Development of a New Bio-based Adhesive for Cardboard Using Latex of Pterocarpus Indicus

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Keywords - bio-based adhesive, latex, Pterocarpus indicus, adhesive strength

I. INTRODUCTION

Bio-based adhesives are derived from renewable resources such as plant-based materials, animal by-products, and microbial sources. Latex-based bio adhesives, specifically those made from natural latex derived from plant sources, have garnered significant research interest. While natural rubber remains the most commonly used bio source for latex adhesives, this study explores the potential of Pterocarpus indicus wild (PIW) latex as an alternative and discusses modifications that can be made to enhance its adhesive properties. Additionally, this research examines the effect of additives such as Polyvinyl Alcohol (PVA) on the adhesive properties of natural latex while evaluating their capacity for adhesive performance. The major challenges faced by existing bio-based adhesives, including low bonding strength and water resistance are acknowledged. Consequently, this study offers guidance on advancing new plant sources for bio-based adhesives, addressing the limitations of current adhesive products.

Adhesives are social substances and can be defined as a mixture in a liquid or semi-liquid state, capable of joining permanently to surfaces, by an adhesive process [1]. Bio-based adhesives are a type of adhesive that is made from natural and renewable resources, such as plant-based materials [2]. These adhesives are becoming increasingly popular due to their sustainability and environmentally friendly nature, as they have a reduced carbon footprint and are biodegradable.

The disadvantages of the current bio sealants can restrict their use in some circumstances. Their lower strength and longevity compared to conventional adhesives are significant drawbacks. Some bio-based adhesives are also moisture-sensitive and may lose their adhesion when exposed to moisture or high humidity [3]. Due to the higher expense of obtaining and processing natural materials, bio-based adhesive production has another disadvantage. Additionally, bio-based adhesives' scalability and broad use may be constrained by the lack of readily available natural materials. Additionally restricting their use in some applications, some bio-based adhesives have a lower shelf life than conventional adhesives.

Making bio-based adhesives calls for specific understanding and proficiency in chemistry and materials science. The final product, though, is a long-lasting and environmentally friendly adhesive that can be applied to many different things, including packaging, textiles, and construction [4].

II. METHODOLOGY

A. *Materials*

Fresh latex was extracted by tapping the bark of PIW tree. Chemicals needed to modify latex samples were supplied by the polymer laboratory, department of material science and Engineering. They are 25% (w/w) Ammonia solution, Poly vinyl alcohol (PVA), Calcium carbonate, Acetone, Acetic acid, ethanol, Carboxymethyl Cellulose (CMC), and Glycerol.

B. *Methods*

PIW latex was applied on 2 cardboard materials that were used for packaging. Cardboard was adhered to by external force and roughly tested for primary adhesive properties. Approximately, 5 ml sample of PIW latex was taken and 0.1 ml of 25% (w/w) of ammonia solution was added using a syringe. The latex sample was kept for 1 day and tested for adhesive strength using cardboard. First, 15 g of CMC was taken and dissolved in 250 ml of boiling water by continuously stirring. Afterwards, 250 ml of cold water was added and stirred again. After 30 minutes CMC was completely mixed. This mixture was put into a container and left closed for 24 hours. 20 g of PVA was dissolved in a 500 ml of boiling water while stirring. After 30 minutes PVA was fully mixed. CMC solution, PIW latex and PVA solution were mixed at different ratios. 2 batches were made.
Batch 1 – CMC solution and Preserved PIW latex were mixed in a ratio of 1:2.
Batch 2 – CMC solution, Preserved PIW latex and PVA solution were mixed in ratio of 1:1:1.

C. *Testing*

- *Bond permanency test*

Each adhesive sample was tested by the following procedure, after each modification. The testing procedure was based on Sri Lanka Standard – Specification for General Purpose Paper Adhesives (SLS 660:1984).

- *Peel resistance test*

Peel resistance is the average load per unit width of the bond line required to produce progressive separation of two bonded, flexible adherents. It is performed on a tensile testing machine using specially made specimens.

III. Results and Discussion

PIW latex was developed as an adhesive CMC. CMC is a water-soluble polymer derived from cellulose, which is a natural component of plant cell walls. It is widely used in various industries, including food, pharmaceuticals, and personal care products, as well as in adhesives [5]. CMC is not typically used as a solvent for adhesives. Instead, CMC is used as an additive or thickener in adhesive formulations to improve their properties. In adhesives, CMC is used as a thickener to increase the viscosity of the adhesive, which helps to control its flow and improve its adhesion properties. CMC can also enhance the adhesive's open time (the time during which the adhesive remains workable before setting) and increase its bond strength. However, CMC itself is not used as a solvent for adhesives. Solvents in adhesives are typically liquids that can dissolve or disperse the adhesive's components, helping to reduce its viscosity and make it easier to apply. Common solvents used in adhesives include water, ethanol, acetone, and toluene. In this approach CMC is dissolved in water and later PIW latex was added to increase the adhesive properties. Additionally, PVA is used as an adhesive enhancer.

PVA is an adhesive that enhances bonding strength through multiple mechanisms. PVA molecules interact with surfaces through hydrogen bonding and van der Waals forces, creating strong adhesive bonds. Its excellent penetration and wetting properties enable it to seep into pores and crevices, forming a mechanical interlocking effect. The suitable viscosity allows PVA to spread and conform to surfaces, increasing contact and bonding area. As it dries, PVA undergoes cross-linking and polymerization, reinforcing the adhesive layer and creating a stable bond. Its elasticity accommodates material movements without compromising the bond's integrity. Moreover, PVA is non-toxic and gentle on substrates, leading to durable, non-damaging bonds.

Shear tests are done for 3 sets of specimens which were made of batch 1, batch 2 and Chemifix. The specimens were made of craft paper 200 gsm. 3 tests were done for each adhesive type and the average shearing force is calculated.

Table 1: Maximum shear force values for adhesive samples

Adhesive Type	Average Shear Force (N)
Batch 1	154.12
Batch 2	175.46
Chemifix	189.76

The above observation shows that PIW latex-based adhesive has nearly better adhesive strength compared to existing products like Chemifix. This observation justifies the effect of PVA which was added in batch 2. PVA increases the adhesive strength.

Peel resistance test was done for batch 1, batch 2 and Chemifix adhesive samples and the following graphs were obtained. According to the test results, below average peel resistance values were obtained. When calculating average value, initial peeling forces were neglected, and force values of continuous peeling were taken.

Table 2: Maximum shear force values for adhesive samples

Adhesive Type	Average Peel Strength (N)
Batch 1	8.42
Batch 2	11.01
Chemifix	11.87

This observation shows that PIW latex alone has good adhesive properties, which are represented by batch 1. Batch 2 was made by adding PVA to the adhesive mixture and it clearly indicated the effect of PVA on adhesive strength. PVA molecules form intermolecular interactions with the surfaces of the materials being bonded. These interactions, such as hydrogen bonding and van der Waals forces, create strong adhesive bonds between the PVA and the substrate. The formation of these interactions increases the surface area of contact between the adhesive and the material, leading to higher bond strength [5].

IV. CONCLUSION

The successful development of a new bio-based adhesive is contingent upon several factors, including the availability of suitable bio sources, the preservation time of the extracted biomaterials used in adhesive production, and the fundamental adhesive properties. Considering the obtained results, it has been found that the adhesive derived from Pterocarpus indicus latex exhibits the highest potential for commercialization. Using CMC as a thickener and PVA as an adhesion increment has given good test results for PIW latex-based adhesive. Nonetheless, certain enhancements are required to optimize its properties, such as reducing the curing time, improving storage stability, and extending the preservation duration. Furthermore, modifications can be made based on the chemical origin of the latex sample. Notably, the bonding strength of the newly modified adhesive demonstrates a noteworthy advancement when compared to existing adhesive products.

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