



QUALITY CONTROL ANALYSIS OF LOCALLY PRODUCED WOOD ADHESIVE FOR INDUSTRIAL APPLICATION

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ABSTRACT: Wood adhesive are polymeric materials that are capable of interacting physically or chemically or both with the surface of wood in such a manner that stresses are transferred between bonded materials, hopefully without rupture of the adhesive or detachment of the adhesive from the wood. Wood adhesive is widely used especially for furniture workings. In this research work, the potential required quality of wood adhesive produced from cassava starch was investigated classically. These suitability tests of the produced adhesive were compared with commercial sample as a matter of standardization. The results showed that, the pH of the locally produced sample was higher (8.06 ± 0.00) than of that of the commercial sample (7.88 ± 0.00), making it alkaline. While, the commercial sample (1.07 ± 0.23) was more resistance to moisture than the produced one (0.73 ± 0.12) and the shelf life of the commercial sample was higher than that of the locally produced sample, from the moisture resistivity observed. Also the solid content of the commercial sample was higher (75.33 ± 3.06) than that of the produced sample (62.80 ± 2.49). Interestingly, the viscosity of the formulated was far higher (39.67 ± 0.58), than that of the commercial sample (28.67 ± 1.15). From these physico-chemical parameters, it can be concluded that the produced sample was a good alternative or substitute to the commercial sample, with improved innovative technology, cassava tuber can be put into optima used.

Keyword: Adhesive, Cassava, polymeric, Resistance, Starch, Wood

1.0 INTRODUCTION

The American Society for Testing and Materials (ASTM) defines an adhesive as a substance capable of holding materials together by surface attachment. An adherend is a substrate held to another substrate by an adhesive. Adhesion is the state in which two surfaces are held together by interfacial forces, which may be valence forces, interlocking action, or both (Cruz et al. 2005, ASTM. 1997).

Valence forces are forces of attraction produced by the interactions of atoms, ions, and molecules that exist within and at the surfaces of both adhesive and adherend. Interlocking action, also called mechanical bonding, means surfaces are held together by an adhesive that has penetrated the porous surface while it is liquid, then anchored itself during solidification. The extent to which valence forces and interlocking action develop between adhesive polymers and wood adherends is uncertain, but both are generally acknowledged as essential for the most effective bonding (Custodio, et al. 2006).

Bonding to porous surfaces, such as wood, paper, and textiles, was thought to be primarily mechanical, but now there is evidence supporting bonding by primary valence forces. In contrast, bonding to hard metal surfaces was believed to involve only valence forces, but this is no longer the accepted view. Metal surfaces roughened by chemical etching or made microscopically porous with a layer of durable bonds. Mechanical interlocking is probably the primary mechanism by which adhesives adhere oxide are capable of mechanical interlocking with an adhesive to produce exceptionally strong to porous structures such as wood (Custodio, et al. 2006).

Adhesives penetrate beyond the surface debris and damaged fibers into sound wood two to six cells deep. Deeper penetration into the fine microstructure increases the surface area of contact between adhesive and wood for more effective mechanical interlocking (Cruz et al. 2005, ASTM. 1997).

The most durable structural bonds to wood are believed to develop not only when an adhesive penetrates deeply into cell cavities, but also when an adhesive diffuses into cell walls to make molecular-level contact with the hemicellulosics and celluloses of wood. If an adhesive penetrates deeply enough into sound wood and becomes rigid enough upon curing, the strength of the bond can be expected to exceed the strength of the wood (Koning 2010, ASTM. 1997).

Physical forces of attraction composed of three intermolecular attraction forces are believed to be important to the formation of bonds between adhesive polymers and molecular structures of wood generally called van der Waal's forces, these include dipole–dipole forces, which are positively and negatively charged polar molecules that have strong attractions for other polar molecules; London forces, which include the weaker forces of attraction that nonpolar molecules have for each other; and hydrogen bonding, a special type of dipole– dipole force that accounts for strong attractions between positively charged hydrogen atoms of one polar molecule and the electronegative atom of another molecule (American Institute of Timber Construction 1992). Hydrogen bonding forces are important in the interfacial attraction of polar adhesive polymers for the hemicellulosics and celluloses, which are rich in polar hydroxyl groups. These physical forces of attraction, sometimes referred to as specific adhesion, are particularly important in wetting of water carriers and adsorption of adhesive polymers onto the molecular structures of wood. Covalent chemical bonds form when atoms of non-metals interact by sharing electrons to form molecules. The simplest example of a purely covalent bond is the sharing of electrons by two hydrogen atoms to form hydrogen. These covalent bonds are the strongest of chemical bonds; they are more than 11 times the strength of the hydrogen bond. Even though covalent chemical bonds between adhesive polymer and the molecular structure of wood seem a possibility, there is no clear evidence that such bonds constitute an important mechanism in adhesive bonding to wood (Pizzi et al. 2003, ASTM. 1997).

For two wood adherends to be held together with maximum strength, a liquid adhesive must wet and spread freely to make intimate contact with both surfaces. Molecules of the adhesive must diffuse over and into each surface to make contact with the molecular structure of wood so that intermolecular forces of attraction between adhesive and wood can become effective. Wood adherends, as well as other materials, differ widely in their attractive energies, bulk properties, surface roughness, and surface chemistry. Wood surfaces may appear to be smooth and flat, but on microscopic examination, they become peaks, valleys, and crevices, littered with loose fibers and other debris. Such surface conditions cause gas pockets and blockages that prevent complete wetting by the adhesive and introduce stress concentrations when the adhesive has cured. Thus, the liquid adhesive must have high wettability, coupled with a viscosity that will produce good capillary flow to penetrate sound wood structure, while displacing and absorbing air, water, and contaminants at the surface. Pressure is normally used to enhance wetting by forcing liquid adhesive to flow over the surfaces, displace air blockages, and penetrate to sound wood (Rowell 2013, ASTM. 1997).

Wetting of a surface occurs when the contact angle (the angle between the edge of a drop of adhesive and the surface of wood) approaches zero. The contact angle approaches zero when the surface has high attractive energy, the adhesive has an affinity for the adherend, and the surface tension of the adhesive is low. If a drop of adhesive spreads to a thin film approaching zero contact angle, the adhesive has spread well and made intimate contact with the surface (ASTM. 1997).

The process of adhesion is essentially after completed transition of the adhesive from liquid to solid form. After the viscosity of a liquid adhesive has increased and the adhesive has solidified to the point where the film effectively resists shear and tensile forces tending to separate the surfaces, the surfaces are effectively bonded. An adhesive film changes from liquid to solid form by one of three mechanisms, although two may be involved in some curing mechanisms. This transition can be a physical change as in thermoplastic adhesives or it can be a chemical change as in thermosetting adhesives. In thermoplastics, the physical change to solid form may occur by either loss of solvent from the adhesive through evaporation and diffusion into the wood, or cooling of molten adhesive on a cooler surface. In thermosets, the solid form occurs through chemical polymerization into cross-linked structures that resist softening on heating. Most thermosetting wood adhesives contain water as a carrier; therefore, water also must be evaporated and absorbed by the wood so that the adhesive can cure completely (Tonukari 2004, ASTM. 1997).

Cassava, is a relatively unknown crop in the old world before the discovery of America, it is fast assuming the status of the saviour of the world, as it is now grown throughout the tropical world. It is second now only to potato as the most important starchy root crop of the tropics used for food and industrial purposes. In Nigeria, it is consumed raw or cooked, used for the manufacture of garri, starch, flour and a variety of other items (Tonukari, 2004). The current drive towards earning foreign exchange from cassava products in Nigeria had raised more awareness on the importance of the crop. Most commercial wood adhesive contain chemicals that are toxic to people

if they are exposed to sufficient concentration for a long period. A notable exception is urea formaldehyde adhesive which can release low concentration of formaldehyde from bonded wood product under certain condition. Formaldehyde is a toxic gas that can react with the protein of the body to cause irritation, inflammation of membrane of eyes, nose and throat (Cruz et al. 2005).

However, the secondary product (cassava starch) from the product of garri (the most important food item from cassava in Nigeria) is not properly utilized in most processing industries. These products are just drained off without any thought for their utilization especially in the rural areas. It is in the light of this and the fact that this cassava is readily available that these studies will be conducted to investigate the possible utilization of cassava starch as a binding material (adhesive).

2.0 MATERIALS AND METHODOLOGY

3.1 Materials

3.1.1 Raw Materials

The raw material used for this production was cassava tuber

3.1.2 Apparatus

The following apparatus were used: Hot plate, Thermometer, stirrer, and Mucilin cloth

3.1.3 Sample Collection and Preparation

The cassava tuber used was obtained by market survey. It was peeled, washed and kept in a clean container, after which it was milled.

3.1.4 Reagents

The following reagent was used: Hydrochloric acid (HCl), Sodium tetra borate ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) and water.

3.2 Methodology

3.2.1 Wood Adhesive Production

The following steps were engaged in the production of wood adhesive using cassava tuber:

➤ **Starch Production**

cassava tuber was washed, peeled and grinded. After which it was pour in a Mucilin cloth and pressed, then the seepage was collected and allow to sediment. The sediment was then dried.

➤ **Wood Adhesive Production**

In the production process of wood adhesive, the same gram of cassava starch was experimented at different concentration of borate solution and temperature.

▪ **Experiment 1**

40g of the dry cassava starch was weighed and poured in 50ml of HCl, and heated on the hot plate at the temperature of 80°C with stirring. It was remove from the hot plate and 15g of sodium tetra borate ($\text{Na}_2\text{B}_4\text{O}_7$) was added piece-wise with stirring till the product becomes sticky.

▪ **Experiment 2**

40g of the dry cassava starch was weighed and poured in 50ml of HCl, and heated on the hot plate at the temperature of 70°C with stirring. It was remove from the hot plate and 30g of sodium tetra borate ($\text{Na}_2\text{B}_4\text{O}_7$) was added piece-wise with stirring till the product becomes sticky.

▪ **Experiment 3**

40g of the dry cassava starch was weighed and poured in 50ml of HCl, and heated on the hot plate at the temperature of 40°C with stirring. It was remove from the hot plate and 20g of sodium tetra borate ($\text{Na}_2\text{B}_4\text{O}_7$) was added piece-wise with stirring till the product becomes sticky.

▪ **Experiment 4**

40g of the dry cassava starch was weighed and poured in 50ml of HCl, and heated on the hot plate at the temperature of 80°C with stirring. It was remove from the hot plate and 15g of Sodium tetra borate ($\text{Na}_2\text{B}_4\text{O}_7$) was added piece-wise with stirring till the product becomes sticky.

The experiment was repeated at various concentration of borate and temperature to determine the most suitable stabilization temperature and the optimum suitable tetra borate requirement.

NB: (And at the end of this it was observed that only experiment 3 has a suitable tetra borate requirement and most suitable stabilized temperature because it was the only one that adhered very well even after a long time of production).

3.2.2 Analysis of Wood Adhesive

The following Analytical tests were carried out; Solid content, pH, Moisture Content, Resistance to Moisture, Shelf life, Viscosity and Tack.

- **Solid Content:** It tells the quantity of solid present in an adhesive.
- **P^H of the Product:** P^H meter was used for this test and the meter was calibrated with P^H 4.0,7.0 and10.0.
- **Moisture Content:** Ditto for the solid content determination.
- **Resistance to Moisture:** Resistance to moisture of the adhesive was determined by bonding papers of equal sizes 4x4 cm to wood using each sample of the adhesive. The bond materials were left to set for 24 hours. Then they were subsequently immersed in water and left for 24 hours. After 24 hours in water, the bonded materials were removed from water and their resistance to moisture determined by pulling the adhered materials apart.
- **Shelf Life Tests:** Here a long-term is carried out on adhesive samples to determine the life span. This was accomplished by observing the change in spreading characteristics. The end of the working life was observed as when the adhesive could no longer spread to provide uniform film.
- **Viscosity Test:** Viscometer was used for this analysis, which compare the viscosity of a sample with that of distilled water.
- **Tack Time:** A 2 X 2cm cardboard paper was divided into 2 units, it was 20 and 40 minutes at a uniform smear of the formulation under test was made on the papers, and then the papers were placed on the board. Pressure was applied over the surface to ensure penetration of the adhesive into the adherents. An increment was observed at the applied force.

3.0 RESULTS AND DISCUSSION

3.1. Results

Quality control parameters like P^H, soil content, moisture content, viscosity test, were carried out and presented in the table below.

Table 2.0: Quality Control parameters

Sample	P ^H	S/C(%)	M/C(%)	V/T(sec)
A	7.88±0.00	75.33±3.06	1.07±0.23	28.67±1.15
B	8.06±0.00	62.80±2.49	0.73±0.12	39.67±0.58

KEY: P^H=Acidity/Alkalinity,
 S/C=Solid Content
 M/C=Moisture Content
 V/T=Viscosity Test
 A=CommercialSample
 B=Produced sample

3.2 DISCUSSION

3.2.1. P^H Content

The pH of the commercial and the produced samples were determined by the use of calibrated pH meter with buffer 4.0, 7.0 and 10 respectively. It was observed that the pH (7.88±0.00) of the commercial sample was lower than that of the produced sample (8.06±0.00). Which means that the produced sample was more alkaline than the commercial sample, hence itching possibility on human skin. In concordance with the work of Tonukari (2004)

3.2.2 Solid Content

The solid content of the commercial adhesive which was 75.33 ± 3.06 % compared to the produced sample 62.80 ± 2.49 % indicated that both of them were within the range of acceptability. The higher the percentage of the solid content obtained the better the quality, however the lesser the solid content, the higher its shrinkage effect, which will definitely lead to cracking. This was in accordance with the work of Rowell (2013)

3.2.3 Moisture Content

The importance of analyzing moisture content was to determine the shelf life of the samples. The higher the percentage of the moisture content in the samples the higher the level of microorganism/microbes that will be habitable, which will grossly reduce the shelf life of the samples. Hence, from the results obtained the commercial adhesive was 1.07 ± 0.23 %, while that of the produced sample was 0.73 ± 0.12 % both were within the normal range, but with more characteristic of dryness within the shortest time. The implication of this was that within the shortest time the adhesive will dry off. Which is similar to the work of Pizzi et al. (2003)

3.2.4 Resistance to Moisture:

The two samples (commercial and produced one) were within standard limit. However, the commercial sample was better than the produced sample.

3.2.5 Viscosity Test:

The viscosity test showed little or no difference between the samples.

3.2.6 Tack Time Determination:

It was observed that the commercial adhesive admits more force than the produced one.

3.2.7 Shelf Life Tests:

Here ten days was used to determine the shelf life of the samples. At the end of the experiment the produced adhesive experienced the shortest time that could no longer spread to provide uniform film. This was accomplished by observing the change in spreading characteristics. This could be as a result of the level of moisture content Compared to the commercial sample. Which is in accordance with work of Tonukari (2004)

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Based on the quality control parameters analyzed, it could be concluded that the produced adhesive is a good alternative/substitute to commercial sample, which was much more economical to commercial sample, since cassava tuber is cheaply readily available as the raw material that can possibly be used as a binding material (adhesive).

4.2 Recommendation

It can strongly be recommended that the locally produced adhesive be used at expense of the commercial sample, because it is more economical than the commercial sample. However, the formulation can still be improved upon, in other to meet the standard global practice for industrialization.

REFERENCES

- AITC. (1992). American National Standard for Wood Products– structural glued laminated timber ANSI/AITC A190.1–1992. New York, NY: American National Standards Institute, Inc.
- AITC. (1992). Inspection Manual for Structural Glued Laminated Timber, AITC 200–92. Englewood, CO: American Institute of Timber Construction.
- APA. (1983). U.S. Product Standard PS1–83 for construction and industrial plywood with typical APA trademarks. Washington, DC: U.S. Department of Commerce, National Bureau of Standards.
- ASTM. (1997). Annual book of ASTM standards, Vol. 15.06 Adhesives. West Conshohocken, PA: American Society for Testing and Materials.

- Blomquist, R.F.; Christiansen, A.W.; Gillespie, R.H.; Myers, G.E. (1984) Adhesive bonding of wood and other structural materials. Clark C. Heritage memorial series on wood, Vol. 3. Educational modules for material science and engineering (EMMSE). University Park, PA: Pennsylvania State University.
- Bryant, B.S. (1977) Wood adhesion. In: Skeist, I., ed. Handbook of adhesives, 2d edition. New York, NY: Van Nostrand Reinhold Company.
- Caster, R.W. (1980) Correlation between exterior exposure and automatic boil test results. In: John, W.E.; Christiansen, A.W. (1990). How over drying wood reduces its bonding to phenol-formaldehyde adhesives: a critical review of the literature. Part I. Physical responses. *Wood and Fiber Science*. 22(4): 441–459.
- Christiansen, A.W. (1991). How over drying wood reduces its bonding to phenol-formaldehyde adhesives: a critical review of the literature. Part II. Chemical reactions. *Wood and Fiber Science*. 23(1): 69–84.
- Cruz, H; Custódio, J; Machado, J. (2005) “A temperatura de serviço elevada e o recobrimento no desempenho de colas epoxídicas usadas em reforço estrutural” (High service temperature and timber embedment effects on the performance of epoxy structural adhesives). *International Journal Construlink*, N°10, Vol. 3, Pp. 1-8.
- Custódio, J; Cruz, H. (2006). “Acção da temperatura no comportamento de colas epoxídicas – usadas em reforço/reparação de estruturas de madeira” (Temperature action on the behaviour of epoxy adhesives – used in repair/strengthening of timber structures). *Journal Ciência e Tecnologia dos Materiais*, N°3/4, Vol. 10, Pp. 2330.
- Gillespie, R.H. (1981) Wood composites. In: Oliver, J.F., ed. Adhesion in cellulose and wood-based composites. New York: Plenum Press.
- Gillespie, R.H., ed. (1984) Adhesives for wood—research, applications, and needs. Park Ridge, NJ: Noyes Publica
- Gillespie, R.H., (1980). Proceedings of a symposium, Wood adhesives— research, application, needs. September 23–25; Madison, WI: Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.
- Koning, J. W., Jr. (2010) Forest Products Laboratory 1910–2010: Celebrating a Century of Accomplishments. University of Wisconsin, Madison. (An excellent history of wood products.)
- Marra, A. A. 1992. Technology of Wood Bonding: Principles in Practice.
- National Particleboard Association. 1993. Particleboard. ANSI A208.1–1993 New York, NY: American National Standards Institute.
- Pizzi, A. and K. L. Mittal (Eds.). (2003). Handbook of Adhesive Technology. 2nd ed. Marcel Dekker, New York. pp. 635–652. (A thorough coverage of wood adhesive chemistry and applications of wood adhesives.)
- River, B.H. (1994). Fracture of adhesive-bonded wood joints. In: Pizzi, A; Mittal, K.L., eds. Handbook of adhesive technology. New York, NY: Marcel Dekker, Inc.
- Rowell, R. M. (2013). Handbook of Wood Chemistry and Wood Composites. 2nd ed. CRC Press, Boca Raton, Florida. (Good chapters on aspects related to adhesives, wood, and wood composites.)
- Tonukari N. J. (2004). Cassava and the future of starch, *Electronic J. of Biotechnology* vol. 7(1), Van Nostrand Reinhold, New York. (Coverage of adhesion for making wood products.)

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