Use of cassava flour in paperboard adhesives

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Abstract

This study outlines preliminary investigations conducted to assess the suitability of cassava flour as a raw material for the formulation of paperboard adhesives. The effects of different levels of sodium hydroxide and borax on the viscosity and pasting temperature of cassava flour were studied with respect to liquid Bauer-type and dry powder adhesives. The results obtained were compared with those of a corn starch-based paperboard adhesive (dry powder type) currently in use in some Ghanaian industries. Sodium hydroxide significantly affected ($p<0.01$) the Steinhall viscosity of the cassava flour, but borax did not have any significant effect. The Steinhall viscosity correlated very well ($r>0.9$) with the sodium hydroxide levels. Levels of sodium hydroxide of between 2.0 and 3.0 g per 100g flour in combination with borax levels of 0-2 g per 100 g of flour, gave results comparable to the corn starch-based adhesive. For the dry powder formulations, the Brabender viscosity of the cassava flour increased as the levels of borax increased. There was no correlation between pasting temperature and level of borax. The adhesive formulation with 0.05 g of borax per 100g cassava flour produced an adhesive most comparable to that made from corn starch. Industrial trials using the cassava flour-based adhesive produced boards with acceptable bond quality. The results confirm the great potential that there is for producing paperboard adhesives from cassava flour. Adoption of cassava-based adhesives would help in expanding the market for the crop.

Keywords: Cassava flour, adhesives, paperboard

Introduction

The lack of market outlets for cassava was identified in needs assessment studies in Ghana in 1994 (Kleih et al. 1994); and the need to add value to cassava and improve producer prices was highlighted. This, it was envisaged, could be achieved through adaptive research and technology transfer activities targeted at improving marketing opportunities for processed cassava products such as starch, flour and dried chips.

Previous strategic research demonstrated that cassava starches and flours are potential substitutes for wheat and maize-based starches and flours (Rickard et al. 1991; Tian et al. 1991). The next logical step was therefore to build on the past research work by placing greater emphasis on the requirements of end users, market demands, industrial specifications for quality and functional properties and the development of technologies with potential for wider commercial uptake and dissemination.

A survey of the market for starches and flours in Ghana (Graffham et al. 1998) found that the current market for starch is approximately 5,000 tons per annum. Current uses include textiles (40%), plywood (27%), pharmaceuticals (20%), paper (10%) and food (3%). The market for flour is dominated by imported wheat flour (250,000 tons/annum) which is mainly used by bakeries, but about 1,200 tons per annum are used by the plywood industry. A preliminary technical and economic evaluation indicated a potential for locally produced cassava flour to substitute for imported materials in the areas of plywood glue extenders, paperboard adhesives and as partial substitutes for wheat flour in a range of snack foods (Graffham et al. 2000). The exploitation of these outlets offers the potential to improve the livelihoods of producers, primary processors and end-users of flours and starches.

Adhesives for paperboard manufacture have traditionally been prepared from corn starch or corn dextrin and other corn starch derivatives (Casey 1983). This choice has been principally based on availability, but the higher viscosity of the cooked corn starch tended to make it more favoured than cassava starch. However the low gelatinisation temperatures of cassava starch and flour enhances their potential as substitutes for corn starch, but it will be necessary to increase the viscosity to an appreciably higher level. Sodium hydroxide and borax are normally used to modify the pasting temperature and viscosity, respectively, of starch used in the manufacture of

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paperboard adhesives (Casey 1983). Two types of adhesives are known to be in use in the industry – the liquid Bauer-type adhesives and the solid dry powder adhesives.

This study was designed with three objectives: (a) to investigate the effects of sodium hydroxide and borax on the pasting temperature and viscosity of cassava flour; (b) to appropriately modify cassava flour for use as an adhesive for paperboard manufacture; and (c) to evaluate in collaboration with potential end-users the suitability of the modified cassava flour (either alone or blended with imported adhesive) for use in paperboard manufacture. The lower production costs of cassava flour as compared with cassava starch makes it a more likely choice as a substitute for the imported adhesive and is therefore the focus of this study.

Materials and methods

Flour production

Freshly harvested cassava roots were peeled, washed and mechanically grated. The grated mash was partially dehydrated in a screw press and dried in an electric hot air cabinet dryer at 69°C for 14 hours. The dried grated material was milled in a disc attrition mill and sieved with a 250μ sieve.

Formulation of liquid (Bauer-type) adhesive

The liquid Bauer-type adhesives were formulated by preparing a slurry containing 25.7% (w/v) of cassava flour and varying levels of sodium hydroxide (NaOH) and borax in water. The levels of NaOH and borax were calculated in percentages as the weight of each additive per unit weight of cassava flour used in the formulation. The required amount of flour was initially mixed with 50ml of water followed by the addition of the sodium hydroxide solution and then the solution of borax. Finally an amount of water was added to make up a suspension of the desired composition. The levels of NaOH used were 0%, 1.0%, 1.5%, 2.0%, 2.5% and 3% whilst those of the borax were 0%, 2.0%, 2.2%, 2.4%, and 2.6%. The compositions of the various formulations made are shown in Table 1. The Steinhall viscosity of the different formulations was measured and compared with that of a suspension of an imported dry powder adhesive (Rouquette 120 supplied by Rouquette, France).

Formulation of dry powder adhesive

Varying levels of borax were added to cassava flour and thoroughly mixed in a blender. The levels of borax used were 0.1%, 1.0%, 1.2%, 1.4%, 1.6%, 1.8%, 2.0%, and 2.2% (of the weight of the cassava f lour) for the initial trials. The exact quantities used are shown in Table 2. The pasting characteristics of the different mixes were measured using 8% suspensions and compared with those of Rouquette 120. On the basis of the results obtained, selected borax-modified cassava flours were then blended with the imported adhesive in ratios of 3:1, 1:1 and 1:3, to study the extent to which the pasting characteristics were affected. In view of the high viscosities obtained for the previous formulations, another set of adhesive formulations were prepared using lower levels of borax (0.05% and 0.1%) and a lower concentration (6%) of adhesive suspension was used for the assessment of the pasting characteristics.

Table 1. Composition of liquid adhesive formulations from cassava flour

Adhesive Formulation		Composition			
% Borax	% NaOH	Weight of Cassava Flour (g)	Volume of 0.025g/ml Borax Solution (ml.)	Volume of 0.05g/ml NaOH Solution (ml.)	Volume of Water (ml)
0	0	25.7	0	0	100
0	1	25.7	0	5.1	94.9
0	1.5	25.7	0	7.7	92.3
0	2	25.7	0	10.2	89.8
0	2.5	25.7	0	12.8	87.2
0	3	25.7	0	15.4	84.6
2	0	25.7	20.4	0	79.6
2	1	25.7	20.4	5.1	74.5
2	1.5	25.7	20.4	7.7	71.9
2	2	25.7	20.4	10.2	69.4
2	2.5	25.7	20.4	12.8	66.8
2	3	25.7	20.4	15.4	64.2
2.2	0	25.7	22.8	0	77.2
2.2	1	25.7	22.8	5.1	72.1
2.2	1.5	25.7	22.8	7.7	69.5
2.2	2	25.7	22.8	10.2	67
2.2	2.5	25.7	22.8	12.8	64.4
2.2	3	25.7	22.8	15.4	61.8
2.4	0	25.7	24.8	0	75.2
2.4	1	25.7	24.8	5.1	70.1
2.4	1.5	25.7	24.8	7.7	67.5
2.4	2	25.7	24.8	10.2	65
2.4	2.5	25.7	24.8	12.8	62.4
2.4	3	25.7	24.8	15.4	59.8
2.6	0	25.7	26.8	0	73.2
2.6	1	25.7	26.8	5.1	68.1
2.6	1.5	25.7	26.8	7.7	65.5
2.6	2	25.7	26.8	10.2	63.0
2.6	2.5	25.7	26.8	12.8	60.4
2.6	3	25.7	26.8	15.4	57.8

Pasting characteristics

The AACC official method for Brabender Visoamylograph as described by Shuey and Tipples (1980) was used. A suspension of the sample (6% and 8% w/w) was made and poured into the Amylograph bowl. The stirrer was placed in the bowl and the head of the Amylograph moved into proper position. The starting temperature was adjusted to 25°C and the gear set to increase at 1.5°C per minute. The Amylograph bowl was set in motion and the viscosity recorded on a moving chart recorder, as the temperature increased from 25°C to 95°C. The following measurements were taken from the curves: pasting temperature, peak viscosity, temperature at the peak viscosity and viscosity at 95°C.

Steinhall viscosity measurement

One hundred milliliters (100 ml) of the adhesive was placed in a Steinhall cup viscometer with an orifice of 6mm diameter. The time taken for the glue mix to completely run through the orifice was measured as the Steinhall viscosity expressed in seconds

Industrial trials

Three hundred kilograms of cassava flour-based adhesive containing 0.05% borax was used by a paperboard manufacturing company for the production of corrugated cardboard boxes. The performance of the adhesive was assessed by the number of reject cardboard boxes from the production line.

Table 2. Composition of dry powder adhesive formulations from cassava flour

Adhesive Formulation (% Borax Content of Flour)	Composition	
	Wt. Of Cassava Flour (g)	Wt. Of Borax (g)
0	200	0
1.0	200	2.0
1.2	200	2.4
1.4	200	2.8
1.6	200	3.2
1.8	200	3.6
2.0	200	4.0
2.2	200	4.4

Results and discussion

The Steinhall viscosities of Bauer-type paperboard adhesive formulations using cassava flour and different levels of NaOH and borax are shown in Table 3. Coefficients of correlation between sodium hydroxide levels and Steinhall viscosities on one hand, and borax levels and Steinhall viscosities on the other, are also indicated. A very good correlation (r>0.9) is observed between the Steinhall viscosity of adhesive formulations and the level of NaOH in the adhesive mix. The variations in Steinhall viscosity with NaOH and borax levels are graphically shown in Figure 1. It can be seen from this figure that Steinhall viscosity increased with increase in NaOH levels. There was, however, no correlation between the borax levels and the Steinhall viscosity of the adhesive formulations. These observations indicate that the Steinhall viscosity is an adequate measure of the effects of NaOH on the viscosity of the adhesive formulation.

Table 3. Steinhall viscosity values for liquid formulations of cassava flour-based paperboard adhesive

Level of NaOH added	Steinhall viscosity values for specified levels of borax					Individual correlations between borax levels and Steinhall viscosity (r)
	0%	2.0%	2.2%	2.4%	2.6%	
0%	17	17	17	17	16	-0.40
1.0%	18	18	18	18	18	0
1.5%	19	20	19	21	20	0.58
2.0%	27	23	20	22	23	-0.84
2.5%	29	27	22	25	24	-0.78
3.0%	29	39	22	25	28	-0.14
Individual correlations between NaOH levels and steinhall viscosity (r)	0.91	0.87	0.97	0.96	0.97	
Overall correlation between NaOH levels and Steinhall viscosity (r)						0.94
Overall correlation between borax level and Steinhall viscosity (r)						-0.26

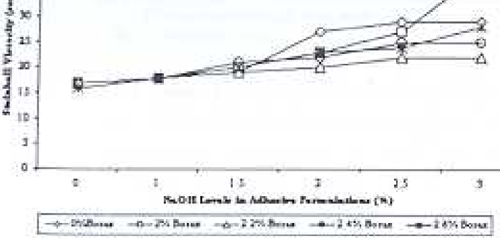

Fig.1.
Change in steinhall viscosities of cassava flour-based liquid adhesive formulations with different levels of sodium hydroxide and borax

Even though borax is the viscosity enhancer in the adhesive its effects are only evident when heat is applied (Casey 1983). However the dissolution of sodium hydroxide in water, being an exothermic reaction, tends to produce enough heat to partially gelatinise the flour in the cold. The results above indicate that it is the viscosity imparted by this partial gelatinisation that is actually being measured by the Steinhall Cup Viscometer. It is therefore understandable that the viscosity measured correlates with the sodium hydroxide levels rather than the borax levels. It is common practice in industry for Steinhall viscosity measurements to be used as an indicator of the quality of an adhesive mix. From the above results it is obvious that this measurement is more a measure of the sodium hydroxide effects in the adhesive rather than the expected viscosity effects of borax.

These observations are further confirmed by the fact that analysis of variance did not show any significant differences in the different levels of borax. However differences in Steinhall viscosities in relation to the levels of NaOH added were highly significant ($p<0.01$). Borax levels of 0-2 g per 100g flour in combination with NaOH levels of 2-3 g per 100 g flour gave viscosities comparable to that of the imported corn starch-based adhesive.

Table 4 shows the pasting characteristics of dry powder adhesive formulations containing different levels of borax.

Table 4. Pasting characteristics* of dry powder cassava flour-based adhesives containing different levels of borax

Level of Borax (%)	Gelatinisation Temp (°C)	Peak Viscosity (BU)	Peak Temperature (°C)	Viscosity at 95°C (BU)
0	62.9	464	69.5	325
1.0	65.0	695	77.0	455
1.2	65.6	706	77.0	455
1.4	63.8	762	71.9	430
1.6	64.4	795	73.4	443
1.8	68.9	800	77.6	485
2.0	66.5	852	75.5	460
2.2	64.4	922	74	464
Correlations between borax levels and pasting characteristics (r)	0.52	0.99	0.48	0.84

* 8% suspensions of adhesive were used
BU = Brabender Units

Correlations between the levels of borax and the different pasting parameters as shown in Table 4 indicate that the peak viscosity and the viscosity at 95°C gave the best correlations (r>0.80) with the borax levels. Comparing the variations in viscosity with borax level as shown in Figure 2, peak viscosity stands out as the best indicator for assessing the effects of borax on the viscosity of the adhesive formulations. Even though the addition of borax caused an increase in the gelatinisation temperature, the

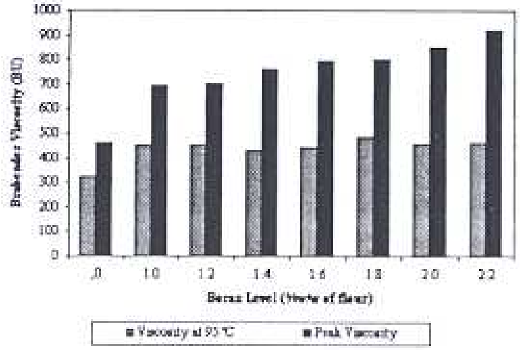

Fig. 2.
Change in brabender viscosity of cassava flour-based powdered adhesives with increasing levels of borax

increase was only slight and unlikely to affect the performance of the adhesive very much. From Table 4 it can be seen that at borax levels of between 1.6% and 2.0% the peak viscosity of the cassava flour-based adhesives compared favourably with that of the imported adhesive. The results in Table 6, however, show that the cassava flour-based adhesives containing 0.05% and 0.1% borax compared even more favourably with the imported adhesive.

Blending the cassava flour-based adhesives with the imported adhesive, produced mixes with much higher peak viscosities than either the imported corn starch-based adhesive or the cassava flour-based adhesive alone (Table 5). The difference between using 0.05% or 0.1% borax for

Table 5 Pasting characteristics* of blends of imported adhesive and dry powder cassava flour-based adhesive containing 1.0 – 2.2% borax

Type of Modified Flour/Adhesive	Ratio of Modified Flour to Imported Adhesive	Gelatinisation Temp. (°C)	Peak Viscosity (BU)	Peak Temperature (°C)	Viscosity at 95°C (BU)
Imported Adhesive (Rouquette 120)	0:1	62.0	820	71.9	385
Cassava Flour containing 2.2% Borax	3:1	69.5	1110	80.0	488
Cassava Flour containing 2.2% Borax	1:1	66.5	1120	77.0	408
Cassava Flour containing 2.2% Borax	1:3	63.5	1190	74.0	230
Cassava Flour containing 1.4% Borax	1:1	65.0	1160	74.0	270
Cassava Flour containing 1.0% Borax	3:1	63.5	865	75.5	435

* 8% suspensions of adhesive were used.
BU = Brabender Units

the cassava flour- based adhesive, either as a neat adhesive or as a blend with the imported one, was not very significant. This can be seen from the comparisons in Table 6. The lower level of borax was, however, considered preferable in terms of the economics of production.

Current trials involving the manufacture of corrugated cardboard boxes using cassava flour-based adhesives containing 0.05% borax gave very satis factory results. There were no rejects from the production line and the products were extremely satisfactory to the production manager who assisted in carrying out the trials. Further trials involving blends of the borax-modified cassava flour with the imported adhesive flour are to be carried out as a follow-up to the current trials.

Table 6 Pasting characteristics* of imported adhesive and dry powder cassava flour-based adhesive containing 0.05% and 0.1% borax

Type of Modified Flour/Adhesive	Ratio of Modified Flour to Imported Adhesive	Gelatinisation Temp (°C)	Peak Viscosity (BU)	Peak Temperature (°C)	Viscosity at 95°C (BU)
Imported Adhesive (Rouquette 120)	0:1	70.7	210	81.5	164
Cassava flour containing 0.1% borax	1:3	74.0	250	84.5	210
Cassava flour containing 0.1% borax	1:1	72.8	266	82.4	210
Cassava flour containing 0.1% borax	3:1	73.1	270	83.0	220
Cassava flour containing 0.1% borax	1:0	69.5	205	92.0	200
Cassava flour containing 0.05% borax.	1:3	72.2	228	84.2	218
Cassava flour containing 0.05% borax.	1:1	69.5	270	80.0	200
Cassava flour containing 0.05% borax.	3:1	72.5	225	83.0	220
Cassava flour containing 0.05% borax.	1:0	71.0	200	82.7	200

* 6% suspensions of adhesive were used.
BU – Brabender Units

Conclusion

From the results above, it may be concluded that for the liquid Bauer-type adhesive, NaOH affected the Steinhall viscosity of the adhesive formulation much more significantly than borax. The viscosity characteristics of the cassava flour-based liquid adhesive formulations containing 0-2 g per100g flour and 2-3 g per 100 g flour of borax and NaOH respectively, were comparable to that of the imported corn starch-based adhesive. The performance of the liquid adhesive formulations would however have to be assessed through industrial trials before any meaningful conclusions can be drawn. The dry powder adhesive formulated from cassava flour and borax has proved to be an acceptable substitute for imported corn starch-based paperboard adhesive. A borax level of 0.05% (w/w) is recommended.

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