IJSAR, 3(2), 2016; 62-68

International Journal of Sciences & Applied Research

www.ijsar.in

Effect of Cassava flour as urea formaldehyde and phenol formaldehyde adhesive extender on the bond strength of plywood

Ranjana Yadav*

Indian Plywood Industries Research & Training Institute, Mohali, Punjab-160055, India.

Correspondence Address: *Ranjana Yadav, IPIRIT Centre, B-65, Phase 7, Industrial Area, Mohali, Punjab-160055, India.

Abstract

Extenders are added to an adhesive formulation to reduce resin utilization leading to cost saving. Cassava flour, which contains 98 percent starch, was tried as an extender for the manufacture of different grades of plywood. In this paper, Phenol Formaldehyde and Urea Formaldehyde resins were synthesized in the laboratory and cassava flour was added to the PF and UF resin in adhesive mixture formulation for exterior and interior plywood manufacturing using a laboratory press. Extender was incorporated in different percentage in the range of 5-25 weight percent of resin. Urea formaldehyde resin extended with 20 percent of resin gave satisfactory results for MR grade plywood confirming the relevant IS specification 848:2006. Conventional Phenol formaldehyde resin extended with 25 percent of resin gave satisfactory results for BWP grade plywood.

Keywords: Extender, Phenol formaldehyde resin, Urea formaldehyde resin, Knife test, Plywood

1. Introduction

Wood adhesive extenders are amylase compounds with some protein content that have adhesive action and contribute to the rheological properties of the glue mixture. The physical chemical properties of these extenders are very important to establish for instance, high ash, high crude fat and high fiber contents pose unpredictable viscosity problems and increase wash water requirement. Protein has been found to influence the water, taking capacity of flour (Robertson 1977, Robertson 1979).

An extender is a substance, generally having some adhesive action, added in limited quantity to synthetic resins to reduce the amount of primary binder required per unit area, thus reducing the cost of the glue line without impairing the quality of the bond. The three main requirements of an extender are (i) it should readily disperse in the liquid, giving a smooth and uniform glue mix which maintains its viscosity during its application; (ii) It should improve the bonding capacity of the glue and increase the pot life (iii) it should help to spread a specific quantity of glue solids.

In this study, we are using cassava flour as an extender for Phenol Formaldehyde and Urea Formaldehyde resin. Cassava (*Manihot esculenta*) belongs to the family euphoiaceae. It was cultivated throughout the tropical world for its tuberous roots from which cassava flour; breads, tapioca, laundry starch, alcohol and even an alcoholic beverage are derived. In 2010, the average yield of cassava crops worldwide was 12.5 tonnes per hectare. The most productive cassava farms in the world were in India, with a nationwide average yield of 34.8 tonnes per hectare in 2010 (FAO 2011). The genus has approximately 150 species. As the reserve food in plants, starch is a carbohydrate consisting of anhydroglucose units linked together primarily through alpha D (1-4) glucosidic bond (Wurzburg 1986). It is chemically similar to cellulose. Thus starch, which is a polymeric polyhydroxyl compound, can be modified to produce adhesive with excellent affinity to polar substrates like wood and paper. The abundance of hydroxyl groups imparts hydrophilic properties to starch. Cassava starch, therefore can be used to act both as an adhesive for wood and paper materials and as an extender in adhesive mixture for plywood production.

Narayanmurti and Ranganath (1943) showed casein could be used as an extender for cresol formaldehyde resin for bonding water resistance plywood. Narayanmurti *et al.* (1962) have shown that decayed wood flour could be incorporated into PF resin as an extender up to 100 percent and 200 percent different grades or plywood respectively. The authors also established the use of coconut shell flour and wall nut shell flour as filler and extenders for PF resin with satisfactory result and reduced the glue line cost considerably (1962).

Roy *et al* (1971) and Roy and Chandra (1971) showed that plywood of CWR, WWR, BWR, BWP grades could be made by blending UF and PF resin with casein.

Rangaraju *et al* (1972) showed that deoiled sal meal could be easily used as an extender with UF resin adhesive for the manufacture of tea-chest, CWR and WWR grades of plywood. Roy and Rajek (1973) developed an adhesive based on PF resin extending with wheat flour for making BWR grades of plywood.

Sumadiwangsa (1985, 1986) used sago flour exclusively and compared it with wheat flour. These experiments on sago flour revealed a poorer quality in bonding strength than that obtained using only wheat flour. Naraynaprasad *et al.* (1990) showed the use of gluten as an extender with PF and UF resin adhesive for the manufacture of different grades of plywood.

Sekyere *et al.* (2004) studied the cassava flour as an extender in liquid and powder UF resin adhesive mix for plywood manufacture in Ghana. Ferreira *et al.* (2009) evaluated the potentiality of babaçu flour under different percent (0%, 50%, 75%, and 100%) as alternative extenders to wheat flour for plywood manufacturing.

Fan *et al* (2010) studied the forestry residue sources oil tea cake (consisting of plant protein, tannin, carbohydrate compounds and tea saponin) is a major by-product from the pressing process of camellia (*Camellia Olifera Abel*) seeds.

Evangelista and Bean (2011) studied on sorghum flour as a protein extender in Phenol Formaldehyde based plywood adhesive for spray line counters or foam extrusion.

The search for alternative extenders for panel making has always been given more importance when there is price fluctuation in the usage of the existing extenders, As the cassava flour is found to be cheaper than Maida/GNCP, the presently being used extenders, there is a wide scope for the material usage by the plywood industries and keeping these points in view work was taken up in this study.

2. Materials and methods

2.1. Materials:

2.1.1. Species of wood veneers: Rotary cut veneers of thickness 1.6 mm from vellapine were used in this study.

2.1.2. Raw material: Phenol, Formalin, Caustic Soda, urea, acetic acid and cassava flour.

Cassava flour was procured for studies to be used as an extender for UF and PF resin adhesive to bond MR and BWP grades of plywood. Analysis of cassava flour extender is given in Table 1:

Table 1: Analysis of cassava flour.

S.N.	Particular	Percentage
1	Moisture content, %	13-14
2	Ash content, %	0.3
3	Starch content, %	98
4	Protein, %	0.3
5	pH of 10% solution	5-6

2.2. Experiment:

2.2.1. Synthetic Resins:

Urea formaldehyde and Phenol formaldehyde resins were used in the experiments to assess the performance of cassava as an extender for bonding different grades of plywood.

2.2.1.1. Preparation of PF resin:

Phenol formaldehyde resin was synthesized with a weight ratio of 1:1.8 of phenol-to-formaldehyde using a base catalyst such as sodium hydroxide. 6 percent catalyst based on phenol was dissolved in 12 percent of water. Phenol was taken in three necked round bottom flask fitted with a condenser and mechanical stirrer. Formaldehyde (37%) solution was added to the phenol through a dropping funnel along with catalyst. Condensation reaction was carried out a temperature of 85±2^{0}C for 60-90 minute till the water tolerance of the resin in hot condition was in the range of 1:12±2 and flow time of the reaction product when measured in B_4 flow cup of IS:3944-1982 was found 14-16 sec. At this stage resin was cooled to ambient temperature. Properties of resin were given in Table 2.

Table 2: Properties of PF resin.

S.N.	Properties	Value
1	Flow time (Sec) in hot condition	14.65
2	Flow time (Sec) in cold condition	18.18
3	pH	10.90 at 29.8^{o}C
4	Solid content (%)	49
5	Water tolerance	1:16

2.2.1.1.1. PF resin adhesive formulation:

PF resin prepared in the laboratory was used in formulating adhesive by incorporating with different percentage of cassava flour, ranging from 5-25 percent of weight of liquid resin of 49 percent solids. Requisite quantities of water together with a small percentage of sodium hydroxide dissolved in water were added to the adhesive mix in order to get a spreadable consistency for the resin adhesive. Detailed formulation are given in Table 3 of adhesive with respect to the proportion of PF resin, percentage of extender, quantity of water added together with sodium hydroxide, flow time of adhesive mix, PF resin concentration in the adhesive mix, adhesive spread.

Table 3: PF resin adhesive formulation.

S.N.	PF resin liquid pts. by wt.	Extender pts. by wt.	Water pts. by wt.	NaOH pts. by wt.	Flow time in B6 flow cup of IS:3944, Sec	Adhesive spread, kg/m^2	pH of Adhesive mix
1	100	5	-	-	7.6	0.365	9.8
2	100	10	-	-	8.9	0.365	9.6
3	100	15	5	0.75	10.4	0.365	9.6
4	100	20	6	1.0	10.7	0.365	9.5
5	100	25	8	1.25	10.9	0.365	9.5

2.2.1.1.2. Method of adhesive mixing of PF resin:

PF liquid resin of 49 percent solids was initially taken in the beaker fitted with a mechanical stirrer, to this extender was gradually added while stirring and stirring continued for approximates 20 minutes in order to get the homogenous adhesive mix. Finally calculated quantity of sodium hydroxide dissolved in knowing the quantity of water was added in order to get an adhesive mix of spreadable consistency.

2.2.1.2. Preparation of UF liquid resin:

Urea formaldehyde resin was synthesized with a weight ratio of 1:2.3 of urea to formaldehyde using an alkaline catalyst sodium hydroxide in Ist stage and acetic acid in second step. Known quantity of formalin was taken into three necked round bottom flask fitted with a condenser and mechanical stirrer. pH of the formalin was raised to 7.5-8 by adding 33% sodium hydroxide solution. To this 90% first urea was added to the round bottom flask containing formalin and stirred continuously till the process of resinification was completed. The pH of the final reactant mixture was maintained around 7.5-8. The reactant mixture is heated and condensed at 90±2^{0}C for about 90 minutes. pH of the reaction product was then lowered to 4.5-5 by adding an aqueous solution of acetic acid and condensed at until the precipitate is formed when a drop of resin is poured into beaker contained in water and flow time of reaction product when measured in B4 flow cup of IS:3944 was around 15-16 sec in hot condition. pH then raises to 7.5-8 by adding aqueous sodium hydroxide. The remaining second urea of 10% was added and the resin is cooled to room temperature. The properties of resin were given in Table 4.

2.2.1.2.1. UF resin adhesive formulation:

Adhesive formulation by using different percentage of cassava four in the range of 5-25 percent on the weight of urea formaldehyde resin. Table 5 gives the details of adhesive formulation employed with a respect to the proportion of UF resin, the percentage of the extender, flow time of adhesive mix, adhesive spread.

Table 4: Properties of UF resin.

S.N.	Properties	Value
1	Flow time of resin (Sec) in hot condition	14.82
2	Flow time (Sec) in cold condition	22
3	Gelation time at 25^{0}C	125
4	Gelation time at 100^{0}C	68
5	pH of the resin	7.7
6	pH of the resin with 1.5% NH_4Cl	5.6
7	Solid content (%)	50.8
8	Water tolerance	1:1.45

2.2.1.2.2. Method of adhesive mixing of UF resin:

UF resin was mixed with the requisite quantities of water along with extender and other additive like buffers, fortifier and hardener and mixed with the help of a mechanical stirrer in order to get homogenous adhesive. Time taken for the preparation of adhesive was around 20-25 minutes.

2.3. Plywood manufacture:

In the laboratory experiments, 1.6 mm thick vellapine veneers of size 0.33 X 0.33 m^2 were used for the making 3 ply plywood. In the laboratory scale studies, veneers were brushed coated. Four plywood panels were made with each adhesive formulation for evaluation. Various conditions employed for different grade plywood.

2.3.1. Plywood bonder for UF resin adhesive for MR grade plywood:

The adhesive mix prepared with UF resin was used for the making MR grade plywood and conditions adopted for the manufacture of plywood are given below.
Species of veneer used: vellapine
Size of veneer: 33cmx 33 cm
Thickness of veneer: 1.6 mm
Moisture content of veneer: 8-10%
Hot press temperature: 110^0C
Specific pressure: 12 kg/cm^2
Hot press time: 4 minutes for 3 ply 4 mm thick plywood
Plywood panels were conditioned and tested for conformity to MR grade plywood.

2.3.2. Plywood bonder for PF resin adhesive for BWP grade plywood:

The adhesive prepared by using a PF liquid resin incorporated with different proportion of cassava flour was spread uniformly on the veneers and hot pressed various condition employed for the manufacture of plywood were as follows:
Species of veneer used: vellapine
Size of veneer: 33cmx 33 cm
Thickness of veneer: 1.6 mm
Moisture content of veneer: 6-8%
Hot press temperature: 140-145^0C
Specific pressure: 14 kg/cm^2
Hot press time: 7 minutes for 3 ply 4 mm thick plywood
Plywood panels were conditioned and tested for conformity to BWP grade plywood.

3. Results and discussion

Result of test carried out on plywood panels bonded with liquid UF and PF resin extended with different percentage (ranging between 5-25%) are given in Table 6 indicate both UF and PF gives the satisfactory results.

As we can see from Table 6 plywood panels bonded to PF resin adhesive for BWP grades of plywood, it may me said that it is advisable to employ PF resin incorporated with a small proportion of the extender, without filler, as it is well established, most of the resin may get absorbed into porous wood laving inadequate quantity of resin in the glue line which was indicated by the higher proportion of wood failure and resin penetration on plywood surface.

From the Table 6 it is also clear that cassava flour extended UF resin for MR grade have good strength properties. Wood failure of cassava extended PF and UF resin adhesive bond was found good, confirmed by IS 848:2006. BWP grade confirmed by continuous six cycles and each cycle consist of 8 h boiling in water and thereafter drying at 65±2^0C for 16 h and adhesive that no separation of plies at the edges or surface of the end of six cycles. MR grade confirmed by continue three cycles and in that each cycle consists of 3 h heating at 60^0C in water and thereafter drying at 65±2^0C for 8 h and adhesive that no separation of plies at the edges or surface of the end of cycles. The effect of different glue composition on the average wood failure of the plywood was represented in Table 6. It is clear from the result that phenol formaldehyde and urea formaldehyde extended resin adhesive with cassava flour are suitable for producing BWP and MR grade plywood.

4. Conclusion

Based on the experimental results, following are the merits and limitations of the use of cassava flour as an extender for PF and UF resin for bonding the BWP and MR grade.

- It is recommended to incorporate a small proportion of extender in order to get better bond quality of PF and UF bonded plywood.
- Starch extender requiring a less quantity of water in the adhesive formulation performs better bonding.
- Up to 25% level of resin gave satisfactory results.
- Starch based extender are comparatively cheaper than other extender.
- Cassava flour can be alternate extender suitable for both PF and UF resins to bond BWP and MR grades of plywood.

Table 5: UF resin adhesive formulation.

S.N.	UF resin liquid pts. by wt.	Extender pts. by wt.	Water pts. by wt.	Hardener pts. by wt.	Liq. NH_3 pts. by wt.	Melamine pts. by wt.	Flow time in B6 flow cup of IS:3944, Sec	Adhesive spread, kg/m2	pH of Adhesive mix
1	100	5	5	0.5	1	2.5	7.8	0.340	6
2	100	10	10	0.5	1	2.5	8.5	0.345	6.5
3	100	15	15	0.5	1	2.5	9.0	0.345	6.2
4	100	20	20	0.5	1	2.5	10.0	0.350	6.2
5	100	25	25	0.5	1	2.5	10.6	0.355	6.3

Table 6: Properties of plywood panel.

S.N.	Knife test	Criteria for conformity	Extender percentage (%)				
			5	**10**	**15**	**20**	**25**
1.	**BWP GRADE (Boiling Water Proof)** Six cycles : Each cycle consisting of 8 hours boiling in water and thereafter drying at 65 ± 20C for 16 hours	No separation of plies at the edges and/or surface at the end of six cycles. On forcible separation of plies with knife, wood failure shall be predominant and shall be more than 75% for excellent bond and not less than 50% of pass standard. For less than 50% wood failure, the specimen shall be considered as failed	90	85	85	85	80
2.	**MR GRADE (Moisture Resistant)** Three cycles : Each cycle consisting of 3 hours at 60 ± 20C in water and thereafter drying at 65 ± 20C for 8 hours	No separation of plies at the edges and/or surface at the end of three cycles. On forcible separation of plies with knife, wood failure shall be predominant and shall be more than 75% for excellent bond and not less than 50% of pass standard. For less than 50% wood failure, the specimen shall be considered as failed	65	60	60	55	55

- Coverage obtainable with UF resin extended with cassava flour is similar to the commonly used extender which is used in the industry for the manufacture of MR grade plywood.

5. References

Bureau of Indian Standards IS 848: 2006: Specification for synthetic resin adhesive (Phenolic and amino plastic).

Evangelista Mila, P. Hojilla, Scott, R. Bean, 2011. Evaluation of sorghum flour as extender in plywood adhesive for spray line coaters or foam extrusion. Indust. Crops & Prod. 34, 1168-1172.

Fan, Dong-bin, Qin, Te-fu, Wang, Chun-Peng, Chu, Fu-Xiang, 2010. Evaluation of forestry residue source oil tea cake as an extender for phenol formaldehyde plywood adhesive. Fore. Produ. J. 60, 610-614.

"FAOSTAT: Production, Crops, Cassava, 2010 data". 2011. Food and Agriculture Organization.

Ferreira, E. da S., Brito, E.O., Iwakin, S., Rosso, S., Batista, D.C., 2009. Use of babacu flour as alternative extender for plywood manufacturing. Ciencia Florestal 193, 327-331.

Narayanmurti, D., Ranganathan, V., 1943. A preliminary note on cresol- formaldehyde and cresol casein formaldehyde adhesive for plywood. Indian forester leaflet No.97.

Narayanmurti, D., George, J., Das, N.R., 1962. Decayed wood flour as an extender for phenol formaldehyde resin and adhesive. Current Sci. 31, 379.

Naraynaprasad, T.R., Mohandas. K.K., Zoolagud, S.S., 1990. A study on deoiled maize gluten as an extender for urea formaldehyde and phenol formaldehyde resins suitable for the manufacture of different grades of plywood. IPIRI Research Report No.46.

Rangaraju T. S., Zoolagud S. S. and Kumar R. N. (1972) Deoiled sal meal as an extender for UF resin adhesive for plywood. IPIRI Journal 2(2), 49-53.

Robertson, J.E., Robertson, R.R., 1977. Review of filler and extender quality evaluation. Fore. Prod. J. 27, 30-38.

Robertson, J.E., Robertson, R.R., 1979. Filler and extenders in plywood production US and foreign practices. Fore. Prod. J. 28, 32-33.

Roy, D.C., Chandra, S.K., 1971. Casein blended urea and phenol formaldehyde resin adhesive for plywood. IPIRI Journal 1(1), 24-30.

Roy, D.C., Chandra, S.K., Chaudhary, S.K., 1971. Ground Nut Oil cake powder blended urea formaldehyde resin adhesive for plywood. IPIRI Journal 1(2), 49-55.

Roy D.C. and Rajek B.N. (1973) Co-condensed ground nut protein urea formaldehyde adhesive for plywood. IPIRI Journal 3 (1), 23-29.

Sekyere, D., DeGraft-Yartey, J., Derkyi, N.S.A., Darkwa, N.A., 2004. Optimization of industrial trial: the use of cassava flour as an extender in plywood adhesive mix for plywood manufacture. Forestry Research Institute of Ghana, Project Report 1-11.

Sumadiwangsa, S., 1985. Sago as an extender for urea-formaldehyde adhesive. J. Forestry Rese. & Develop. 1(2).

Sumadiwangsa, S., 1986. Mixture of wheat and sago flour as an extender for plywood adhesive. Forest Products Research Journal 3(4), Forest Products Research and Development Center. Bogor (In Indonesian).

Wurzburg, O.B., 1986. Introduction; In; Modified starches: Properties and uses, Wurzburg OB (Ed.), CRC Press, Boca Raton, USA, pp18-40.