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Preparation and Characterization of Water-Based Wood Adhesive Using Tamarind Seed Powder

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Abstract – Adhesives are used all over the world to combine the materials together. Due to its extended usage environment conservation authorities emphasize the importance of reducing the volatile organic content in adhesive manufacturing processes. As a solution, researchers are focusing on water-based adhesives instead of adhesives based on organic solvents. The binders that can be dissolved in water are needed to develop such water-based adhesives. In this study the possibility of using tamarind seed powder as a binder was analyzed. Tamarind seed powder can be used to develop an effective water-based wood adhesive with characteristics compatible with commercial glues. By comparing viscosity, fixture time and bond strength, the minimum initial seed powder concentration for an effective glue was identified as 6.25 %(w/v). In terms of the cost, minimal usage of raw material gives an additional advantage. Therefore 6.25% was selected, as it was the glue with minimum seed powder concentration which showed the above parameters compatible with commercial glues. This will be a green light to adhesive industries to reduce human health hazards and environmental hazards. On the other hand, it will be one of the value addition processes for the tamarind seed waste.

***Keywords* -** Tamarind seed powder, Biopolymer, Wood adhesion

1. Introduction

Attention towards the adhesives has boosted in the society due to its vast variety of applications. They are used in day-to-day life to join different type of surfaces (paper, glass, wood, etc.) and are used in industries to bind the raw materials together (in manufacturing processes of papers, fabrics, paints, plywood, etc.). Generally, non-metallic substances that are capable of joining two materials by surface bonding (adhesion) are known as adhesives (Gierenz & Karmann, 2001). Binders present in the adhesives can be used to determine the adhesiveness of those materials. The binders used for adhesives are primarily high polymers having optimal strength properties. Most of the commercially available adhesive materials are synthesized inorganic media such as ethanol, xylene, light aliphatic naphtha, N-hexane, toluene (Gierenz & Karmann, 2001) etc. With the environmental concerns, researchers in the field of adhesives nowadays try to replace the medium of the glue from organic solvents to water in order to avoid the use of volatile organic compounds in adhesive manufacturing process (Gierenz & Karmann, 2001).

The endosperm of the tamarind seeds can be used as a binder material to develop water based adhesive materials. Tamarind (Tamarindus indica L.) is a tree bearing edible fruits which belongs to Leguminosae family. It is commonly grown in India, Bangladesh, Myanmar, Thailand, Malaysia, and Sri Lanka (Kumar & Bhattacharya, 2008; El-Siddig, et al., 2006) Tamarind pulp is used in several industries such as beverages, sauces, and candies (Kumar & Bhattacharya, 2008). Tamarind pulp industries release a large number of seeds as an underutilized by-product. The seed comprises of seed coat (20-30%) and seed kernel (endosperm) (70-80%) (Amirthalingam, *et al.*, 2012). The preparation of adhesive using the tamarind seeds as a binder material will provide a value to the by-product of the tamarind pulp industry and end product will

Table 1: Sample preparation-method parameters

Sample number	Seed powder weight (g)	Volume of water (cm^3)	Concentration (% w/v)
1	1.00	20.0	5.00
2	1.25	20.0	6.25
3	1.50	20.0	7.50
4	1.75	20.0	8.75
5	2.00	20.0	10.00

be environmentally friendly due to non-emission of volatile organic compounds during the manufacturing.

Tamarind seed powder consist of a highly branched polysaccharide (Chawananorasest, *et al.*, 2016; Gupta, *et al.*, 2010). It is a polymer having a cellulose-type backbone with xylose and galactoxylose substituents. Its' monomer is formed from three sugars namely glucose, galactose and xylose in the molar ratio of 3:2:1. Therefore tamarind seed polysaccharide can be considered as a galactoxyloglucan (Chawanano-rasest, *et al.*, 2016; Gupta, *et al.*, 2010).

Binding properties of tamarind seeds has been used in pharmaceutical industry (Chawanano-rasest, *et al*., 2016; Gupta, *et al*., 2010; Singh, *et al*., 2011), food industry (Goyal, *et al*., 2007) textile and paper industry (Kumar & Bhattacharya, 2008) and to develop composite materials (Amirthalingam, *et al*., 2012). However, there are no evidences about its' usage as a glue to join surfaces. In this study, we are focusing to develop a water-based glue from tamarind seeds to join different types of surfaces together specially wood surfaces. This will be a green light to adhesive industries to reduce human health hazards and environmental hazards. On the other hand, it will be one of the value addition processes for the tamarind seed waste.

2. METHODOLOGY

2.1 Preparation of the tamarind seed glue

Tamarind seeds which were removed as waste from kitchen were collected and washed properly using running water and finally with distilled water. Cleaned seeds were boiled in distilled water at 90 ^{0}C for 6 hrs. Peels were removed to separate the kernels. The seed kernels were oven dried at 120 ^{0}C for 2 hrs and ground into powder form. Seed powder was mixed with de-ionized water and a slurry was obtained. The slurry was stirred at 90 ^{0}C for 2 hrs. The resultant solution was centrifuged for 1 hr at 4000 rpm and the supernatant with adhesive properties was collected as a pure homogeneous glue. Initial seed powder concentration was varied and a series of 5 different glue samples were obtained as tabulated in the Table 1.

2.2 Characterization of the tamarind seed glue

Viscosity: Viscosity of the glue samples were determined using ATAGO-base viscometer. Each glue sample was placed in a test tube with 1.0 cm diameter and viscosity readings were taken at room temperature within 1 min time period by using R7 spindle which was run at 60.00 rpm.

Fixture time: According to the definition given in ASTM standard D 1144, the time taken to reach the point at which, adherents can no longer be moved independently was considered as the fixture time. Fixture time was measured for three types of materials namely wood, hardboard and paper. Two similar pieces of each material having 4 cm x 1 cm dimensions were pasted using a same amount of glue and allowed to dry at room temperature and fixture time was measured.

Adhesive Bond strength: The adhesive bond strength was measured by the single lap shear test. The lap shear strength is reported as the failure stress in the adhesive, which is calculated by dividing the failing load by the bond area. The maximum force at breaking stage was recorded using JTM s1000 universal testing machine. Adhesive bond strength was calculated according to the equation 01 where the F_{max} is the maximum force at break and the A is the cross-section area which glue was applied (Ferdosian, et al., 2017).

$$\text{adhesive bond strength} = \frac{F_{max}}{A}$$

3. Results and Discussion

Viscosity

All the viscosity measurements were obtained at room temperature because the temperature variations can affect the viscosity values. As shown in Figure 1, there is an increase in viscosity with the increase of seed powder concentration. This can be attributed to the increase in solute content. When the solute content is increased, it will retard the flowability and subsequently increase the viscosity.

At the uncured fluid state, the viscosity of an adhesive is an important parameter to determine its applicability. In the case of wood adhesives, if the viscosities are too low the glue will either drain off or penetrate into the wood substrate, leaving the adhesive layer too thin. On the other hand, if the viscosity is too high, it will create difficulties in handling and also decrease its ability to properly wet, flow, and penetrate into the wood material(Nordqvist, et al., 2013).

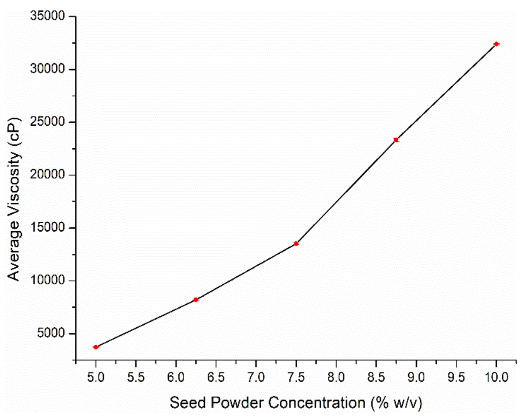

Figure 1: Viscosity of the glue samples Vs the seed powder concentration

Therefore, dispersions or emulsions with initial viscosities in the 10,000 cP – 40,000 cPare suitable for wood adhesives(Nordqvist, et al., 2013). In this study, viscosities of all the glues except 5% sample are within that suitable range.

Fixture time

As shown in Figure 2, glues show significant reduction in fixture time when increasing the concentration (%w/v) from 5.00 to 10.00 irrespective to the material. It is due to the reduction of water content per unit volume of the glue. Samples having more water take much time to dry, while samples having less water take less time to dry. Fixture time for wood and hardboard is significantly higher than that of paper. Papers absorb water easily from the glue compared to other two and release out very fast to the atmosphere. This will lead to a quick drying.

Lower the fixture time is an advantage of an adhesive because it will help to enhance the productivity. Fixture time for wood materials are less than 5 hrs for all the samples and for 10 %(w/v) sample which is having the lowest fixture time is around 3 hours and 20 minutes.

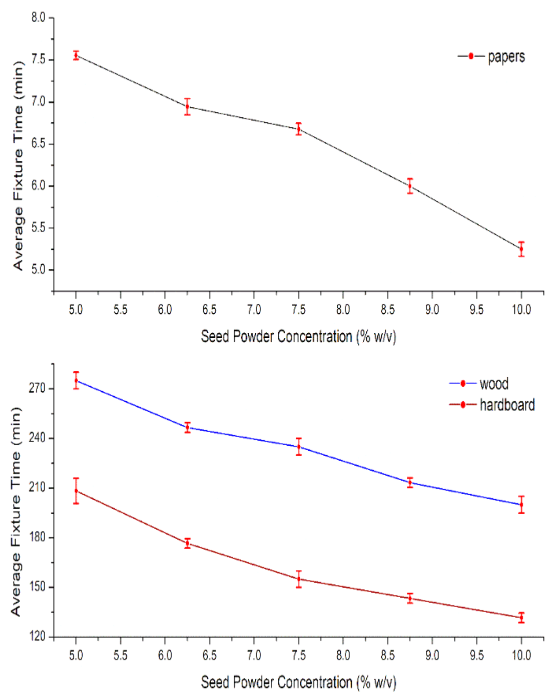

Figure 2: Fixture time variation with respect to seed powder concentration for different materials

These fixture times are compatible with those of common commercially available glues. Literature has recommended to fix the adherends for 4 hours when the polyurethane-based wood adhesives are used to obtain the required bond strengths (Mölleken , et al., 2016).

Adhesive Bond strength

Bond strength was measured in order to verify how strong the formed bonds between the tamarind glue and the material. The bonding strength of the glue with wood materials is very high. It is because of the ability of xyloglucan which is present in the tamarind glue to make strong bonds with cellulose in wood materials. Due to the presence of higher amount of hydroxyl groups in xyloglucan, it has a good ability to form strong hydrogen bonds with cellulose. (Chawananorasest, et al., 2016; Gupta, et al., 2010). There is a nonlinear growth in adhesive bonding strength with the increase of the concentration (%w/v) from 5.00 to 10.00 (Figure 3). This can be attributed to the increase in the extent of hydrogen bonding with the increase of the amount of xyloglucan per unit area.

Bond strength of polyurethane based commercial wood adhesive was reported as 4.9 MPa (Kong, et al., 2011). When the bond strengths of the samples of this study are compared with commercial wood adhesives 10.00 %(w/v) sample shows a higher strength than the commercial samples and 8.75 %(w/v) sample is more closed to the commercial sample strength.

When the characteristics of the tamarind seed glue are compared with literature data, seed glue samples with concentrations of 6.25%(w/v) or above can be effectively used as a wood glue. It is a cost effective and environmentally friendly glue. Better characteristics can be observed with higher concentrations. In future studies, the stability of the glue will be studied and also the possibility to precipitate the binder from the glue and make it available as a powder form and allow the user to disperse in water at the workplace will be analysed.

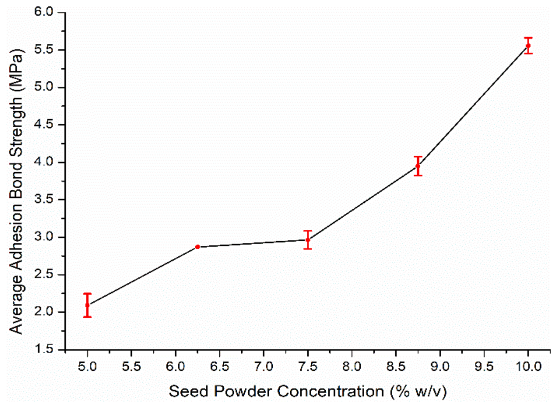

Figure 3: Average Bond strength variation with respect to seed powder concentration for different materials

4. Conclusion

Tamarind seed powder can be used to develop a water-based wood adhesive which is environmentally friendly and cost effective. The viscosity, fixture time and bond strength values were compared for glue samples with different concentrations and concluded that the properties are enhanced with higher concentrations. The minimum initial seed powder concentration for an effective glue was identified as 6.25 %(w/v). The supernatant of the above sample showed the good adhesive properties. The viscosity, fixture time and bond strength values of above sample are compatible with commercial wood glues. Therefore, it can be concluded that the tamarind seed can be used as an effective binder to develop water-based wood adhesives.

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