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PREPARATION AND CHARACTERIZATION OF BIODEGRADABLE FOAM FROM JACKFRUIT SEED STARCH AND SUGARCANE BAGASSE BY THERMOPRESSING METHOD

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ABSTRACT

Styrofoam is a trade name for Expanded Polystyrene (EPS) which is composed of styrene monomer. Styrofoam is widely used as food packaging because it provides good insulation in maintaining food conditions and its lightweight nature is suitable for storing large quantities of food to keep it safe without adding weight. However, styrofoam has a negative impact on health and the environment because it is difficult to recycle and difficult to degrade naturally so it is necessary to find an alternative environmentally friendly foam (biodegradable foam). In this study, biodegradable foam was prepared from jackfruit seed starch and sugarcane bagasse by thermopressing method. Biodegradable foam with a composition of jackfruit seed starch and sugarcane bagasse of 70:20 had the highest compressive strength, which was 13.63 Mpa, and with the addition of 10% chitosan the compressive strength increased to 52.2 MPa. Meanwhile, the water absorption capacity of biodegradable foam with a composition of jackfruit seed starch and sugarcene bagasse of 70:20 was 48% and with the addition of 10% chitosan, the water absorption capacity decreased to 16%. The biodegradation rate of biodegradable foam with the addition of 10% chitosan was slightly lower than that of biodegradable foam without the addition of chitosan. The results of the SEM analysis of biodegradable foam with the addition of 10% chitosan appeared to have a denser and more homogeneous structure compared to biodegradable foam without the addition of chitosan.

KEYWORDS: biodegradable foam, jackfruit seed starch, sugar cane bagasse, thermopressing method

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1. INTRODUCTION

Styrofoam is the trade name for Expanded Polystyrene (EPS), which is composed of styrene monomers. Polystyrene (PS), with the chemical formula $(C8H8)n$, is a stable and rigid synthetic resin produced from the polymerization reaction of styrene. Styrofoam is commonly used in the food service industry as disposable cups and boxes or as cushioning material in packaging. Styrofoam provides good insulation in maintaining food conditions and its lightweight nature makes it attractive for packaging large quantities of food to keep it safe without adding weight [1]. Styrofoam has a serious impact on the environment because it is difficult to recycle and also difficult to degrade naturally. Therefore, now many naturally degradable foams or biodegradable foams are being developed using starch and cellulose [2], [3]. Starch and cellulose are derived from biomass, which is a natural resource with abundant availability. Apart from being able to degrade naturally, biomass itself can also absorb carbon dioxide ($CO2$) during its growth, thereby contributing to the reduction of greenhouse gases [4].

Starch that has the potential to be used as a biodegradable foam material is jackfruit seed starch (Artocarpus heterophyllus). Jackfruit is a tropical plant that grows abundantly in Indonesia and can bear fruit year-round. Unlike jackfruit flesh, which is often consumed directly, jackfruit seeds can be consumed by boiling them first. Jackfruit seed starch has been used as a biodegradable plastic material [5]. Meanwhile, sugarcane bagasse, which is a waste product from the sugarcane processing process, contains cellulose, which can also be used as a biodegradable foam material [6], [7]. In the manufacture of biodegradable foam, fillers such as chitosan can be added to increase the compressive strength and reduce the water absorption of the biodegradable foam [8].

Biodegradable foam can be made by several methods, including baking, microwave-assisted molding, extrusion, and thermopressing [9]. Thermopressing is relatively simpler and less expensive than other methods [10].

In this study, biodegradable foam was prepared from jackfruit seed starch and sugarcane bagasse with various weight ratios by thermopressing method. The resulting biodegradable foam was studied for its characteristics, including compressive strength, water absorption capacity, biodegradation rate, and microstructure. The effect of chitosan addition on the characteristics of the biodegradable foam was also studied. The results of this study are expected to contribute to the development of environmentally friendly biodegradable foam by utilizing materials with low economic value.

2. METHODS

Materials used in this study were jackfruit seeds, sugarcane bagasse, chitosan, acetic acid (Merck), glycerol, soy protein isolate, and distilled water. Jackfruit seeds and sugarcane bagasse were obtained from traders in Semarang City, Indonesia. Chitosan and glycerol were obtained from Alfa Chemical. Soy protein isolate was obtained from Multi Chemical Indotrading.

The study was divided into four stages: jackfruit seed starch preparation, sugarcane bagasse preparation, biodegradable foam preparation, and biodegradable foam characterization.

2.1 Preparation of Jackfruit Seed Starch

Jackfruit seeds were washed with water and their skins were removed. Next, the jackfruit seeds were ground using a blender and distilled water was added to facilitate crushing with a weight ratio of jackfruit seeds and water was 2:1. The jackfruit seed pulp was then filtered using gauze and the resulting filtrate was put into a beaker glass. The filtrate was left for 24 hours until a precipitate formed, then the precipitate was filtered. Next, the precipitate was washed with water and dried using an oven at a temperature of 50 oC for 5 hours. Next, the dried precipitate, which is jackfruit seed starch, was sieved using a standard sieve of 100 mesh. Jackfruit seed starch has composition as shown in Table 1.

Table 1: Composition of jackfruit seed starch

Parameters	*wt-%*
Water	9.900
Ash	0.631
Fat	2.029
Protein	2.912
Total carbohydrate*	84.528

***by difference**

2.2 Preparation of Sugarcane Bagasse

The sugarcane bagasse was cut into small pieces and dried in an oven at 105 oC for 1 hour. The dried sugarcane bagasse was then ground using a shredder. The resulting sugarcane bagasse powder was then sieved using a standard sieve of 100 mesh.

2.3 Preparation of Biodegradable Foam

In the preparation of biodegradable foam, the composition used was 10% soy protein isolate and 90% mixture of jackfruit seed starch and sugarcane bagasse with a weight ratio of 85:5, 80:10, 75:15, 70:20, 65:25. The weight ratio of distilled water used to the mixture of jackfruit seed starch and sugarcane bagasse was 1:2. Soy protein isolate and glycerol as much as 5% of the weight of the starch were put into a container and then stirred with a mixer for 20 minutes until a homogeneous dough is formed by adding distilled water little by little. After that, jackfruit seed starch and sugarcane bagasse with a weight ratio according to the variation were put into the dough and stirred again until homogeneous for 20 minutes. After that, the dough was put into a mold with a length of 250 mm, a width of 150 mm, and a depth of 20 mm with a metal guide of 1.0 mm thickness. The mold lid was placed on top of the dough and applied with a thermopressing machine equipped with an electric heating system, then pressed to a temperature of 110 oC for 60 minutes.

Chitosan was added at varying concentrations of 0%, 2%, 4%, 6%, 8%, and 10% of the starch weight. Chitosan was first dissolved in acetic acid and then added to the biodegradable foam mixture.

2.4 Characterization of Biodegradable Foam

Characteristic analysis on the resulting biodegradable foam included compressive strength, water absorption capacity, biodegradation rate, and microstructure. The compressive strength analysis was carried out using a Universal Testing Machine. The water absorption capacity analysis was based on the ABNT NBR NM-ISO 535 standard. The biodegradation rate analysis used the soil burial test method [11], namely a sample measuring 2.5 cm x 5 cm was weighed (m0) and then buried in the soil. After a certain time, the sample was taken and cleaned and then weighed (mt). The percentage of degradation based on mass loss was calculated using the following equation:

$$mass\ loss\ (\%) = \frac{m_0 - m_t}{m_0} x100\% \qquad (1)$$

Microstructural analysis of biodegradable foam was performed using a JEOL JSM6510LA Scanning Electron Microscope (SEM) with a magnification of 5000x.

3. RESULTS AND DISCUSSION

3.1 Compressive Strength and Water Absorption Capacity of Biodegradable Foam

The effect of the weight ratio of jackfruit seed starch and sugarcane bagasse on the characteristics of biodegradable foam, including compressive strength and water absorption capacity, is shown in Figures 1 and 2, respectively.

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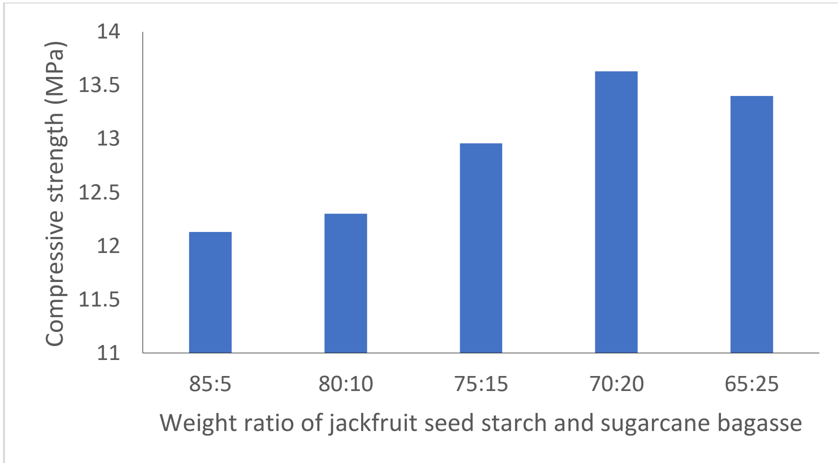

Figure 1: Compressive strength of biodegradable foam at various weight ratios of jackfruit seed starch and sugarcane bagasse

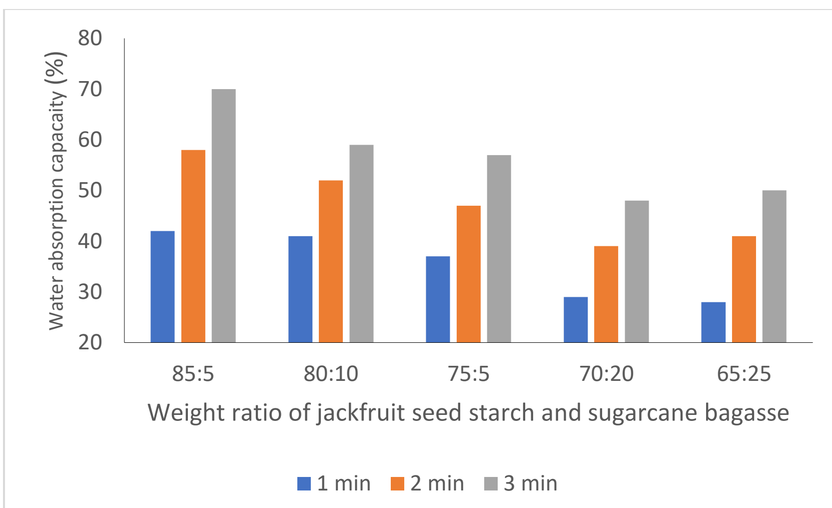

Figure 2: Water adsorption capacity of biodegradable foam at various weight ratios of jackfruit seed starch and sugarcane bagasse

Biodegradable foam with a weight ratio of jackfruit seed starch and sugarcane bagasse of 70:20 has the highest compressive strength of 13.63 MPa. Increasing the content of sugarcane bagasse, which is cellulose, from 5% to 20% can increase the compressive strength of biodegradable foam. However, adding 25% bagasse decreases the compressive strength of biodegradable foam. This can occur because the sugarcane bagasse or cellulose content is too high, making it impossible for the water used in making the

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biodegradable foam mixture to be bound and resulting in a low dough viscosity. Low dough viscosity can result in excessive expansion so that the resulting biodegradable foam becomes more brittle or less strong [12].

Water absorption capacity is the amount of water absorbed by biodegradable foam after being immersed in water. The water absorption capacity analysis was conducted by weighing the sample before and after being immersed in water for varying times of 1, 2, and 3 minutes. The results showed that the longer the immersion time, the greater the water absorption capacity of the biodegradable foam. Increasing the content of bagasse or cellulose in biodegradable foam will decrease the water absorption capacity. This is because cellulose is insoluble in water [13]. The water absorption capacity for 3 minutes of biodegradable foam with a composition of jackfruit seed starch and sugarcane bagasse of 70:20 was 48%.

In biodegradable foam with a composition of jackfruit seed starch and sugarcane bagasse of 70:20, chitosan was added in various variations. The addition of chitosan affected the compressive strength and water absorption capacity of the resulting biodegradable foam, as shown in Figures 3 and 4.

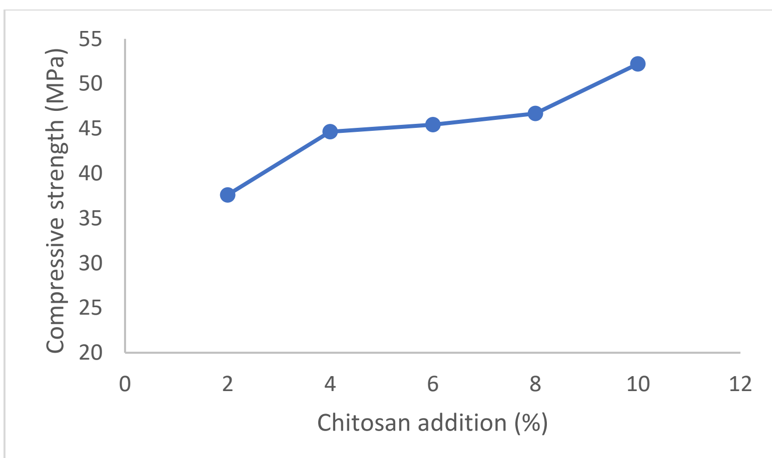

Figure 3: Compressive strength of biodegradable foam at weight ratio of jackfruit seed starch: sugarcane bagasse=70:20 with variations in chitosan addition

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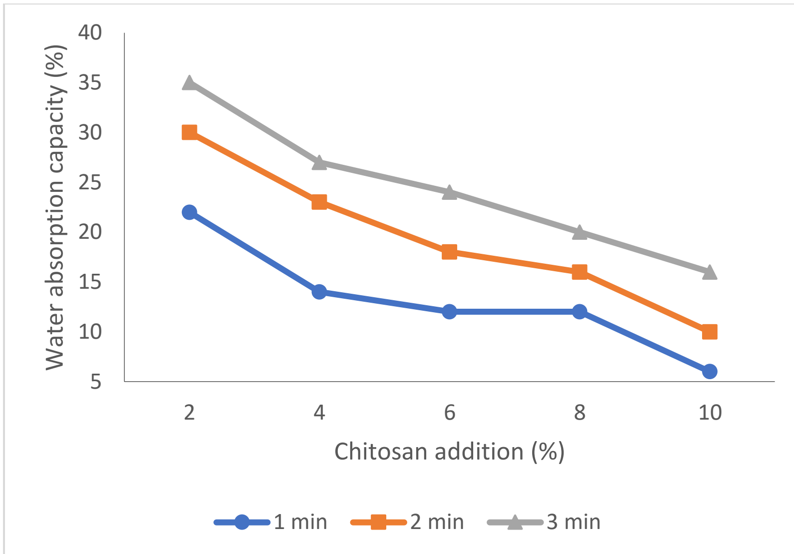

Figure 4: Water absorption capacity of biodegradable foam at weight ratio of jackfruit seed starch: sugarcane bagasse=70:20 with variations in chitosan addition

Biodegradable foam with increasing levels of chitosan has a compressive strength that also increases. The highest biodegradable compressive strength was obtained with 10% chitosan addition, which was 52.2 MPa. The presence of chitosan causes the formation of hydrogen bonds between the -NH3+ groups in chitosan and the -OH groups in starch. The -NH3+ groups are formed from the protonation of the -NH2 groups in chitosan in acetic acid solution. These hydrogen bonds result in a stronger structure of biodegradable foam, resulting in higher compressive strength [14].

Meanwhile, the more chitosan added, the lower the water absorption capacity of biodegradable foam. The addition of chitosan, which is a hydrophobic biopolymer, can reduce the water absorption capacity of biodegradable foam [7]. The water absorption capacity for 3 minutes in biodegradable foam with 10% chitosan added was 16%.

3.2 Biodegradation Rate of Biodegradable Foam

The biodegradation rate based on the mass loss of biodegradable foam without chitosan and with the addition of 10% chitosan by the soil burial test method for 12 days is presented in Table 2. Biodegradable foam with the addition of 10% chitosan has a slightly lower biodegradation rate than biodegradable foam without chitosan. The same results were also obtained in other study [15]. This is because the addition of chitosan causes the biodegradable foam to have a stronger structure due to the hydrogen bonds formed between the -NH3+ group of chitosan and the -OH group of starch. This stronger structure causes the

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biodegradable foam with the addition of chitosan to take a longer time to degrade naturally compared to the biodegradable foam without chitosan.

Table 2: Biodegradation rate of biodegradable foam for 12 days

Materials	*Mass loss (%)*
Biodegradable foam without chitosan	16.52
Biodegradable foam with the addition of 10% chitosan	11.82

3.3 Appearance of Biodegradable Foam

The visual appearance of biodegradable foam from jackfruit seed starch and sugarcane bagasse with a composition of 70:20 without chitosan and with the addition of 10% chitosan is shown in Figure 5(a) and 5(b), respectively. Biodegradable foam with chitosan appears denser and darker in color. Similar results were also obtained in other study [7]. Meanwhile, the results of SEM analysis in Figure 6 for biodegradable foam from jackfruit seed starch and sugarcane bagasse with a composition of 70:20 without chitosan (a) and with the addition of 10% chitosan (b) show that there are differences in the microstructure of the biodegradable foam. In the biodegradable foam without chitosan, the surface appears uneven and hollow, while in the biodegradable foam with the addition of 10% chitosan, the surface appears smoother and more homogeneous.

(a) (b)

Figure 5: Biodegradable foam without chitosan (a) and with the addition of 10% chitosan (b)

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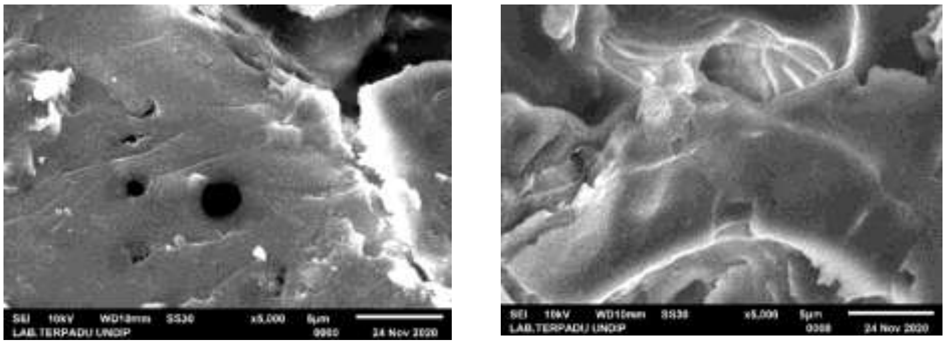

(a) (b)

Figure 6: SEM images of biodegradable foam without chitosan (a) and with the addition of 10% chitosan (b)

4. CONCLUSIONS

Biodegradable foam had been prepared from jackfruit seed starch and sugarcane bagasse by thermopressing method. Biodegradable foam with a composition of jackfruit seed starch and sugarcane bagasse of 70:20 had the highest compressive strength, which was 13.63 MPa, with a water absorption capacity of 48%. The addition of 10% chitosan to the biodegradable foam could increase the compressive strength to 52.2 MPa with a water absorption capacity of 16%. Biodegradable foam with the addition of 10% chitosan had a slightly lower biodegradation rate than biodegradable foam without the addition of chitosan. Furthermore, the structure of biodegradable foam with the addition of 10% chitosan appeared denser and more homogeneous compared to biodegradable foam without the addition of chitosan based on SEM analysis.

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