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Characterization of Sago Starch-Based Biofoam with Corn Husk Fiber Filler

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Abstract

The use of biofoam is one of the ways to reduce plastic waste that pollutes the environment. In this research, we want to develop biofoam from sago starch as a basic ingredient with the addition of corn husk fiber filler and the addition of magnesium stearate which aims to improve mechanical characteristics, thermal, morphological, water absorption and biodegradabillity. Variations of corn husk fiber used were 45 g, 50 g, 55 g and 60 g, with variations in the concentration of NaOH solvent used for cellulose extraction were 3%, 5%, 7% and 9%. The mechanical characteristics (tensile strength) of the resulting biofoam range from 1.37 – 2.45 MPa. The chemical bonding of biofoam was seen through Fourier Transform Infrared Spectroscopy (FTIR) and showed that biofoam is hydrophilic which binds to water so that it is easily degraded by soil. Thermal characteristics were tested through Differential Scanning Calorimetry (DSC) and showed a melting point of 410.68°C at 45 g of fiber and 5% NaOH and a melting point of 410.86°C at 55 g fiber and 5% NaOH. Thermal stability was analyzed through Thermal Gravimetry Analysis (TGA) and the most thermally stable biofoam was biofoam with 45 g of corn husk fiber and 5% NaOH. The surface morphology test using a Scanning Electron Microscope (SEM) showed that the morphological structure of the corn husk fiber biofoam was uneven and there were bubbles on the surface of the biofoam. The water absorption test shows results between 5.72 – 14.43%. The lowest density test for biofoam is using 55 g fiber weight and 3% NaOH concentration, while the highest density is 60 g fiber weight and 9% NaOH concentration. The results of the biodegradability test showed that the biofoam decomposes completely within 40-45 days, the soil moisture factor greatly affects the rate of biodegradability.

INTRODUCTION

Styrofoam is used as a disposable food container. Indonesia's Food and Drug Administration (BPOM) says that styrofoam contains styrene, which is harmful to health. Styrofoam is difficult to decompose, so the Environmentally Protection Agency (EPA) says that styrofoam is the fifth biggest threat to the environment. So, it is important to replace styrofoam with biodegradable foam (biofoam) that is environmentally friendly and can decompose quickly. Starch and cellulose from agricultural products or waste can be used as biopolymers, one of which is to make biofoam.

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Luna et al. (2021) used sorghum (*Sorghum Bicolor L. Moench*) for biofoam development because sorghum has a high cellulose content resulting in good mechanical properties and water resistance. The quality of starch-based biofoam was improved by using sago as a base material. Sago contains 65.7% starch and the rest contains fiber, protein,fat and ash. Sago starch contains cellulose as a macromolecular material (Saleh et al., 2022) As in the research of Chongpeng (Qiu et al., 2021) making bamboo fiber-based biofoam containing a large amount of lignocellulose which is converted into high-value products. Biofoam made from starch has disadvantages, namely it is not resistant to water, it also has poor physical and mechanical properties. Therefore, it is necessary to add additives as modifications to improve mechanical properties, thermal properties and water resistance (Yudanto & Pudjihastuti, 2020). One of the additives that can be added in this biofoam manufacturing process is corn husk. Corn husk has a high cellulose fiber content and has a chemical composition of 15% lignin; 5.09% ash; 4.57% alcohol-cyclohexane; and 44.08% cellulose (Hendrawati et al., 2021).

This research was conducted to study the effect of fiber addition ratio on the manufacture of starch-based biofoam by thermopressing method. In this study, sago starch (*Metroxylon* sp.)-based corn husk fiber biofoam research used 3%, 5%, 7% and 9% NaOH concentrations, sago starch and the fibers used were 45 g, 50 g, 55 g and 60 g corn husk fiber. Sago starch is employed in the production of biodegradable foam due to its abundance, low cost, and high biodegradability (Hendrawati et al., 2021). Sago is a local ingredient in Indonesia with potential as a functional food. It has a low glycemic index, high amylose, and valuable antioxidant content. The starch content of each modified starch was found to be within the range of 85% to 87%. This indicates that the non-starch component present in the sago starch was within the range of 13% to 15% (Marta et al., 2022). Tapioca starch is not used much in industrial food packaging because it is hydrophilic, brittle, and unstable. It is also expensive to produce and requires a lot of land (Marta et al., 2022). Zhang et al. (2020) made biofoam from potato starch modified with chitosan by microwave assisted method. Chitosan and potato starch formic acid solutions were mixed and placed in a mold made of polytetrafluoroethylene for microwave treatment to form starch foam. The results show that chitosan improves the density and compressive properties of starch-based foam. Variations in the weight of different corn husk fibers and NaOH were used to determine the best characteristics of the biofoam produced in terms of mechanical properties, thermal properties, functional groups, morphology, water absorption, density and biodegradability.

MATERIALS AND METHOD

The statistical analysis used in this study is quantitative and qualitative. Sago stems were taken from the sago plantation of North Aceh province, Simpang Keramat sub-district, and starch was processed from the harvest. Corn husk fiber waste is taken from the largest corn plantation in Aceh Province, precisely in Pidie district. Magnesium sterate $[CH_3(CH_2)_{16}CO_2]_2Mg$ was from Sigma-Aldrich-415057-25-G with palmitate salt, 25% stearate salt, 65% (composition). Sodium Hydroxide (NaOH) 90% was from Sigma-Aldrich-1310-73-2. Aquadest is from PT Bratachem in Surabaya, Indonesia. The main equipment used in the study were hot plate and hot press

Biofoam Preparation

Biofoam was made by smoothing corn husk fiber and cooking it in a NaOH solution by varying the concentration from 3% to 9%. The boiling was carried out for 1 hour at 100°C, then the samples were filtered, washed to neutral pH and dried. The corn husk fiber was then immersed in boiling water and heated until it was fully cooked. The sample was analyzed using a series of varying weight amounts, such as 45 g, 50 g, 55 g, and 60 g. Following this, the sample was mixed with 60 g of sago starch and 3 g of magnesium stearate. Then the molding stage uses the thermopressing method, the dough is put into a mold at 170°C for 30 minutes with a weight of 4 kg. Followed by drying using room temperature for 24 hours.

Characterization and Testing

Mechanical characteristics of sago starch based-biofoam with corn husk fiber filler were carried out by tensile test, elongation and Young's Modulus test. The tensile strength test used the ASTM D-638 (American Standard Testing and Material) standard. Analysis of tensile strength and elongation was carried out using a Mechanical Universal Testing Machine. Functional group

Table 1. Tensile strength on sago starch-based biofoam using corn husk fiber.

NaOH Concentration (%)	Corn Husk Fiber Weight (gr)	Tensile Strength (MPa)	Elongation (%)	Modulus Young (MPa)
5	45	1.37	33	5.54
	50	1.96	102.62	2
	55	5.88	16.78	36.77
	60	2.45	48.02	5.11

analysis was carried out with Fourier Transformation Infra-Red (FTIR) to determine the functional groups contained in the biofoam produced. Testing the thermal properties of biofoam was done by Differential Scanning Calorimetry (DSC) analysis to determine the energy absorbed. TGA test records the mass change of dehydrated, decomposed and oxidized biofoam with time and temperature. Scanning Electron Microscopy (SEM) is an electron microscope that uses an electron beam to obtain images of the surface shape of the sample. SEM testing was carried out to see the morphological shape of the biofoam. Biofoam resistance to water was done by swelling test (water absorption). Density analysis was conducted using the Polat method (Etikaningrum et al., 2016) and a biofoam sample with a size of 2.5 × 5 cm was cut. Biodegradability analysis was carried out following the ASTM G-21-70 reference with the method of direct contact of biofoam with soil.

RESULTS AND DISCUSSION

Analysis of Mechanical Properties with Tensile Strength Test

Measurement of mechanical properties, namely tensile strength, elongation and young's modulus was carried out using a texture analyzer. The tensile strength value is inversely proportional to the elongation value and the young modulus is directly proportional to the elongation value. The tensile strength test results with various weight variations of corn husk fiber can be seen in Table 1.

The biofoam tensile strength values obtained in this study ranged from 1.37 Mpa - 5.88 MPa. The lowest biofoam tensile strength is corn husk fiber biofoam with a weight of 45 g while the highest biofoam tensile strength is corn husk fiber biofoam with a weight of 55 g. Arnold (Cabanillas et al., 2019) used pineapple shell fibers, which are considered waste in the industry used as reinforcing material to produce cassava starch-based biofoam by compression molding process. Biofoam was prepared with starch/fiber ratio and then characterized according to its microstructure and physical and mechanical properties. From Figure 1 above, it can be seen that the addition of fiber at a certain weight can increase the tensile strength. High tensile strength in biofoam is expected, because biofoam with high compressive strength is able to withstand the load, so that biofoam is not easily broken when used as a food container (Iriani et al., 2020) From Figure 1 above, it can be seen that the addition of fiber at a certain weight can increase the tensile strength.

Elongation is a measure of a material's ability to stretch when pulled and determines the elasticity of a material. The higher the elongation value, the more elastic the biofoam is so that the material has a large creep value. From Table 1, it can be seen that the highest elongation test value is 50 g of corn husk fiber weight with an elongation value of 102.62%. At corn husk fiber weight of 45 g, 55 g and 60 g. The elongation value of corn husk fiber biofoam decreased. The elongation value obtained in sago starch-based biofoam using corn husk fiber is 16.78-102.62%. For biofoam application as a food container, high elongation is not required.

The modulus of elasticity value in sago starch-based biofoam using corn husk fiber is 2 - 36.77 MPa. In the research conducted by (Marlina et al., 2021) the elastic modulus values obtained ranged from 5.69 - 45.16 MPa. In this study, biofoam with a fiber mass of 50 g, elongation and elastic modulus had significant values compared to the use of other mass variations. The values obtained for elongation were 102.62% and elastic modulus was 2 MPa. While at the use of 60 gr there is a significant decrease in mechanical value compared to the others, with a tensile strength of 2.45 MPa. This occurs possibly due to incomplete stirring. Then during the molding process, the biofoam is too thick which can affect the mechanical properties of plastic, one of which is elongation and elastic modulus. Excessive filler addition causes clustering in the foam material

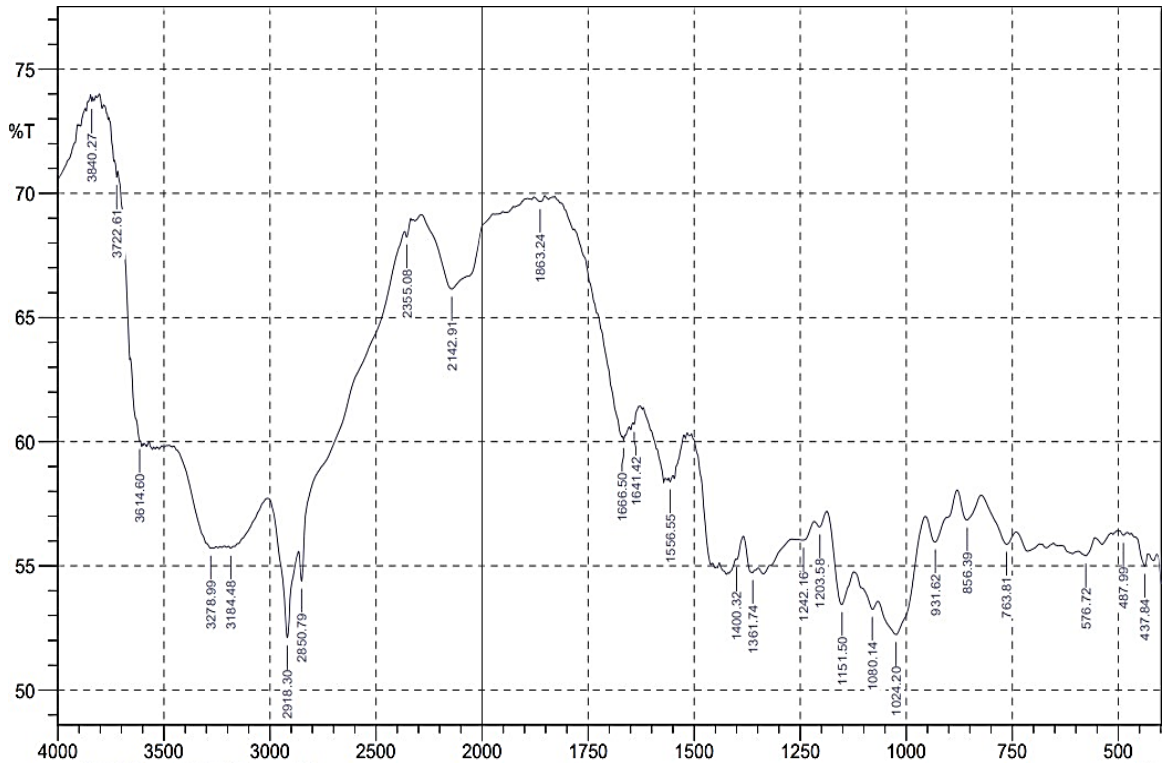


Figure1. Results of FTIR on sago starch-based biofoam using corn husk fiber with 5% NaOH concentration.

matrix, reducing its mechanical properties (Kurt et al., 2024)

Based on the data according to MatWeb Properties, the mechanical values in this study are comparable to biofoam in the category of "polymers, thermoplastics and polylactic acid (PLA) biopolymers" with a tensile strength of 0.200 MPa and flexural strength of 0.300 MPa. The addition of starch can affect the elasticity value because starch is a polysaccharide that is used as the main ingredient in making biofoam and functions as a polymer group binder. The more starch that is added, the stiffer the biofoam produced which causes the elastic modulus value to be greater.

Fourier Transform Infrared Spectroscopy (FTIR) Test

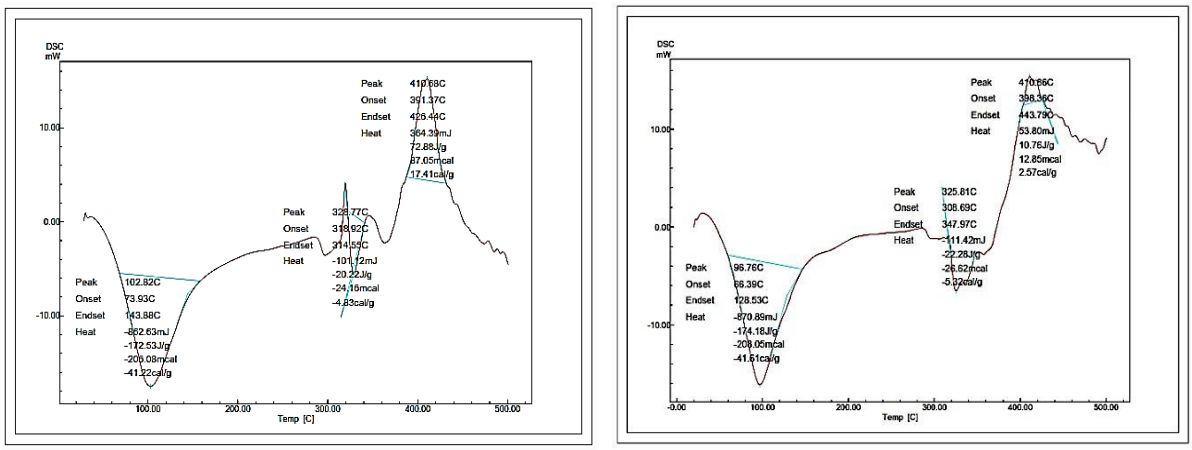
Functional group analysis with FTIR aims to determine the functional groups contained in the biofoam produced. Figure 1 shows the Fourier-Transform Infrared Spectroscopy (FTIR) test on the corn husk fiber biofoam sample with a concentration of 5% NaOH.

The infrared spectrum of biofoam from sago starch and corn husk fiber shown in Figure 1 can be observed that at wave number 3278.99 cm^{-1} which shows the presence of O-H stretching vibrations. This indicates that in corn husk fiber cellulose synthesized from biofoam there are more free -OH hydroxyl groups caused by reduced atoms that can bond hydrogen. The -OH group in cellulose comes from lignin, hemicellulose and extractive substances. (Coniwanti et al., 2018) conducted FTIR analysis on pineapple leaf fiber biofoam and bagasse found that biofoam has C-H, C=C, alkyne, C-N and O-H functional groups. The most functional groups are alkane functional groups. Biofoam also contains many O-H groups so that biofoam can easily absorb water. This O-H group also affects the biodegradable properties of biofoam.

Differential Scanning Calorimetry (DSC) Test

In this study, DSC was conducted to determine how much energy was absorbed by the biofoam. In DSC analysis, using fiber variations of 45 g and 55 g because the surface structure of the biofoam is the most evenly distributed and can compare the DSC results obtained. The results of DSC testing on biofoam with 45 g and 55 g corn husk fiber with 5% NaOH concentration can be seen in Figure 2.

One of the quality indicators of biofoam is their heat resistance, which can be analyzed by DSC. Figure 2 illustrates the reversible changes that begin with hydrated material, dehydration being the



(a) (b)

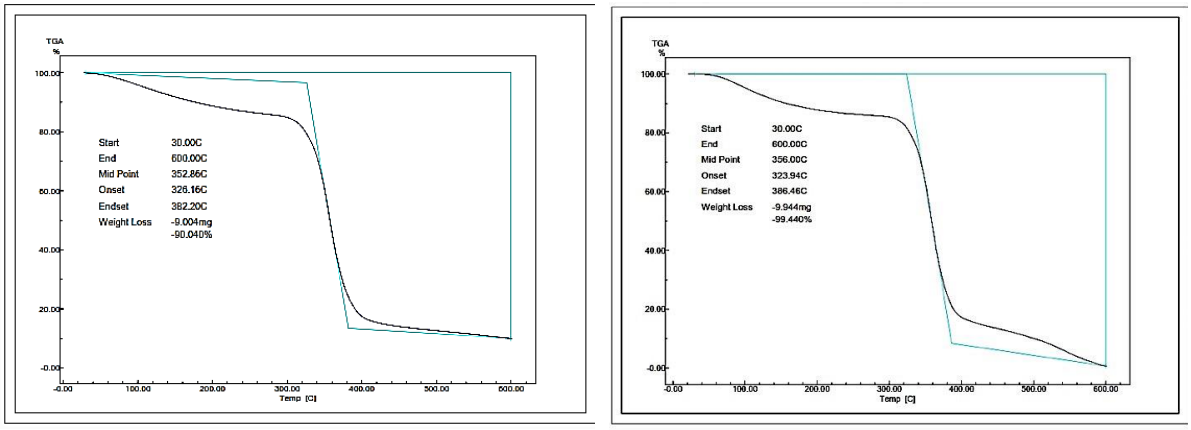
Figure 2. Results of DSC on sago starch based biofoam with corns husk fiber: (a) cellulose fiber 45 g 5% NaOH, (b) cellulose fiber 55 g 5% NaOH.

first process to occur upon heating and indicated by an endotherm. The thermogram of the 45 g corn husk fiber biofoam sample shows several artifacts, namely at 102.82°C showing a very sharp thermogram peak. This peak shows physical changes, namely the loss of water groups that are still present in the synthesis results. It is known that water begins to evaporate at 100°C. This dehydration corresponds to the loss of H_2O molecules from the sample that are physically bound to its surface. At 328.77°C, an endothermic peak starts to occur. This indicates a glass transition state. This point is important for the construction of the biofoam compound lattice. At 410.68°C a thermogram peak appears with an exothermic enthalpy character indicating a crystallization process. At this temperature, the process of preparing the crystal lattice lattice from the original form is amorph has occurred.

For the thermogram of the 55 g corn husk fiber biofoam sample, dehydration occurred at 96.72°C slightly lower than the biofoam sample with 45 g corn husk fiber content. At 325.81°C a sloping peak was formed which is characteristic of endothermic enthalpy and this can be identified as a glass transition. At 410.86°C, a thermogram peak with an exothermic enthalpy character also appeared, indicating a crystallization process. The latent heat of melting (ΔH) for biofoam with 45 g corn husk fiber is 72.88 J/g, while for biofoam with 55 g corn husk fiber is 10.76 J/g. The melting point of the 45 g corn husk fiber biofoam sample obtained is almost the same as the melting point of the 55 g corn husk fiber biofoam sample, indicating that there is a homogenization formation between starch and corn husk fiber. When compared to the melting point of sago starch which is only around 70°C. The addition of corn husk fiber and NaOH into biofoam has increased the melting point of corn husk fiber biofoam. The higher the melting point indicates the more mixing of cellulose fibers added. The melting point is influenced by the hydrogen bonds contained in the plastic. The more hydrogen bonds in biofoam, the higher the melting point will be because the energy required to break the bond will also be greater (Gunawardene et al., 2021) Research conducted by Darni et al. (2021) on the manufacture of biofoam made from a mixture of starch and sorghum stems shows the melting point (Tm) of the biofoam is 93.25°C with a heatflow of -15.28 Mw. In this study, the biofoam produced has a melting point (Tm) which is quite low so it still cannot be used as heat-resistant packaging (Darni et al., 2021). The sago starch-based biofoam with corn husk fiber has a mass of 45 g and a melting point of 318.92 °C, and 55 g and 396.36 °C. DSC analysis shows that sago starch biofoam with corn husk fiber has good thermal characteristics and stability. The more hydrogen bonds in the plastic, the higher the melting point (Gunawardene et al., 2021). This is because the energy required to break the bonds will also be greater, so that biofoam can be used as food packaging.

Thermogravimetric Analysis (TGA) Test

TGA tests are commonly used to determine sample purity, decomposition, thermal degradation, chemical reactions involving weight changes of materials due to adsorption, desorption and chemical kinetics. TGA is a measurement technique using weight variation as a function of heating temperature. This characterization is used to determine the weight loss or weight increase of



(a) (b)

Figure 3. Results of TGA on sago starch based biofoam with corns husk fiber: (a) cellulose fiber 45 g 5% NaOH, (b) cellulose fiber 55 g 5% NaOH.

the sample (gas fixation). The results of TGA testing on 45 g corn husk fiber and 55 g corn husk fiber can be seen in Figure 3.

Biofoam of corn husk fiber 45 g 5% NaOH and corn husk fiber 55 g 5% NaOH showed a decrease in mass in each sample. This shows that the thermal temperature of each variation has undergone an endothermic process due to the formation between starch, NaOH, cellulose fibers from the materials used. From Figure 3, it can be seen from each variation that the mass decrease in 45 g 5% NaOH corn husk fiber biofoam is 9.004 mg and in 55 g 5% NaOH corn husk fiber biofoam there is a mass decrease of 9.944 mg. The resulting curve in the TGA analysis is the change in mass vs temperature as the TGA curve shown in Figure 3. Figure 3 shows that the thermal temperature of each variation has undergone an endothermic process due to the formation between starch, NaOH, cellulose fibers from the materials used 45 g corn husk fiber biofoam and 55 g corn husk fiber shows a decrease in mass (decomposition) in each sample which starts slowly at a temperature of 30°C. At these temperatures weight loss is caused by contaminants and other additives contained in the biofoam. Extreme weight loss begins at temperatures of 350°C to 400°C. At these conditions most of the material is decomposed and completely depleted at 600°C. The total weight loss for both samples is the same at 90.040% and 99.440%. The long peaks shown in the temperature range of 326.16 -382.20°C (45 g mass) and 323.94-386.46°C (55 g mass) indicate that the sample has high thermal stability. Significant weight loss occurred due to the decomposition of gelatin from starch. The information generated by TGA curves can be used to select suitable materials for end-use applications, predict product performance, and improve the quality of biofoam products produced (Marichelvam et al., 2019) Research conducted by (Harunsyah et al., 2020) on biofoam made from starch with bagasse fiber from the results of TGA analysis obtained by bagasse fiber biofoam at 387.86°C decomposed 9.130 mg and still remaining 1.13 mg. TGA thermogram changes occur due to changes in biofoam heat but also by the occurrence of reactions of structural changes and phase changes in the biofoam. So, it can be concluded that the higher the residual weight that is decomposed, the better the thermal resistance of the biofoam.

Scanning Electron Macroscopy (SEM) Test

SEM testing was carried out to see the morphological shape of the sago starch-based corn husk fiber biofoam. SEM testing was carried out to see the morphological shape of 45 g and 55 g corn husk fiber biofoam with 5% NaOH concentration as can be seen in Figure 4.

This testing process is intended to see the comparison between 2 samples with variations in the mass of biofoam, namely corn husk fiber 45 g 5% NaOH, corn husk fiber 55 g 5% NaOH. In the 2nd SEM results obtained on corn husk fiber 45 g 5% NaOH and corn husk fiber 55 g 5% NaOH, it can be seen that there are white clumps and indentations on the surface of corn husk fiber biofoam. In these morphological results that sago starch and fiber in biofoam have not dissolved completely so that corn husk fiber biofoam has an uneven morphology. Factors that occur during stirring also affect the solubility of sago starch and fiber, the longer the stirring time, the solubility of

(a)

(b)

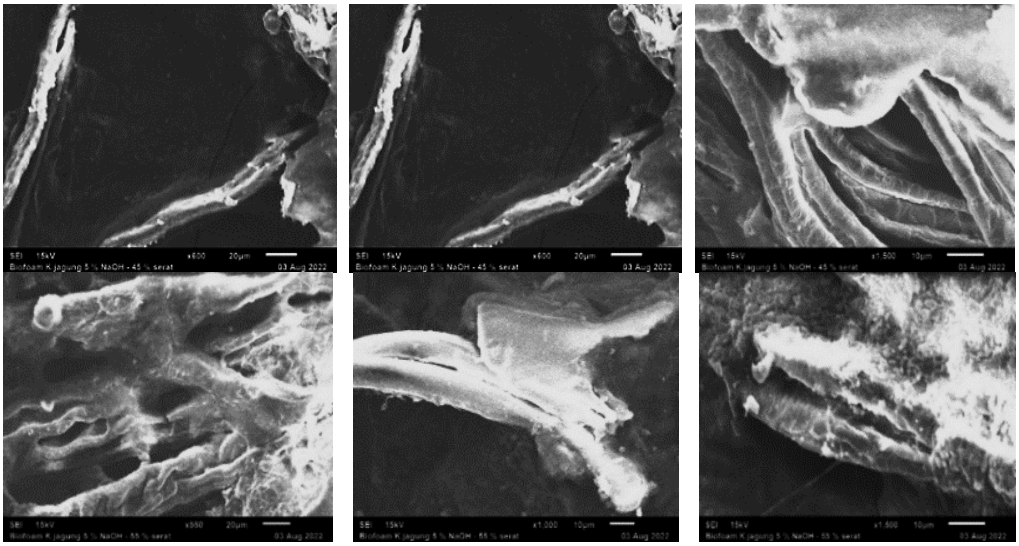


Figure 4. Results of SEM on sago starch based biofoam with corns husk fiber with Magnification of 600 ×. 1000 × and 1500 ×: (a) cellulose fiber 45 g 5% NaOH, (b) cellulose fiber 55 g 5% NaOH.

sago starch and fiber will also be better, while the faster the stirring time will cause the solubility of sago starch and fiber to be less perfect. The morphology of biofoam and noted visible white lumps and grooves on the surface. These features indicate a degree of solubility that is not optimal, potentially influenced by the duration of agitation. The results of biodegradable foam morphology on SEM can be divided into two, namely closed cell and open cell. Biodegradable foam that has closed cells absorbs less water, cell walls look clear and homogeneous. While open cell is the opposite, namely the cell wall is unclear and inhomogeneous and absorbs more water (Hendrawati et al., 2021).

The most evenly distributed corn husk fiber biofoam is the 55 g 5% NaOH corn husk fiber biofoam which can be seen in Figure 4 (b). The viscosity of the polymer matrix can affect the biofoam, morphology and density of the biofoam. Less viscous starch content cannot hold vapor bubbles as effectively as thicker starch content (Engel et al., 2019). It is also described in research by Obradovic et al. (2017) that in the biofoam wall, cells with all the surrounding walls intact are called close cells while the two walls are damaged unevenly in biofoam called open cells. The results of biodegradable foam produced in the experiment obtained include open cell because the structure formed is not the same so that there is a gap between the cell walls. This is what causes this biofoam to be more hydrophilic, which absorbs more water. So, this sago starch-based biofoam research using corn husk fiber is an open cell biofoam because it is seen from its uneven structure and is hydrophilic.

Water Absorption Test

This test was conducted to determine the resistance of biofoam to water absorption. Water absorption is an important parameter for biofoam as a food packaging material because it greatly affects the product to be packaged. The results can be seen in Figure 5.

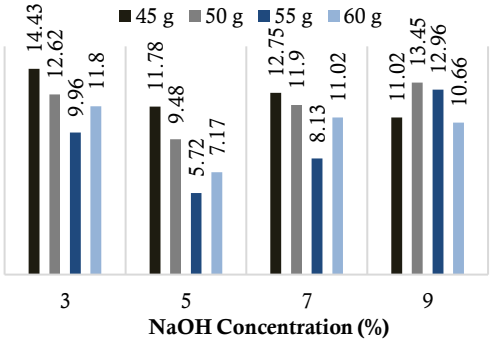


Figure 5. Results of water absorption test (%) on sago starch-based biofoam using corn husk fiber.

The results of the water absorption test in this study ranged from 5.72 - 14.43% with the smallest water absorption found in biofoam with 5% NaOH and a weight of 55 g, while the highest water absorption was found in biofoam with 3% corn husk fiber and a weight of 45 g. The water absorption results obtained obtained a stable value for sago starch-based biofoam using corn husk fiber. Despite the hydrophilic and hygroscopic properties of cellulose, which are the result of inter- and intramolecular hydrogen bonding between the hydroxyl groups in the macromolecular chains, it is

insoluble in water and most organic solvents. There are two methods for the dissolution of cellulose: the first is the dissolution of cellulose in a solvent without any further modification, and the second is the process of derivatization (Tofanica et al., 2022). The decrease in the percentage of biofoam moisture content is due to water that is not bound by corn husk fiber during the biofoam heating process (Coniwanti et al., 2018)

Biofoam with 55 g corn husk fiber at 5% NaOH concentration has a low water absorption compared to other corn husk fibers, this is because the higher the NaOH concentration, the higher the percentage of cellulose that will be obtained, on the other hand, the smaller the NaOH concentration, the smaller the percentage of cellulose. The addition of corn husk fiber affects the water absorption rate of biofoam. Coniwanti et al. (2018) stated the percentage of biofoam water content as the weight ratio of the added fiber increases.

Density Test

As a packaging product, biofoam is expected to have a low density because it will affect the overall weight of the product. The density test was carried out by the Polat method by Etikaningrum et al. (2016) carried out by weighing the mass of biofoam samples that had been cut with a size of 3 × 3 cm and calculating the volume of biofoam to be tested. The density test results is shown in Figure 6.

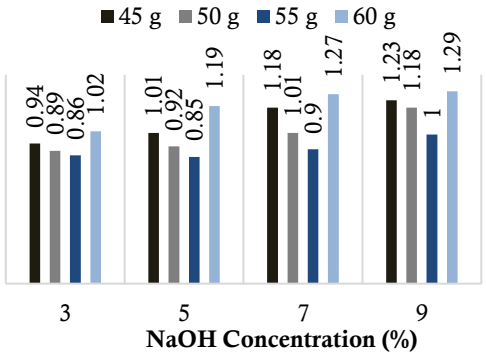


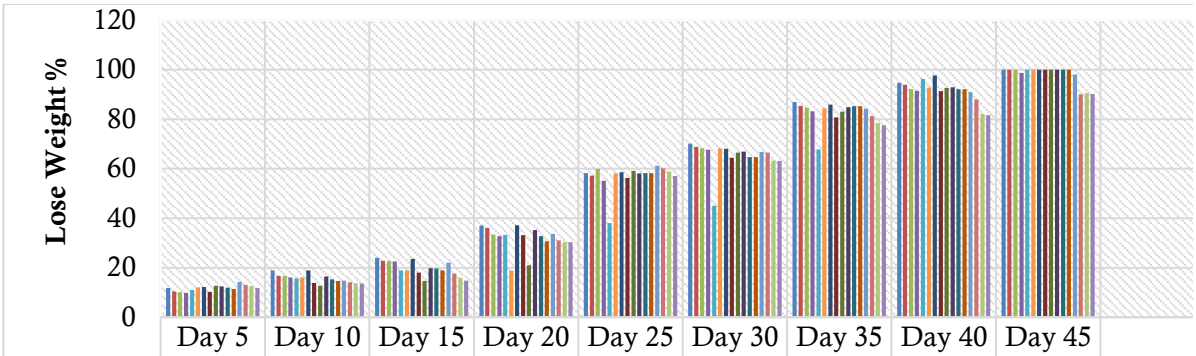
Figure 7. Results of density (g/cm^3) on sago starch-based biofoam using corn husk fiber.

The expansion process in sago starch-based biofoam will produce a hollow structure and is easier to fill with water, so it is necessary to have a filler material in the form of cellulose fibers obtained from corn husk fibers to fill the cavity. The results of the water absorption test in this study ranged from 5.72 - 14.43% with the smallest water absorption found in biofoam with 5% corn husk fiber and a weight of 55 g, while the highest water absorption was found in biofoam with 3% corn husk fiber and a weight of 45 g. The water absorption results obtained obtained a stable value for sago starch-based biofoam using corn husk fiber. The addition of plasticizers can increase water absorption because plasticizers have hydrophilic properties that will stretch the available hydrogen bonds (Qiu et al., 2021). Even if more starch is added than cellulose, the biofoam will produce a structure that tends to be more hollow and can increase the level of water adsorption, because the characteristics of starch are hydrophilic and tend to bind to water (Yudanto & Pudjihastuti, 2020).

Biodegradability Rate Test

To determine the level of biofoam decomposition in soil, a biodegradation test can be conducted. The biodegradation test is conducted to determine the size of the sample broken down by microorganisms in the soil.

Figure 8 shows that the longer the biofoam burial time in the soil, the greater the percentage of damage or mass loss (degradability). The results of the biodegradation of biofoam buried in soil decomposed completely within 40-45 days. Biodegradation of biofoam in this study ranged from 9.82 - 100%. From Figure 8, it can be seen that the biofoam is increasing day by day to degrade. It happens that the addition of sago starch, corn husk fiber and NaOH affects the degradation of biofoam. The soil moisture factor is also very influential on the level of biofoam degradation. The level of biofoam biodegradation that decomposes quickly is biofoam using a fiber weight of 55 g and a concentration of 5% NaOH. According to Sari (2022) biofoam is very quickly decomposed by soil because it contains cellulose levels that are able to bind good water which allows microorganisms to live. Microorganisms will decompose biofoam well because of the cellulose content which causes biofoam to degrade faster. The degradation time of biofoam for 40 days resulted in a percentage of damage of 90-98%, where this value will continue to increase from day to day until the biofoam can be completely degraded in 100% in the soil naturally. The soil moisture factor greatly affects the rate of biodegradabillity (Sari, 2022).



	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40	Day 45
3% : 45	11.78	18.85	23.9	37.03	58.23	70.1	86.9	94.67	100
3% : 50	10.43	16.66	22.78	36.05	57.2	68.9	85.46	93.89	100
3% : 55	10.1	16.72	22.64	33.44	59.95	68.23	84.67	92.2	100
3% : 60	9.82	16	22.54	32.72	55.1	67.69	83.24	91.45	98.7
5% : 45	11.07	15.63	18.89	33.22	38.1	45.09	67.75	96.25	100
5% : 50	12	16.03	18.89	18.9	58.12	68.2	84.32	92.8	100
5% : 55	12.14	18.92	23.57	37.14	58.65	68.12	85.89	97.65	100
5% : 60	10.28	13.82	18	33.11	56.23	64.45	80.68	91.34	100
7% : 45	12.73	12.73	14.6	20.97	59.12	66.5	83.1	92.67	100
7% : 50	12.45	16.48	19.78	35.16	58.15	66.9	84.9	92.9	100
7% : 55	11.89	15.24	19.7	32.71	58.17	64.76	85.23	92.1	100
7% : 60	11.42	14.64	18.92	30.71	58.17	64.76	85.23	92.1	100
9% : 45	14.28	14.7	21.97	33.69	61.2	66.78	84.23	90.95	98.12
9% : 50	13.02	14.17	17.62	31.03	60.23	66.57	81.21	88.02	90.1
9% : 55	12.5	13.79	15.9	30.3	58.9	63.27	78.6	82.1	90.52
9% : 60	11.8	13.65	14.76	30.25	57.12	63.13	77.45	81.68	90.24

Figure 8. Results of biodegradabillity rate on sago starch-based biofoam using corn husk fiber.

CONCLUSION

The mechanical properties (tensile strength) of the biofoam in the study ranged from 1.37 - 2.45 MPa, the elongation value obtained was 16.78 - 102.62%, and the elastic modulus value was 2 - 36.77 MPa. Chemical bonding through Fourier Transform Infrared Spectroscopy (FTIR) shows that biofoam is hydrophilic which binds to water so that it is easily degraded by soil. Thermal characteristics and thermal degradation through Differential Scanning Calorymetry (DSC) obtained 410.68°C melting point at 45 g 5% NaOH corn husk fiber and 410.86°C at 55 g 5% NaOH corn husk fiber. The Thermal Gravimetry Analysis (TGA) test showed that the most thermally stable biofoam was 45 g 5% NaOH corn husk fiber. From the surface morphology test using SEM, it can be seen that the morphological structure of the corn husk fiber biofoam is uneven and there are bubbles in the biofoam. The moisture content indicated by the water absorption test in this study ranged from 5.72 - 14.43%. The results of the biofoam biodegradability test decomposed completely within 40-45 days (100%) with the soil moisture factor greatly affecting the level of biodegradabillity rate.

The biofoam produced from this research is feasible to be developed as an alternative to styrofoam when viewed from the mechanical properties of the tensile strength and elongation tests and its thermal properties as well as the biodegradability rate, but it needs to be optimized again in order to obtain an elastic modulus that is comparable to the elongation obtained and obtain a smaller water absorption. Furthermore, further research is needed to obtain a better morphological structure.

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