KnE Life Sciences
PGPR 2021
First Asian PGPR Indonesian Chapter International e-Conference 2021
Volume 2022

Research article

Synthesis of Biofoam From Sago Waste as a Biodegradable Food Storage Candidate

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Abstract.
The goal of this research was to find a biodegradable material that could potentially replace plastics. The production of biofoam from sago pulp was therefore investigated. The first steps in making biofoam from sago pulp were to characterize it and determine the best conditions for the biofoam polymerization process. According to the results, the whiteness degree of the biofoam raw material was 88.03%, the biofoam water content was 5.44-8.88 cents, the biofoam density was 0.27-0.30, the water absorption from the biofoam was around 0.35-0.66%, and the grade of biodegradability was 44.3%.

Keywords: Biofoam, sago waste, biodegradable, food storage

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Published 07 June 2022

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the PGPR 2021 Conference Committee.

1. Introduction

Characteristics of plastics that are lightweight, strong, durable and inexpensive, making plastic suitable for manufacturing various products. The flexibility of plastic has led to a large increase in usage over the past three decades. The main problem with the use of plastics is that the decomposition time reaches 50-100 years [1]. The widespread use of plastics has driven an increase in global plastic production to reach 288 million tons in 2012, increase 620% since 1975 [2]. Increasing plastic production and the length of the decomposition time, make plastic one of the sea pollutant agents. Plastic pollution in the sea has a detrimental effect on marine biota. In a meeting of The United Nation Environment Assembly in Nairobi, Kenya in early December 2017 noted that we disposed of 4.8 to 12.7 million tons of plastic in the ocean [3]. Among the garbage in the sea is dominated by plastic waste, the proportion of which is consistently varied between 60% and 80% of the total waste in the sea. There needs to be an action to replace the synthetic plastic material with materials that are environmentally friendly namely with biodegradable material.

Some approaches have been made to obtain biodegradable biofoam material as a plastic replacement material that is more environmentally friendly, starch is one as its material. Biofoam starch has been widely recognized as one of the best choices for disposable packaging applications. Biofoam starch can be easily processed in several ways including extrusion, baking or compression, injection molding, and microwave heating using water as a blowing agent [4]. In addition, the starch foam can be used to replace polystyrene products, but it must be known that thermoplastic starch composites are weak in their mechanical properties [5].

Efforts to improve the quality of biofoam from starch were developed by replacing basic ingredients from sago pulp waste. Sago pulp waste contains 65.7% starch and the rest contains crude fiber, crude protein, fat, and ash. In sago waste, it contains cellulose as a macromolecule material. Cellulose usually finds on plant cell walls and generally reacts with other substances such as lignin and hemicellulose, making it difficult to find in pure form [6]. Waste of sago pulp from biofoam base material is chosen because it has characteristics that are easily formed / elastic, and have a high viscosity [7].

2. Methodology

2.1. Production procedures of biofoam from sago pulp production procedures

The production of biofoam begins with the characterization of sago pulp waste, and the determination of optimum conditions for the polymerization process. Bleaching of biofoam raw materials is carried out in accordance with patent no.xxx. While biofoam production is in accordance with the patent no. xxx.

2.2. Analysis of biodegradable biofoam

Biofoam characterization is carried out by analyzing physical, mechanical, thermal and biodegradability properties. Physical analysis is the observation of water content, density, color, water absorption and morphological structure with SEM (Scanning Electron Microscope). Mechanical analysis is an observation of the tensile strength parameters and compressive strength with UTM. Thermal analysis with parameters of the glass transition point and melting point using the Differential Scanning Calorie meter (DSC) tool. Biodegradability analysis is carried out both quantitatively (DNS).

3. Results and Discussion

3.1. Physicochemical characteristics and thermal sago pulp

The characteristics of sago pulp including the composition of water, starch, lipid, protein, fiber and amylose to amylopectin ratio (Table 1) will affect the flow and thickness of starch or flour [8]. The characteristics of these raw materials will affect the expansion capability of biofoam, in addition to the influence of process conditions. This agricultural waste experienced a reduction in size of 80 mesh before being sterilized.

Table 1: Physicochemical characteristicsof sago pulp.

No	Parameter	Sago pulp	Tapioca	Hydrophobic starch
1	Rendemen (%)	40	-	-
2	Water (%)	11.8993	14.11715	9.2937
3	Ash (%)	5.911	0.16825	1.6917
4	Protein (%)	1.58155	0.3079	0.1978
5	Lipid (%)	0.6126	0.198	2.1098
6	Fiber (%)	16.65975	2.06185	2.50225
7	Carbohydrate (%)	63.3355	83.1466	84.0683
8	Energy (Cal/100g)	257.2465	323.4369	343.7309
9	Starch (%)	48.555	75.60835	77.89025
10	Amylose (%)	14.38705	27.123	27.3586
11	Amilopektin (%)	34.16785	48.48525	50.5316

The starch content affects the expansion ability of biofoam. While fiber affects the ability to form a sturdy structure of biofoam. Amylose will maximally expand at 225 ^{o}C and amylopectin at 135 ^{o}C [9]. Thus starch with high amylose content requires a higher process temperature compared to starch containing high amylopectin. In addition, amylose tends to expand longitudinally or extensively while amylopectin will expand radially so that the product tends to have a larger diameter. Biofoam produced by the starch raw material with high amylopectin levels has smaller pores and lower density compared to biofoam which uses starch as a raw material with high amylose content. High levels of amylose also tend to be less developed and stiff, but have a lower sensitivity to water. The sago pulp analyzed has a high amylose content.

3.2. Thermal properties of sago pulp flour

Analysis of the thermal properties of sago pulp is using the Rapid Visco Analyzer (RVA) instrument. Produces thermal properties include gelatinization temperature and

maximum temperature during heating with a certain temperature. Besides, RVA also delivers a pasta profile (profile of dough formation) which includes parameters of maximum viscosity, viscosity breakdown, setback viscosity, and final viscosity.

TABLE 2: A. thermal parameter of sago pulp.

Parameter	Sago pulp
Gelatinization temperature (°C)	72
Maximum temperature (°C)	87
Maximum viscosity (cp)	4869
Breakdownviscosity (cp)	3435
Setbackviscosity (cp)	6845
Final viscosity (cp)	8279

Based on the results of the analysis with RVA, it can be seen that sago pulp has a high increase in viscosity during heating. This property is largely determined by the content/composition of the ingredients contained in each sample. Sago pulp has increased viscosity during heating because its starch content is quite high.

Based on the RVA curve (Figure 1) produced, the sago pulp sample has a typical curve shape for starch-containing samples. This is indicated by the increase in viscosity until it reaches the peak, then decreases after the peak gelatinization is exceeded. Sago pulp has a gelatinization temperature of 72 oC, a maximum temperature of 87 oC, with a maximum viscosity of 4869 cP, a viscosity breakdown of 3435 cP, a setback viscosity of 6845 cP, a final viscosity of 8279 cP. Sago pulp has a high setback viscosity, which indicates that the sago pulp gel is easily retrograde after the temperature has decreased. The final viscosity it has is also high which shows good gel formation potential.

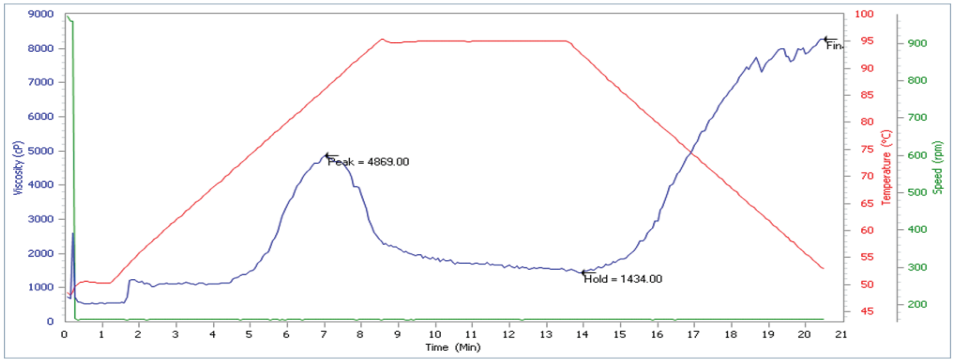

Figure 1: The RVA curve of sago pulp.

Analysis of the thermal properties of sago pulp was also carried out using the Differential Scanning Calorimeter (DSC), to determine the temperature at which glass transitions and melting points. Glass transition temperature is the temperature when the

material changes from the amorphous phase to the glass phase which contributes to forming a rigid structure in biofoam products. The results of DSC analysis of sago starch flour showed that sago pulp flour had a relatively low melting point, namely 129.59 ^{o}C, with melting enthalpy -129.32 J/g.

3.3. The Characteristics of functional properties and morphological structure of sago pulp

One of the physical properties of biofoam observed was water absorption. to determine water absorption, it can be done with DSA measurements. DSA measurement results show water absorbed in biofoam in a certain time interval. The results showed that the sago pulp flour had the highest water absorption capacity of 1563.05%, tapioca was 65.8%, while the lowest was hydrophobic starch with a value of 13.31%. The high absorption of water in sago pulp flour is due to the fact that most of the fiber in sago pulp flour comes from the hemicellulose group. Hemicellulose is part of the cell walls of plants that absorb the most water. This is because hemicellulose has a larger amorphous region compared to cellulose [10].

Observation of the morphological structure using Scanning Electron Microscopy (SEM) can be seen in Figure 2. Observation using SEM not only gives a description of the shape or structure of the morphology of the raw material but also its size. While the degree of whiteness of sago pulp, the result of the optimization of the bleaching process of sago pulp as biofoam material was highest at 88.03%.

3.4. Characterization and morphological structure of biofoam products

Water content parameters, the results of the analysis show that the water content of biofoam ranges from 5.44-8.88%. This value is much higher than styrofoam which is less than 1% [11]. The difference in the value of water content can be caused by the composition of materials, processes and storage conditions. When compared to styrofoam, the water foam content of sago pulp is much higher because biofoam products are naturally hydrophilic from the nature of starch which is hygroscopic so that it absorbs moisture from the environment [12], [13]. Addition of PVOH and glycerol has an effect on increasing water content. This is due to the ability of PVOH and glycerol to absorb water during processing so that the water content of biofoam at the end of the process increases. The same condition shows a decrease in the density of biofoam

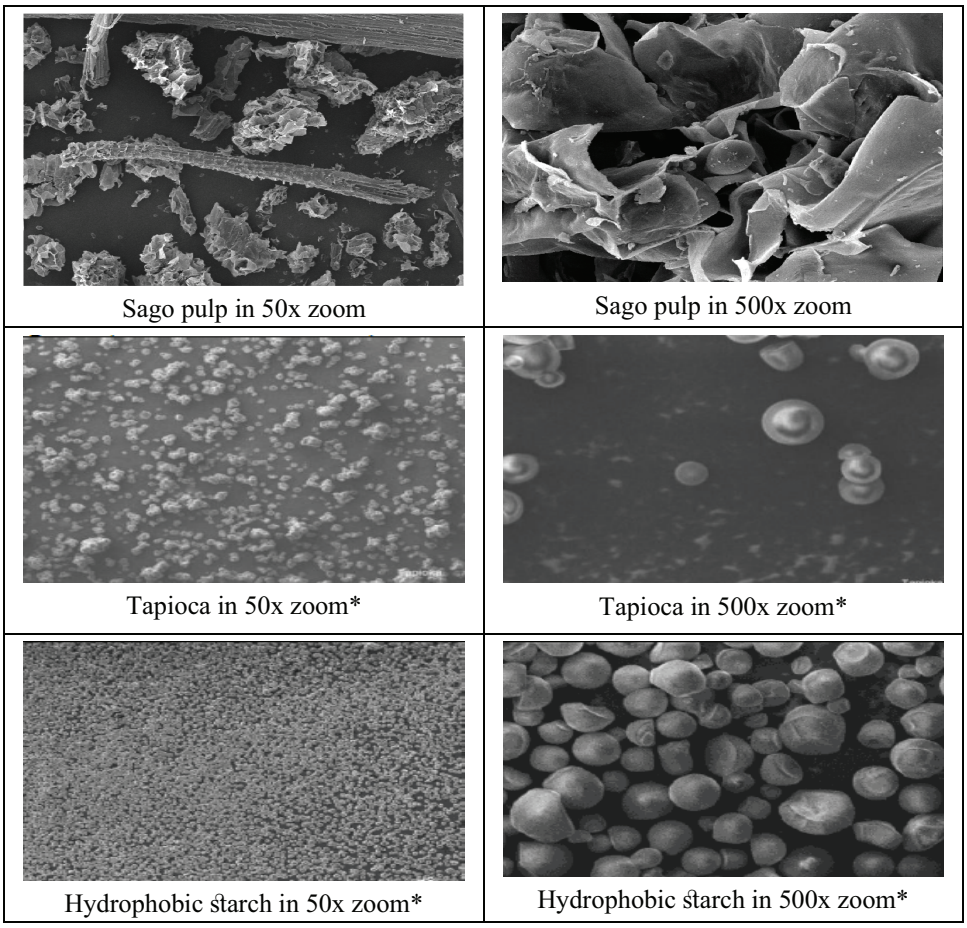

Figure 2: SEM of sago pulp, tapioca flour and hydrophobic starch *) with the approval of [14].

made from sago pulp. This range of biofoam density values is 0.27-0.30. The addition of PVOH and glycerol turned out to have a negative effect on the increase of biofoam hydrophobicity. With increasing concentrations of biofoam and glycerol, the absorption of water from biofoam from sago pulp has decreased. The value of absorbing water from biofoam ranges from 0.35-0.66%, much smaller than styrofoam which also ranges from 26%. The morphological structure of biofoam can be seen in Figure 3. The structure of hollow biofoam slices shows the process of expansion due to the gelatinized starch content.

3.5. Biodegradability properties

The biodegradability analysis of biofoam products is carried out quantitatively through enzymatic reactions. Biofoam which has reacted with enzymes will produce sugar which is analyzed by the dinitro salicylic acid (DNS) reagent. In this study the maltose sugar standard was used to produce a standard absorbance curve as presented in. The results of the degradation of biofoam products with DNS reagents then read the

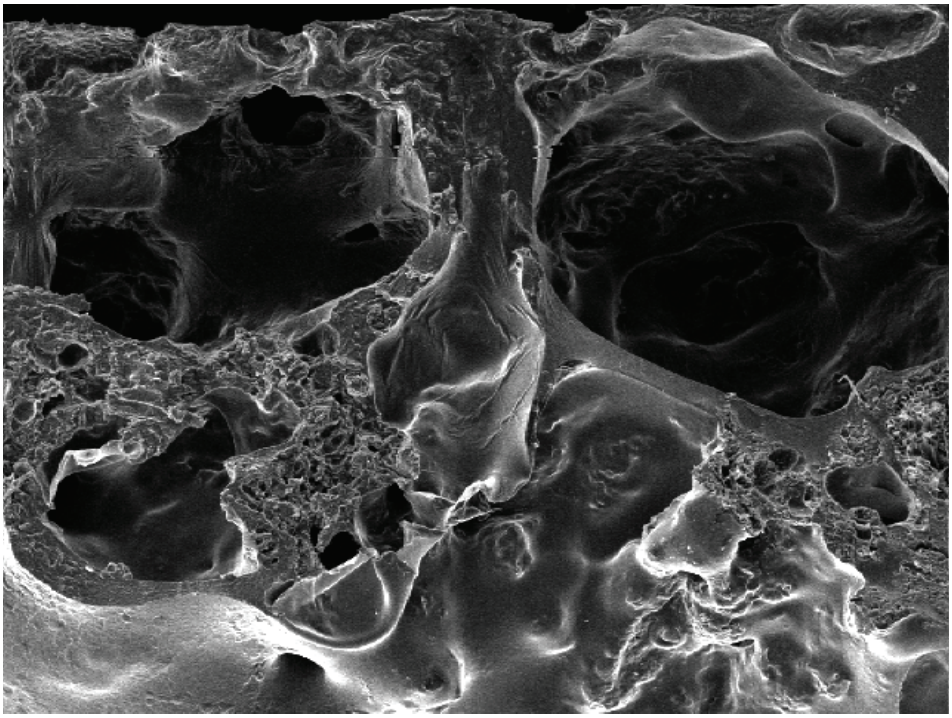

Figure 3: SEM of biofoam in 35x zoom.

absorbance to find out the sugar content in it. The value of reducing sugars or the value of hydrolyzed starch will be assumed to be a degraded part so that the percentage of biodegradability of thermoplastics will be obtained. The higher the level of sugar detected, shows that biofoam products are more easily degraded. Biofoam from sago pulp has a biodegradability level of 44.3%. That is, in the condition of the analysis carried out in this study, as much as 44.3% of the weight of biofoam can be degraded enzymatically.

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