E-ISSN: 2829-7687
Journal of Fibers and Polymer Composites
Vol. 4 No. 1 (2025): 1-10

Moisture Characteristics of Biocomposites from PVA/Cassava Starch Reinforced by Lemon Peel Fiber

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Abstract. *This study reports the moisture absorption and surface morphological characteristics of Polyvinyl Alcohol (PVA) and cassava starch biocomposite with lemon peel fiber as reinforcement. Biocomposite is produced by film casting method. The addition of lemon peel fiber decreases moisture absorption properties. The lowest moisture absorption is 53,37 % for PVA/Cassava starch with 4% lemon peel fiber. This result is much lower than PVA and PVA/starch. Good adhesion of interfacial bonding and the compact structure of the biocomposite thus reduce the moisture absorption. From these results, the created biocomposite can serve as an environmentally friendly alternative.*
Keywords: *Polyvinyl Alcohol; Cassava Starch; Lemon Peel Fiber; Biocomposites; Moisture Absorption.*

Type of the Paper: Regular Article.

1. Introduction

Innovations in advanced materials for creating environmentally friendly biocomposites by utilizing natural fibers to produce alternatives to synthetic plastics are continuously being pursued [1]. Biocomposites have become one of the materials that have been widely researched in recent years because they are environmentally friendly and can biodegrade naturally [2,3]. Biocomposites are materials made by combining two or more substances that retain their respective advantages [4,5]. Several components of biocomposites have environmental advantages and biodegradable capabilities, one of which is Polyvinyl Alcohol (PVA) [6].

Polyvinyl alcohol (PVA) is a promising material for bioplastic production due to its biodegradable properties and water solubility [7]. PVA is a type of bioplastic that exhibits characteristics such as chemical resistance and good gelatinization ability [8]. Additionally, PVA is used in various applications, including packaging [9]. Unfortunately, PVA has weaknesses, including high cost and slow degradability, mixing it with starch becomes one solution to reduce production costs [10]. Mixing Polyvinyl Alcohol with starch tends to reduce mechanical properties. Asrofi et al. [10], reported that the decrease in mechanical properties from the blending

https://doi.org/10.55043/jfpc.v4i1.218
Received October 22, 2024; Received in revised November 19,2024; Accepted November 25,2024; Published March 29, 2025
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of PVA and starch is due to poor interfacial bonding between PVA and starch, as well as the presence of free O-H groups between PVA and starch. This potentially leads to increased moisture absorption in large amounts due to the abundance of O-H groups [11]. To address this issue, adding a filler in the form of natural cellulose fibers is necessary [12,13].

Incorporating natural cellulose fibers into polyvinyl alcohol and starch has been done before to improve their properties. Mohammed et al. [14], conducted a study adding coconut husk fibers to the PVA-starch matrix. The result was a lightweight biocomposite with reduced moisture absorption due to good interfacial bonding. The reduction in moisture absorption led to an increase in the tensile strength of the biocomposite up to 245 MPa. Another study by Abral et al. [15], reported that mixing PVA and tapioca starch with the addition of bacterial cellulose lowered moisture absorption as the bacterial cellulose content increased. The dispersed fibers formed hydrogen bonds with the matrix and reduced the number of free O-H groups. Adding natural cellulose fibers to the biocomposite proved effective in reducing water absorption, which had a positive impact on mechanical properties.

Based on several studies, many benefits of biocomposites for life have been found. However, some issues are related to natural polymer matrices, specifically high moisture absorption caused by numerous hydroxyl groups in their structure. The accumulated moisture within the biocomposite can cause physical degradation such as increased thickness and dimensional changes, as well as lower mechanical film properties. Consequently, moisture absorption triggers negative effects on the mechanical properties of biocomposites. Therefore, water absorption tests are conducted to achieve optimal conditions for biocomposites. The purpose of this research is to investigate the influence of adding lemon peel fibers on the value of moisture absorption in biocomposites. Lemon peel fibers contain 21.2% weight cellulose, 1.6% weight hemicellulose, 0.4% weight lignin, and 5.1% weight proteins, along with 31% weight pectins and other extracts [16]. Lemon peel fibers are one of the less studied natural fibers used as fillers in biocomposites. Utilizing natural fibers as reinforcements in biocomposites is one method to develop environmentally beneficial products.

2. Materials and Methods

2.1. Materials

Polyvinyl alcohol (87% purity) was obtained from Chang Chun Petrochemical Co., Ltd. Cassava starch (99% purity) was acquired from Intelligent Materials Pvt., Ltd. Lemon Peel collected from local herbal medicine facilities in Jember, Indonesia. Sodium hydroxide (NaOH) Merck Ltd. brand and other chemicals purchased from the local chemical store, UD. Aneka Kimia, Jember, Indonesia.

2.2. Lemon Peel Fiber Preparation

Lemon peel is dried in an oven at 90°C for 12 hours until stable weight is achieved. After drying, the fibers undergo treatment with a 5% sodium hydroxide solution for 3 hours. Following alkaline treatment, the fibers are washed thoroughly with distilled water until clean. Then, the lemon peel was dried again until a stable weight was reached. Ground the lemon peel fiber into powder using a high-speed blender. The powdered fibers are then sieved using a mesh screen measuring 149–177 µm.

2.3. Biocomposite Film Preparation

Polyvinyl Alcohol (PVA) and cassava starch as matrices are mixed and dissolved in distilled water using a hot plate magnetic stirrer at 90°C for 60 minutes to produce a homogeneous gelatin solution. After that, the prepared lemon peel fiber powder is added to the solution with varying weight percentages and stirred continuously for 40 minutes to ensure even distribution. The resulting mixture is then poured onto glass molds and dried in an oven at 40°C for 24 hours to obtain biocomposite films. The scheme for making biocomposite samples is presented in Fig. 1. Table 1 shows the composition of the biocomposite that will be made.

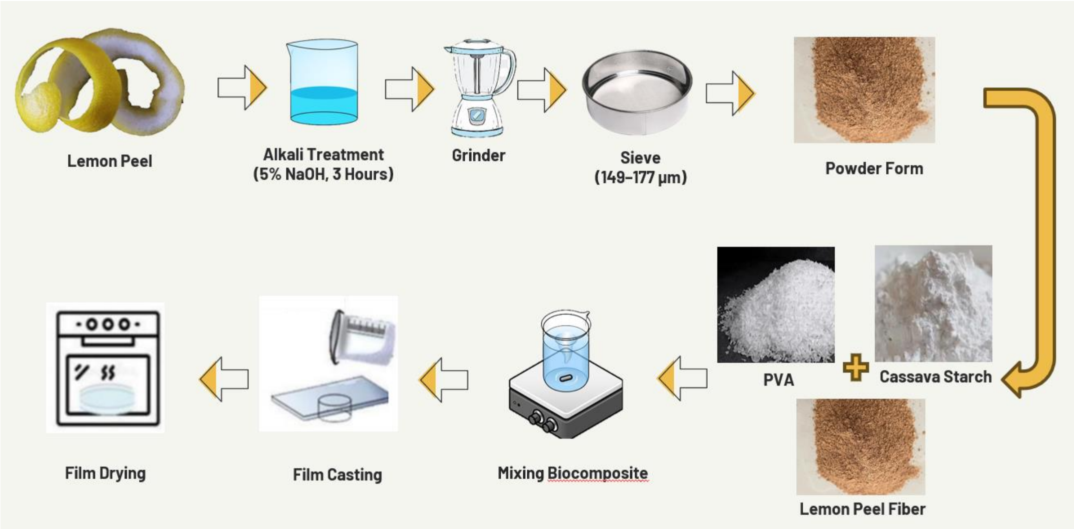

Fig. 1. Biocomposite Fabrication Scheme

Table 1. Biocomposite Composition

Sample Code	Mixture Polyvinyl Alcohol (wt%)	Cassava Starch (wt%)	Lemon Peel Fiber (wt%)
PVA	100	0	0
PVA/CS	80	20	0
PVA/CS/1LPF	80	19	1
PVA/CS/2LPF	80	18	2
PVA/CS/3LPF	80	17	3
PVA/CS/4LPF	80	16	4

2.4. Moisture Absorption

The samples tested were sized 2 cm x 2 cm and dried in an oven until reaching a stable weight. Initial and final weights were marked as (Wo) and (Wt). The moisture absorption process took place in a humidity-controlled chamber with RH of 99% at a temperature of 25°C. Final weight (Wt) resulted from weighing the sample every 30 minutes. Fig. 1 shows the moisture absorption testing scheme. The percentage of moisture absorption was calculated using the equation presented below in Eq. (1), as previously reported in earlier research by Asrofi et al. [10].

$$Moisture\ Absorption\ (\%) = [\frac{(\mathrm{Wt} - \mathrm{Wo})}{\mathrm{Wo}}]x100 \quad (1)$$

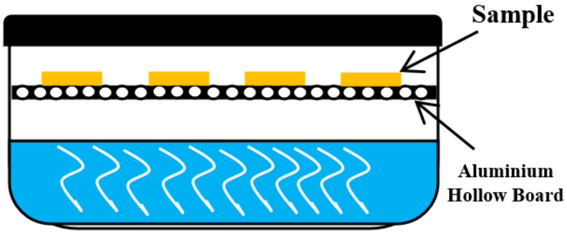

Fig. 2. Moisture Absorption Scheme

2.5. Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy is used to observe the morphology of the PVA/Cassava Starch/Lemon Peel Fiber biocomposite. The instrument used is the Thermo Scientific Quattro S with a magnification of 2500x and 5 kV voltage.

3. Results and Discussion

3.1 Moisture Absorption Properties

Fig. 3 presents the data on moisture absorption from the biocomposite. From the graph shown, significant increases in water absorption occur during the first 90 minutes, followed by stabilization after 180 minutes.

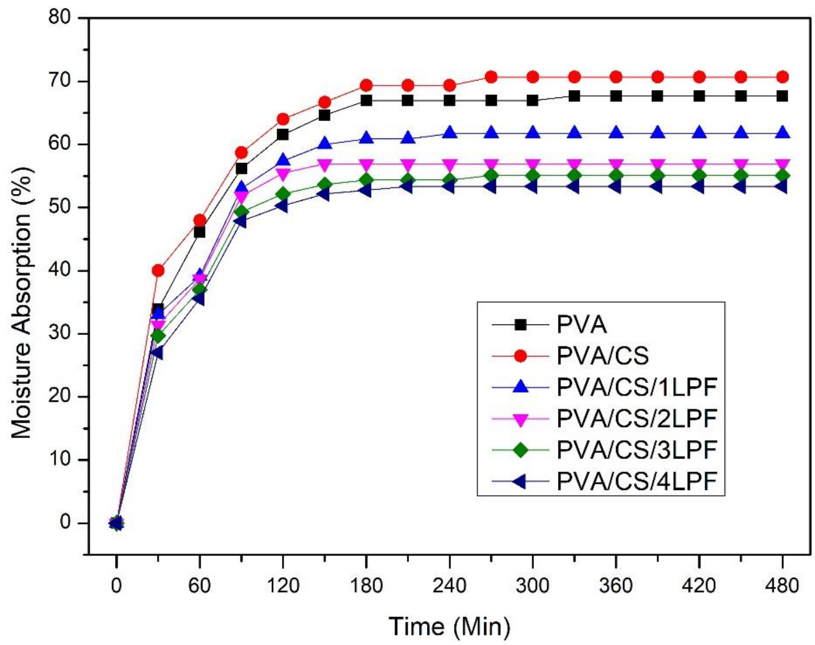

Fig. 3. Moisture Absorption Properties of Biocomposites

The highest water absorption values for each film PVA, PVA/cassava starch (CS), PVA/CS/1LPF, PVA/CS/2LPF, PVA/CS/3LPF, and PVA/CS/4LPF are 67.69%, 70.67%, 61.74%, 56.93%, 55.07%, and 53.37%, respectively. The combination of PVA and cassava starch shows high water absorption levels due to the higher hydrophilicity of the added starch [17]. Furthermore, factors contributing to high water absorption in pure PVA and blended PVA-CS systems include the presence of free O-H groups [18]. In previous research, Tian et al. [19], reported that PVA-CS blend (9:1) resulted in increased water absorption than pure PVA. PVA-CS blends have the highest moisture absorption, this phenomenon is found because both PVA and starch are hydrophilic polymers with abundant OH groups. In addition, air humidity is also a factor that causes the water sensitivity of the blend to be higher, leading to increased water absorption. These free O-H groups allow water to occupy empty spaces within the film.

When 1% lemon peel fibers are added, the water absorption decreases. This phenomenon is favorable since adding lemon peel can reduce water absorption, thereby increasing water resistance. This trend continues as the percentage of added fibers increases. The lowest water absorption value occurs when 4% lemon peel fibers are included. Decreased water absorption is attributed to enhanced hydrogen bonding between molecular interactions between fibers and matrix [20,21]. This phenomenon is supported by SEM results presented in Fig. 4F. Reduced numbers of free O-H groups lead to decreased diffusive abilities of water molecules. Combining PVA/Cassava starch and fibers improves compatibility among these components, lowering overall moisture absorption. Similar findings were reported by Mohammed et al. [14], regarding blends involving wheat starch and sugar palm fibers. Added fibers enhance water resistance effectively while certain loadings may reduce this effect if porosity in the starch matrix increases, causing greater water diffusion. Mahardika et al. [22] observed similar trends where added fibers reduce water absorption in PVA-based composites. Water absorption diffuses through hydrophilic films but decreases with increasing percentages of hydrophobic fibers. Results showing decreased water absorption upon adding fibers align with multiple studies [15,23,24].

3.2 Surface Morphology

Fig. 4 presents the surface morphology of the biocomposite of PVA, cassava starch, and lemon peel analyzed using SEM. Fig. 4A shows pure PVA, which has a smooth surface. The smooth surface of PVA is due to the absence of any mixtures or additional fillers [25]. Fig. 4B shows PVA when cassava starch is added, indicated by the yellow arrow. The resulting interface shows starch in the form of granules or seeds [26]. The water absorption in the mixture of PVA and cassava starch is the highest due to the addition of more hydrophilic starch, which results in free O-H groups [18]. Fig. 4B. illustrates that the bonding between starch and PVA is not perfect.

Fig. 4C. depicts PVA/cassava starch with the addition of 1% lemon peel, showing gaps and porosity or empty spaces in the biocomposite sample, as indicated by the yellow arrow. This is caused by non-uniform fibers that are not evenly distributed and the presence of non-homogeneous bonding between the matrix and fibers [27]. Fig. 4D shows PVA/cassava starch with the addition of 2% lemon peel, highlighting the lemon peel fibers with a yellow arrow. The interface of the film still exhibits porosity. The presence of porosity in the film leads to higher water absorption [28]. Fig. 4E and Fig. 4F show good adhesion at the interface between PVA, cassava starch, and lemon peel fibers, characterized by a wavy surface (indicated by arrows). This phenomenon is attributed to a compact structure, which occurs due to good fiber dispersion without fiber accumulation [22]. Good bonding in the biocomposite results in better water resistance, thereby reducing moisture absorption [29].

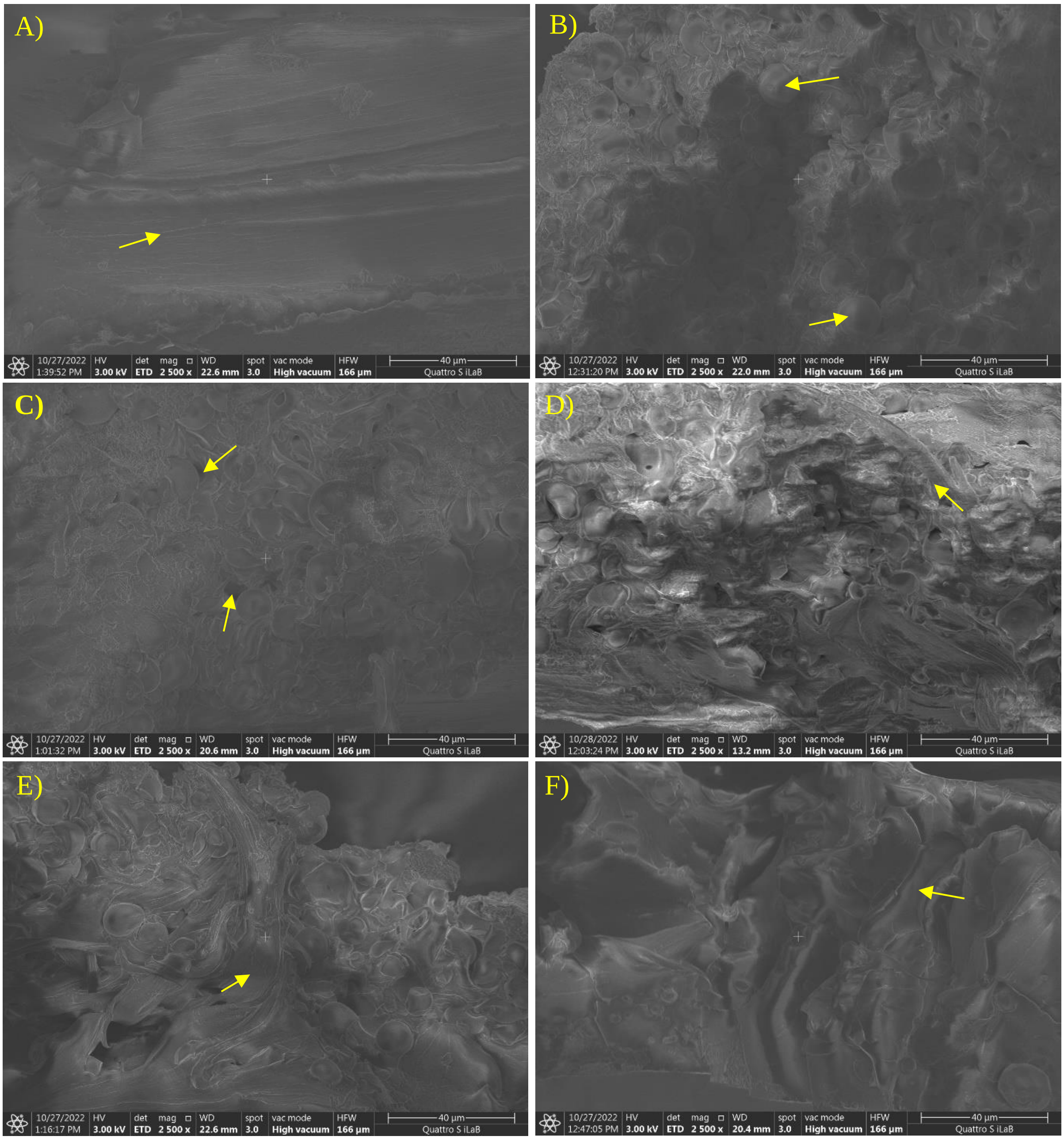

Fig. 1. Surface Morphology Observation of Biocomposite by SEM with variations of: A) PVA, B) PVA/CS, C) PVA/CS/1LPF, D) PVA/CS/2LPF, E)PVA/CS/3LPF, F)PVA/CS/4LPF.

4. Conclusions

The biocomposite composed of Polyvinyl Alcohol (PVA) and cassava starch with the addition of lemon peel fibers was successfully produced. The incorporation of lemon peel fibers into the biocomposite affected the moisture absorption values. The moisture absorption decreased as the percentage of lemon peel fibers increased, achieving the lowest value at 4% lemon peel fibers with value of 53.37%. These results were supported by morphological observations of the biocomposite, which revealed strong interfacial bonding between the matrix and fibers with wave-like structures. The reduction in moisture absorption indicates improved water resistance, aiming to create a new environmentally friendly material.

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