhesive (36 g) were mixed by using Henschel mixer 5 minutes. The mixture was then laid in a mold. Care must be taken to get uniform surface layer in cold press section. Later, this mat was carefully transferred to the hydraulic press machine. The pressing process was performed at 2000 psi pressure for 15 minutes. The boards were kept dried at room temperature for 10 minutes and then the edges and both sides of the boards were polished with lacquer. The produced particleboards were measured for their thickness, modulus of rupture, water absorption, density and hardness. As control, various types of particleboard were prepared by bonding with standard PF resin. The result are presented in Table 3.

### **Results and Discussion**

In the present work, quality wood adhesives were prepared on the basis of defatted lentil flour, phenol and formaldehyde. Defatted lentil flour-based adhesive I, II and III were prepared on the basis of 9.67%,





Table 1. Physicomechanical properties of prepared defatted lentil flour based adhesives, standard phenol formaldehyde (PF) adhesive and urea formaldehyde (UF) adhesive (From ply I).

Physical Parameters	Lentil flour based Adhesive I	Lentil flour based Adhesive II	Lentil flour based Adhesive III	Standard Phenol formaldehyde (PF) adhesive	Urea formaldehyde (UF) adhesive
pH	8.9	8.6	8.1	9.8	6.7
Appearance	Pale red	Pale yellow	Pale	Reddish brown	White
Viscosity (cps)	859.6	2865	4378	733.049	136
Solid content (%)	43	45	51.2	50.14	53.1
Specific gravity ( $g/cm^3$ )	1.02	1.065	1.087	0.97	1.2
Shelf life (month)	>3	>3	>3	2	2
Pot Life (hr)	>24	>24	>24	8	10
Free formaldehyde(%)	0.23	0.19	0.12	0.65	2.16

Table 2. shows the comparison study on the physical strength of 3-ply plywood using different types of adhesive; viz, prepared adhesive III, standard phenol formaldehyde (PF) resin and urea formaldehyde (UF) resin (from ply I).

Table 2. Comparison study on the optimum physical properties of 3-ply plywood by using three types of adhesives

Physical	Type of adhesive	Flour-based Adhesive	PF Adhesive	UF Adhesive
Applied pressure (psi)		2200	2200	2200
Pressing time (min)		5	5	4
Temperature ( $^{\circ}C$ )		150	150	120
Mass (g) (6" $\times$ 6") overlap		7	7	7.4
Shear strength (1" $\times$ 1") overlap (psi)		407	418	347.6
Shear strength (1" $\times$ 1") overlap (psi) (cold water resistance)		200.2	213.4	134.2
Shear strength (psi) (hot water resistance)		81.4	147.4	0.0

The prepared lentil flour-based adhesive III was found to be successful in applying parquet flooring. The performance and appearance of parquet flooring was visually similar to that of commercially available adhesive.

Table 3. shows the comparison study on the physical properties of various particleboards by using prepared adhesive and phenol formaldehyde resin. Finding from these measurements indicated that the prepared adhesive do provide proper bonding of particleboard. The prepared adhesive has been used to produce particleboards having tensile strength (modulus of rupture) and water resistance values equal to those obtained using a standard PF adhesive.

**Table 3. Comparison study on the physical properties of particleboards using two types of adhesives.**

Items	Adhesive Types	Temperature (°C)	Pressure (psi)	Adhesive (%)	Thickness (cm)	Water Absorption (%)	Density (g cm <sup>-3</sup> )	Modulus of Rupture (lb/cm <sup>2</sup> )
Coir (Coconut fiber)	Prepared flour-based adhesive	150	2000	15	0.5	44.21	1.5	3226.78
	PF adhesive	150	2000	15	0.3	49.23	1.2	2360.43
Saw dust (wood flour)	Prepared flour-based adhesive	150	2000	15	0.45	46.21	1.25	667.25
	PF adhesive	150	2000	15	0.5	42.01	1.06	560.44
Straw fiber	Prepared flour-based Adhesive	150	2000	15	0.65	31.18	1.34	2752.75
	PF adhesive	150	2000	15	0.35	43.14	1.4	2360.13
Bagasse	Prepared flour-based Adhesive	150	2000	15	0.4	40.02	1.32	2632.71
	PF adhesive	150	2000	15	0.35	38.64	1.28	2465.85

## Conclusion

From the overall assessment of the present work, the following inferences may be deduced.

- A good quality wood adhesive based on lentil flour was prepared in 90% yield by using the optimum parameters: namely; defatted lentil flour (15.15%), phenol (59.4%), and formaldehyde (25.5%).
- The physicochemical properties of prepared adhesive III were measured and compared with standard phenol-formaldehyde adhesive. It was observed that pH (8.1, 9.8), viscosity (4378 cps, 733.049 cps); solid content (51.2%, 50.14%); pot life (> 24 hr; 8 hr); self life (> 3 month, 2 month); specific gravity ( $1.087 \text{ gcm}^{-3}$ ,  $0.97 \text{ gcm}^{-3}$ ); and free formaldehyde (0.12%, 0.65%), respectively.
- Thus, the prepared adhesive, with higher viscosity (4378 cps), longer shelf life (> 3 months) and low free formaldehyde (0.12%), is superior in adhesive property than the standard phenol-formaldehyde adhesive.
- The prepared adhesive was applied successfully in plywood industries, parquet flooring and particleboard making. The prepared adhesive bonded 3-ply plywood has nearly the same shear strength (407.0 psi) and cold water resistance (200.2 psi) as those of standard phenol-formaldehyde (PF) and urea-formaldehyde (UF) adhesives. The lap joint bonded with prepared adhesive did not delaminate and retained reasonably high shear strength (81.4 psi) after they experienced a boiling water treatment for 3 hours.
- A specific study was made on the preparation and physicochemical properties of various types of particleboard by using different raw material such as sawdust (wood flour), coir (coconut fiber), straw fibre and bagasse and 15% w/w of adhesive.
- The produced particleboards were measured for their thickness, modulus of rupture, water absorption, density and hardness. Finding from these measurements indicated that the prepared adhesive can effect proper bonding of particleboard. As control, various types of particleboard were prepared by bonding with standard PF resin. The prepared adhesive has been used to produce particleboards having high tensile strength (modulus of rupture) and water resistance value equal to those obtained using a standard PF adhesive.



- Thus the lentil flour based phenol-formaldehyde adhesive is cost effective and can be used as good quality adhesive in plywood industry, parquet flooring and particleboard making.

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