Sustainable Chemical Engineering
https://ojs.wiserpub.com/index.php/SCE/

Research Article

Preparation of Adhesive from Cassava Starch and Evaluation of its Physicochemical Properties

T. Raja[*], **S. Sivamani**

Engineering Department, University of Technology and Applied Sciences, Salalah, Oman
E-mail: raja.t@sct.edu.om

Received: 28 December 2022; **Revised:** 17 April 2023; **Accepted:** 28 April 2023

Abstract: Adhesives can be used as sealing agents to eliminate the effect of self-loosening caused by dynamic loads, for sealing areas to prevent oxidation and corrosion, for waterproofing, and so on. The aim of the present study is to prepare an adhesive from fresh cassava roots and to evaluate its physicochemical properties, such as density, viscosity, and pH. Adhesives are prepared by mixing starch, hydrochloric acid, and borax. Three samples of adhesives were prepared by mixing various proportions (S1: 5 g starch, 100 mL hydrochloric acid, and 5 g borax; S2: 8 g starch, 100 mL hydrochloric acid, and 5 g borax; S3: 5 g starch, 120 mL hydrochloric acid, and 8 g borax). The physicochemical properties of prepared adhesives were compared with a commercial adhesive, and S2 was found to have properties closer to the commercial adhesive. Hence, it could be concluded that an increase in starch content by 60% could improve the properties of adhesives.

Keywords**:** cassava, starch, adhesives, density, viscosity, pH

1. Introduction

The adhesive is any non-metallic substance applied to one or both surfaces of two separate items that binds them together and resists their separation. When applied to one or both surfaces, adhesives bind two objects together and make them difficult to separate.[1] When it comes to the functionality of adhesive joints, the glue's physical and chemical qualities matter the most. The nature of the surface pretreatment or primer, as well as the types of adherents (e.g.; metal alloy, plastic, composite material), play key roles in determining the performance of the adhesive junction. A bonded structure's durability is affected by the adhesive, adherent, and surface.[2,3]

The mechanical behavior of a bonded structure is affected by the joint design and the method of load transfer between the adherents.[4] For an adequate adhesive bond to form, it is essential that the adhesive can moisten and spread over the adherents.[5] It is necessary to achieve such molecular interfacial contact in order to create adhesive bonds that are both strong and stable. When a surface is wet, a wide variety of intrinsic adhesive forces are generated across the contact.[6]

Since 1960s, physicochemical research has been conducted to pinpoint the specific nature of these mechanisms, leading to the development of a wide variety of adhesion theories.[7] The basic process of adhesion is explained by the adsorption theory, which states that substances adhere largely as a result of tight intermolecular contact.[8] Intermolecular

DOI: https://doi.org/10.37256/sce.4220232288

or valence forces generated by molecules in the surface layers of the adhesive and adherent create this contact at adhesive junctions. There have been four hypothesized adhesion processes including adsorption:[9]

• When an adhesive seeps into a porous adherent surface or flows around protrusions, mechanical interlocking occurs.

• Liquid adhesives dissolve and diffuse into adhering materials, a process known as interdiffusion.

• When adhesive molecules adsorb onto a solid surface and react chemically with it, a bond is formed. The chemical reaction distinguishes this process from straightforward adsorption, albeit some scientists view it as a natural aspect of adsorption rather than a separate adhesion mechanism.

• When two materials with different electronic band structures meet, electrostatic forces are generated, as predicted by the theory of electronic, or electrostatic, attraction.

Different adhesives and adherents rely on different combinations of these mechanisms to achieve their maximum holding power.

When an adhesive bond is formed, a transitional zone appears at the interface between the adherent and adhesive. It is possible that the adhesive's chemical and physical characteristics will change in this interphase area compared to the noncontact regions.[10] The interphase composition is thought to be the primary driver of stress transfer and the determinant of an adhesive joint's strength and longevity.[11] A number of environmental assaults lead to joint failure, and one common target is the interphase area.[12]

Polymers are the chemical building blocks of all synthetic adhesives and some natural adhesives.[13] Thermoplastic elastomers, such as styrene-isoprene-styrene block copolymers, are good examples of adhesives that undergo polymerization either simultaneously with the bond formation or beforehand.[14] Adequate adhesion can be formed because polymers are strong, flexible, and able to spread and interact with adherent surface features.[15]

The cassava starch adhesive is for general-purpose household applications, offering both performance and durability and an ideal replacement for traditional epoxy-based adhesives. As far as the toxicity is concerned, touching, or smearing on the skin of the body is harmless. On oral ingestion, the adhesive moves past when wet, but set firm when dry. Hence, small amounts of adhesive when ingested accidentally, drinking water can wash it down into the stomach, with no serious aftereffects.[16]

The aim of this study is to produce an adhesive from cassava tuber with the following objectives: (i) To synthesize adhesive from cassava starch; (ii) to determine the physical and chemical properties of cassava adhesive; and (iii) to compare the cassava adhesive with the commercial adhesive.

2. Experimental methods

2.1 *Materials*

Cassava roots were purchased from the local commercial market in Salalah City. The roots were stored at 4 °C in an airtight plastic bag until further use. Hydrochloric acid and borax of analytical grade were procured from the VWR International FZ-LLC, UAE.

2.2 *Extraction of starch from cassava tuber*

Fresh cassava roots were peeled and made into pieces. Then, 500 g of peeled roots were mixed with 250 mL of water to make slurry. Then, the mixed slurry was filtered to separate the starch slurry and fibrous residue. Water is removed from the starch slurry by pressing it in a clean bag and dried in a hot air oven at 105 °C to constant weight. Extraction of starch from fresh cassava roots was performed following the steps outlined in Figure 1.

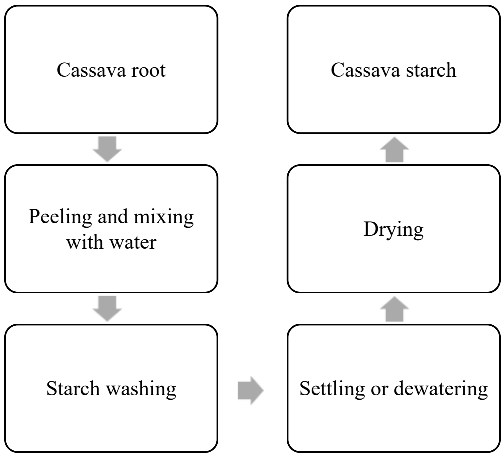

Figure 1. Extraction of starch from fresh cassava root

2.3 *Preparation of adhesive from cassava starch*

The adhesive was prepared by using cassava starch, hydrochloric acid, and borax. 5 g of dried starch and 100 mL of 0.01 M hydrochloric acid were mixed with stirring at 100 °C. After the starch dissolved completely, the temperature was decreased to 70 °C. Later, 5 g of borax was added piece by piece to prepare the adhesive. The preparation of adhesive from cassava starch was performed following the steps outlined in Figure 2. Three samples were prepared with varying cassava starch, hydrochloric acid, and borax (Table 1).

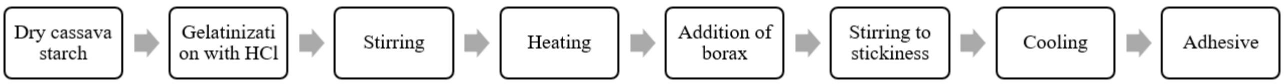

Figure 2. Preparation of adhesive from cassava starch

Table 1. Sample codes for various proportions of starch, hydrochloric acid, and borax for preparation of adhesive

Sample code	Mass of cassava starch (g)	Volume of hydrochloric acid (mL)	Mass of borax (g)
S1	5	100	5
S2	8	100	5
S3	5	120	8

2.4 *Evaluation of physicochemical properties of adhesive from cassava starch*

The prepared adhesive was evaluated for physicochemical properties such as density, viscosity, and pH. The pycnometer, rotational viscometer, and pH meter were used to calculate/measure the density, viscosity, and pH of the prepared adhesive, respectively.

3. Results and discussion

Sample 1 (S1) contains an equal proportion of starch and borax. Sample 2 (S2) contains more starch than borax. Sample 3 (S3) contains more borax than starch. The physicochemical properties of samples are compared with commercial adhesive (C).

3.1 *The density of adhesives*

Figure 3 shows the effect of the sample on the density of the adhesive. The density of prepared adhesives was compared with commercial adhesives. A good adhesive has low density (1.08-1.10 g/mL). The density of S1, S2, S3 and C were 1.28, 1.161, 1.266 and 1.09 g/mL, respectively. The density of sample S2 is closer to the commercial adhesive.

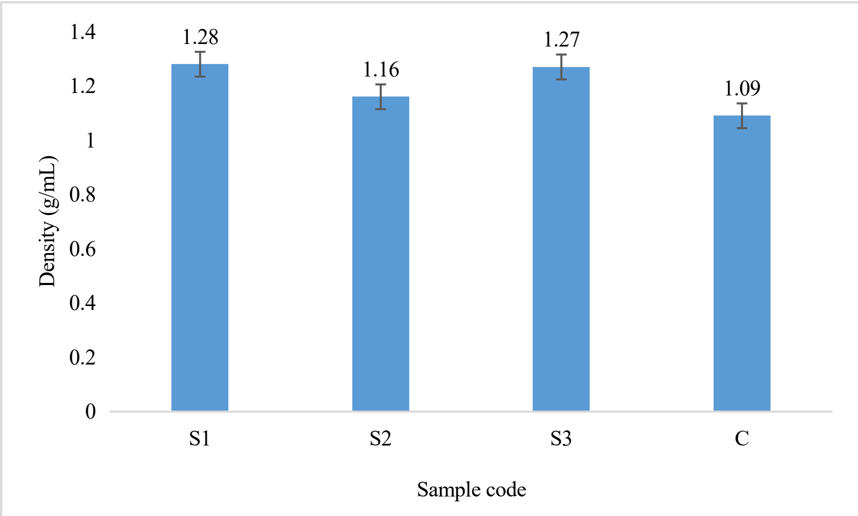

Figure 3. Effect of the sample on the density of adhesive (S1-S3 are samples and C is commercial adhesive)

3.2 *The viscosity of adhesives*

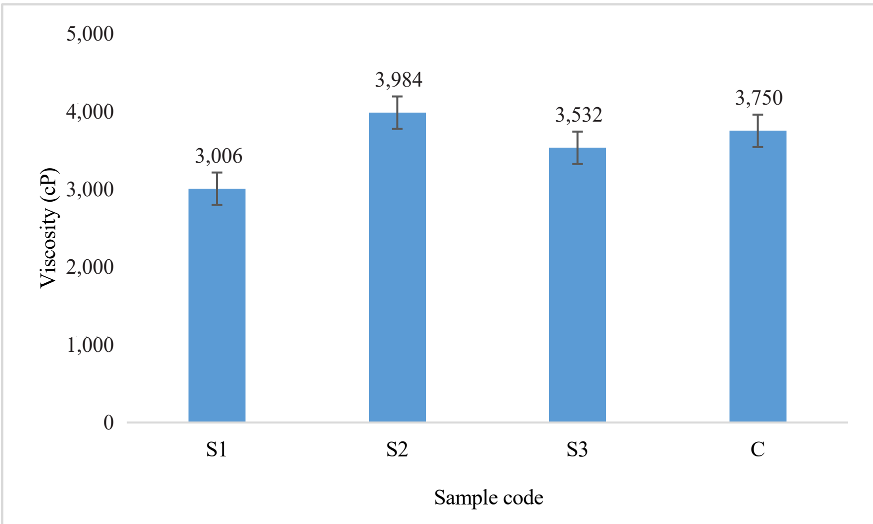

Figure 4. Effect of sample on the viscosity of adhesive (S1-S3 are samples and C is commercial adhesive)

Figure 4 shows the effect of the sample on the viscosity of the adhesive. The viscosity of prepared adhesives was compared with commercial adhesives. The viscosity of the adhesive depends on the application, which ranges from 200 to 1,500,000 cP. The viscosity of S1, S2, S3 and C were 3,006, 3,984, 3,532 and 3,750 cP, respectively. The viscosity of sample S2 is closer to the commercial adhesive.

3.3 *The pH of adhesives*

Figure 5 shows the effect of the sample on the pH of the adhesive. The pH of prepared adhesives was compared with commercial adhesives. A good adhesive has a neutral pH of 7. pH of S1, S2, S3 and C were 7.18, 7.01, 7.13 and 7, respectively. The pH of sample S2 is closer to the commercial adhesive.

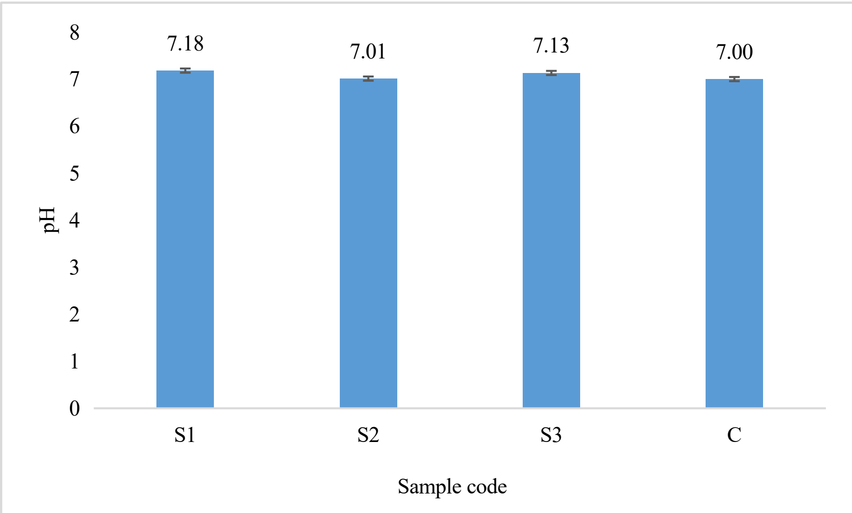

Figure 5. Effect of sample on pH of adhesive [S1-S3 are samples and C is commercial adhesive]

4. Conclusions

The work focused on preparing an adhesive from fresh cassava roots and evaluating its physicochemical properties such as density, viscosity, and pH. Three samples of adhesives were prepared by mixing various proportions (S1: 5 g starch, 100 mL hydrochloric acid and 5 g borax; S2: 8 g starch, 100 mL hydrochloric acid and 5 g borax; S3: 5 g starch, 120 mL hydrochloric acid and 8 g borax). The physicochemical properties of prepared adhesives were compared with commercial adhesive and S2 was found to have properties closer to the commercial adhesive. Hence, it could be concluded that an increase in starch content by 60% could improve the properties of adhesives.

Future scope

The present work would extend to studying the effect of drying time and bond strength on the acidity and HCN content of adhesive.

Conflict of interest

The authors declare no competing financial interest.

References

[1] Lengowski, E. C.; Bonfatti Júnior, E. A.; Kumode, M. M. N.; Carneiro, M. E.; Satyanarayana, K. G. *Sustainable Polymer Composites and Nanocomposites: Nanocellulose-reinforced adhesives for wood-based panels*; Springer: Switzerland, 2019.

[2] Islam, M. N.; Rahman, F.; Das, A. K.; Hiziroglu, S. *Int. J. Adhes. Adhes.* **2022,** *112*, 102992.

[3] Croll, A. B.; Hosseini, N.; Bartlett, M. D. *Adv. Mater. Technol.* **2019,** *4*, 1900193.

[4] Jeevi, G.; Nayak, S. K.; Abdul Kader, M. *J. Adhes. Sci. Technol.* **2019,** *33*, 1497-1520.

[5] Pethrick, R. A. *Proc. Inst. Mech.* **2015,** *229*, 349-379.

[6] Bukhari, M. D.; Gohar, G. A.; Akhtar, A.; Ullah, S.; Akram, M.; Abid, J.; Raza, H. *VW Appl. Sci.* **2020,** *2*, 74-86.

[7] Petković, G.; Rožić, M.; Vukoje, M.; Pasanec Preprotić, S. *Ann. Fac. Eng. Hunedoara.* **2017,** *15*, 35-42.

[8] Creton, C.; Ciccotti, M. *Rep. Prog. Phys.* **2016,** *79*, 046601.

[9] Xiao, Z.; Zhao, Q.; Niu, Y.; Zhao, D. *Soft Matter.* **2022,** *18*, 3447-3464.

[10] Zhao, L.; Pan, S.; Holzmann, N.; Schwerdtfeger, P.; Frenking, G. *Chem. Rev.* **2019,** *119*, 8781-8845.

[11] Guadagno, L.; Sarno, M.; Vietri, U.; Raimondo, M.; Cirillo, C.; Ciambelli, P. *RSC Adv.* **2015,** *5*, 27874-27886.

[12] Croll, S. G. *Prog. Org. Coat.* **2020,** *148*, 105847.

[13] Ghobril, C.; Grinstaff, M. W. *Chem. Soc. Rev.* **2015**, *44*, 1820-1835.

[14] Scognamiglio, F.; Travan, A.; Rustighi, I.; Tarchi, P.; Palmisano, S.; Marsich, E.; Borgogna, M.; Donati, I.; de Manzini, N.; Paoletti, S. *J. Biomed. Mater.* **2016,** *104*, 626-639.

[15] Sundriyal, P.; Pandey, M.; Bhattacharya, S. *Int. J. Adhes. Adhes.* **2020,** *101*, 102626.

[16] Oghenejoboh, K. M. *Br. Biotechnol. J.* **2012,** *2*, 257.