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CASSAVA FLOUR-BASED WATERPROOF ADHESIVE FOR PLYWOOD MANUFACTURE

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ABSTRACT

The aim of this work was to substitute cassava flour, alocal material for imported wheat flour as extender in adhesive mix for plywood. And also to improve the water resistance of UF resin by adding locally extracted tannin, a phenolic compound to the UF resin.

Cassava flour from Atebubu and tannin extract from pine bark and prekese fruit were used with UF obtained from a local plywood mill for this work. The adhesive mixture processed were used to produce a 3-ply mixed hardwood plywood with an experimental press and the shear strength of the bonds tested on an INSTRON machine.

The results indicate that wheat flour can be replaced with cassava flour with no loss of shear strength. Tannin can also improve the water resistance of the glue bond but only slightly and at extended time of pressing.

INTRODUCTION

The aim of this portion of the project was the partial or complete replacement of wheat flour with cassava flour. And also to replace some of the U/F resin with tannin extracted from local sources. This has become necessary as a result of the cost of adhesive mixture in plywood production. It has been stated that the cost of adhesive mixture in plywood production is about 25%(Rajak, 1973). But in Ghana this cost is about 42.9% in the case of U/F resins and 60.7% in the case of P/F resin (personal comm.). Components of the mixture, which can be substituted easily in Ghana, are the extender and some of the urea. Cassava flour as has been reported can be used under different conditions to produce three types of adhesives suitable for three different products.

Wood glue extenders are amylose compounds with considerable protein content that have adhesive action and contribute to the rheological properties of the glue mix. The extender of choice is wheat flour, which is imported and therefore costly. Interest has been shown in the use of cassava flour, to replace wheat flour in the preparation of the glue mix.

It has also been said that the P/F resins produce better plywood than the U/F resins. But the P/F resins cost about twice that of the U/F resins. Thus 80-90% of the resins used in the country are of U/F type. In fact during our survey, only one mill has been using P/F resin and this is mostly for the export markets. Since tannins are phenolic in nature and have been used in adhesive preparation, it was thought that locally prepared tannins could be used to replace some of the Urea in U/F to improve its properties.

In this work, cassava flour was used as an extender in the preparation of urea-formaldehyde adhesives and tannin-urea-formaldehyde adhesives. Wheat flour was used as a control, whilst urea-formaldehyde and tannin-urea-formaldehyde without extenders were used as checks.

MATERIALS AND METHODS

The cassava flour for this portion of the work was obtained from Atebubu area. The U/F was obtained from LLL and OMEGA Company and ammonium chloride was used as hardener. Formalin was used as preservative.

Formulation of Urea-Formaldehyde adhesive

Water was added to powdered urea-formaldehyde glue to form a 64% solution. This was thoroughly mixed. Cassava flour and wheat flour were separately added as extenders. Tables 1 and 2 show the two glue mixes prepared at different glue extensions.

Table 1: Glue mix of UF with cassava flour at different extensions.

COMPONENT	PARTS BY WEIGHT EXTENSION			
	CE1	CE2	CE3	CE4
UF Solution	100	100	100	100
Cassava flour	10	15	20	30
Water	13	19.5	26	39

Table 2: Glue mix of UF with wheat flour at different extensions.

COMPONENT	PARTS BY WEIGHT EXTENSION			
	WE1	WE2	WE3	WE4
UF Solution	100	100	100	100
Wheat flour	10	15	20	30
Water	13	19.5	26	39

Preparation of Tannin Solution

The bark of *Pinus radiata* was collected and chopped into smaller pieces and boiled for several hours until the infusion had a deep colour. The infusion was sieved through a mesh and then dried in the oven.

Similarly, *Tetrapleura tetraptera* fruits were collected and the pulp chopped into smaller pieces and boiled for several hours until the infusion had a deep colour. The infusion was sieved through a mesh and then dried in the oven.

The pinus extract and the tetrapleura extract were mixed in the ratio 2:3. Fifty- three grams of water was added to 47g of the mixture to form 100g of tannin solution. The pH of the solution was adjusted to 6.4 using sodium hydroxide solution.

Formulation of Tannin-Urea-Formaldehyde Adhesive

30 parts by weight of formaldehyde was added to 100 parts by weight of the tannin solution, the pH was adjusted to 6.4 and the solution heated at 65°C for 1hour. The solution was cooled to room temperature and 10 parts by weight of powdered urea-formaldehyde glue added and thoroughly mixed. Cassava flour and wheat flour were separately used as extenders. Tables 3 and 4 show the two glue mixes prepared at different glue extensions.

Table 3: Glue mix of TUF with cassava flour at different extensions.

COMPONENT	PARTS BY WEIGHT EXTENSION			
	TCE1	TCE2	TCE3	TCE4
Tannin Solution	100	100	100	100
Formaldehyde	30	30	30	30
UF Powder	10	10	10	10
Cassava flour	10	15	20	30
Water	-	7	10.5	14

Table 4: Glue mix of TUF with wheat flour at different extensions.

COMPONENT	PARTS BY WEIGHT EXTENSION			
	TWE1	TWE2	TWE3	TWE4
Tannin Solution	100	100	100	100
Formaldehyde	30	30	30	30
UF Powder	10	10	10	10
Wheat flour	10	15	20	30
Water	-	7	10.5	14

Preparation of the test samples

Three-ply plywood was prepared using veneer sheets of dimensions 30cm X 30cm X 3mm from Otie as face and back and Ceiba as core. Twenty- five grams of adhesive mixture were used on each face to bond the sheets. The three-sheet plywood was sandwiched between two metal sheets and placed in the opening of manual operated laboratory press. The plywood was then pressed at a temperature of 120oC and pressure of 10kg/cm2. Pressing time was varied at 6, 7 and 8mins to obtain plywood of 9.2mm thickness.

Testing of plywood samples

The samples were prepared in accordance with ISO standard procedure and were tested using an INSTRON machine with speed of 1mm/min (Position) and 1KN/min (Load). Five samples of each adhesive mixture were tested.

The samples were tested dry, wet and cyclic boiled. In the wet testing, the samples were soaked 24hours in water before testing. Cyclic treatment (CBR), the samples were submerged in boiling water for 4hrs, dried at 60oC for 20hrs in an oven. The samples were submerged in boiling water again for 4hrs and finally placed in cold water for three days before testing.

RESULTS AND DISCUSSIONS

Table 5 shows the results of the formulation trials prepared. The results indicate that the modified UF with tannin mixtures had lower solids and viscosities but higher pH and pot life.

Table 5: Characteristics of the various adhesive mix prepared using UF and Tannin with both cassava and starch.

Adhesive Mix	PH	Viscosity (cP)	Pot Life (hours)	Solids Content (%)
C E	5.8	3100 – 3240	4 – 6	60
W E	5.8	3160 – 3300	4 – 6	60
T C E	6.2	2600 – 2760	5 – 8	56
T W E	6.2	2600 – 2710	5 – 8	56
TUF	6.4	2750	6 - 8	56
U F	5.9	3400	5 - 6	60

UF = Urea formaldehyde adhesive
CE = Urea formaldehyde adhesive with cassava extension
WE = Urea formaldehyde adhesive with wheat extension
TCE = Tannin-Urea formaldehyde adhesive with cassava extension
TWE = Tannin-Urea formaldehyde adhesive with wheat extension
TUF = Tannin-Urea formaldehyde adhesive

The ISO standard states that for mixed species hardwood and single species hardwood plywood, the shear strength should be above 0.8 and 1.0Mpa respectively. Thus from Table 6, except for sample T all the samples gave satisfactory result in the dry treatments at all the pressing times. However with the wet treatment only three samples: CE-3 at 8minutes, WE-3 at 8minutes and TCE-3 at 8minutes from Table 7 gave results above 0.8Mpa, with TCE-3 at 8minutes giving the highest figure. This is to be expected, since the tannin addition is to increase the plywood-bonding capability in water.

In the CBR treatment, the standard states that if two or more of the samples delaminate then the resin is not suitable for exterior treatment. In this case all the samples delaminated after the treatment.

Table 6: Average shear strength of 9.2mm plywood samples after dry treatment.

Type Of Adhesive	Average Shear Strength (Mpa)					
	6		7		8	
CE-1	1.377	(0.354)	1.391	(0.307)	1.559	(0.568)
CE-2	1.025	(0.429)	1.19	(0.122)	1.91	(0.260)
CE-3	1.601	(0.249)	1.59	(0.138)	1.667	(0.282)
E	1.179	(0.410)	1.669	(0.235)	1.172	(0.453)
C4	1.338	(0.244)	1.431	(0.174)	1.917	(0.141)
C5	1.263	(0.095)	0.922	(0.174)	1.085	(0.162)
CO	1.636	(0.136)	1.674	(0.154)	1.678	(0.086)
W5	0.95	(0.023)	1.137	(0.216)	1.099	(0.185)
WO	1.095	(0.138)	1.338	(0.249)	1.261	(0.170)
WE-3	1.464	(0.139)	1.632	(0.207)	1.688	(0.127)
WE-2	0	0.000	1.281	(0.275)	1.443	(0.311)
WE-1	1.149	(0.229)	2.075	(0.383)	1.51	(0.118)
T	0.635	(0.032)	0.46	(0.241)	0.607	(0.066)
TCE-2	1.291	0.108	1.305	(0.153)	1.151	(0.263)
TCE-4	1.025	(0.184)	1.326	(0.272)	1.459	(0.239)
TCE-3	1.289	(0.272)	1.118	(0.245)	1.127	(0.261)
TWE-5	1.3	(0.253)	1.319	(0.199)	1.363	(0.277)
TWE-1	0	0.000	1.158	(0.412)	0.959	(0.225)
TWE-2	1.452	(0.159)	1.317	(0.211)	1.083	(0.364)
TWE-4	1.347	(0.233)	0.864	(0.113)	0.976	(0.190)

Table 7 Average shear strength of 9.2mm plywood samples after cold soaked treatment.

Type Of Adhesive	Average Shear Strength (Mpa)					
	6		7		8	
CE-1	0.105	0.066	0.029	(0.015)	0.047	(0.012)
CE-3	0.64	(0.065)	0.768	(0.280)	1.032	(0.160)
CO	0.662	(0.084)	0.901	(0.102)	0.36	(0.130)
C5	0.439	(0.324)	0.672	(0.117)	0.289	(0.159)
C4	0.436	(0.098)	0.46	(0.119)	0.549	(0.116)
E1	0.105	0.000	0.271	(0.081)	0.173	(0.097)
WE-1	0.058	0.000	0.047	0.000	0	0.000
WE-2	0.023	0.000	0.315	0.000	0.012	0.000
WE-3	0.43	(0.142)	0.6	(0.259)	0.838	(0.300)
W5	0.441	(0.284)	0.257	(0.183)	0.257	(0.135)
TWE-5	0.598	(0.152)	0.285	(0.077)	0.766	(0.179)
TWE-1	0	0.000	0.233	0.000	0.163	(0.083)
TWE-2	0.609	(0.105)	0.341	(0.078)	0.89	(0.034)
TWE-4	0.397	(0.108)	0.343	(0.156)	0.225	(0.063)
TCE-3	0.368	(0.093)	0.301	(0.091)	1.127	(0.261)
TCE-4	0.268	(0.071)	0.468	(0.109)	0.31	(0.140)
TCE-2	0	0.000	0.429	(0.085)	0.198	

Note: Figures in brackets denote standard deviation.

CONCLUSION

The results of this project indicate that:

i. Cassava flour can be used as a substitute for wheat flour as extender in UF resin for plywood,

ii. That 25% of the UF can also be substitute by tannin locally extracted from pines and prekese woods and

iii. That pressing time should be more than 8minutes to achieve some water resistance.