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# Characteristics of Biodegradable Foam with Proportional Treatment of Tapioca Flour and Soybean Peel Flour with Added Glycerol

*Arini Rista Fauzi[1], Ulya Sarofa[1*] and Dedin F. Rosida[1]*

[1] *Food Science and Technology, Faculty of Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, Indonesia.*
*Corresponding author: sarofaulya@yahoo.co.id*

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CORRESPONDING AUTHOR

*E-mail: sarofaulya@yahoo.co.id

**ABSTRACT**

The food industry has increased so the need for food packaging has also increased. One of the packaging that is often used is Styrofoam, where Styrofoam contains chemical substances namely styrene, butyl hydroxytoluene, and polytyrene which can migrate to food and is harmful to humans because it is carcinogenic. One of the alternatives to styrofoam is bio-foam. Biofoam is an alternative packaging to replace styrofoam because it is made from natural raw materials, namely a mixture of starch, fibers, and synthetic polymers that are easily biodegradable. The natural ingredients used in the study were tapioca flour as a source of starch and yellow soybean hull flour as a source of fiber. The purpose of this study was to determine the effect of the ratio of proportions in opioids and yellow soybean hulls with the addition of glycerol on the characteristics of the bio-foam produced. This study uses a completely random design method with 2 factors. Factor I is the ratio of tapioca flour and yellow soybean hull flour, which is 70:30, 50:50, and 30:70. Factor II is the addition of glycerol by 5%, 10%, and 15%. The observation data was analyzed using ANOVA, if there was a real interaction or influence on the two treatments, then a DMRT test was carried out with a confidence level of 5%. The best treatment results were obtained through the Zeleny method, namely the treatment of the proportion of tapioca flour as a basic ingredient: yellow soybean hulls flour (30:70) and the addition of glycerol of 15% with the results of the analysis of moisture content of 15.76%, starch content of 17.53%, density of 1.13 gr/cm3, water absorption of 14.67%, biodegradability of 8.14% (±8 weeks) and tensile strength of 11.03Mpa

## 1. INTRODUCTION

### *1.1. Research Background*

The food industry has increased, causing a high need for food packaging. The food industry tends to produce disposable food packaging such as styrofoam. Styrofoam is a type of plastic made from polystyrene. Styrofoam is used as a container for food or beverages because it is cheap, easy to get, non-corrosive, and not easily damaged [1] besides that it can be thrown away immediately if it has been used or with a lump sum so that unused food packaging has become one of the environmental problems globally and tends to damage the environment. This is because unused food packaging becomes waste and takes a long time for the decomposition process in the soil. Research by the Indonesian Institute of Sciences (LIPI) shows that in 18 Indonesian cities, 270,000 to 590,000 tons of waste were found to be styrofoam, which is more dominant than other types of waste [2]. Styrofoam takes a million years to decompose in a landfill environment without air and light, even styrofoam will never completely decompose when styrofoam is exposed to sunlight and wind [3].

Styrofoam is also a plastic product that must be avoided for use because it can harm consumer health, the content of chemical substances contained in styrofoam, namely styrene, butyl hydroxytoluene, and polystyrene, can migrate to packaged food and are harmful to humans because they are carcinogenic [4]. Recent research proves that, in food packaging material, dioctyl phthalate (DOP) is found to contain benzene, a chemical solution that is difficult for the digestive system to digest. This benzene also cannot be excreted through feces (feces) or urine (urine). As a result, the substance accumulates and becomes more and more covered in fat. This is what can trigger the emergence of cancer. In addition to some of the things mentioned above, other impacts such as environmental, economic, and safety impacts have prompted many scientists to replace some petrochemical-based polymers with other types that are easily degradable naturally, such as biodegradable foam (bio-foam

Biodegradable which means that this product can decompose on its own naturally because of its nature made of organic materials (plants), The foam in question is the use of starch that expands due to the heat and pressure process. Biofoam is made from a mixture of starches, fibers, and synthetic polymers that are biodegradable and can be used as an alternative packaging to replace styrofoam because it is made from natural raw materials [4]. The research that has developed biofoam products has developed its such as biofoam made from cassava starch and empty bunch fiber of palm oil [5], biofoam made from sago starch and bagasse sugarcane by [6], biofoam made from durian seed starch and nanocellulose tea grounds by [7]. In this study, the researcher used tapioca flour as a source of starch and soybean hull flour as a source of fiber.

One of the sources of starch whose production is quite high is tapioca considering its cheaper price when compared to other sources of starch. Tapioca has high starch levels, this condition will affect the gelatinization process [8] Tapioca also has a higher gelatinization temperature compared to other starch sources. However, considering that biofoam products produced from starch are generally brittle, rigid, and hydrophilic, fiber and some biofillers must be added to produce packaged products according to the desired characteristics.

Based on the above background, this study uses tapioca flour and yellow soybean hulls flour as the main raw materials with the addition of glycerol. The use of yellow soybean hulls flour as a source of crude fiber which is useful for reducing the moisture content of the product. In a study conducted by [9] explained in their research that the tensile strength of biofoam can be increased by mixing fibers. The yellow soybean kernel hulls has a content of 24.84% crude fiber, 17.98% crude protein, 5.5% fat [10]. The utilization of yellow soybean hull flour is still low with a high crude fiber content. One way to increase the economic value and long storage is to make a product, one of which is biofoam.

The addition of glycerol to the biofoam manufacturing process here as a plasticizer material that functions to increase elasticity and as a stabilizing material, namely it can reduce the degree of hydrogen bonding and increase the distance between molecules from the polymer.

There are three methods of forming biofoam, namely the thermopressing method, the extrusion method, and the baking method. The baking method also known as the oven method is a method of making biofoam by heating it using an oven, this method is easier to do and can be done by anyone without special tools such as thermomachine pressing (thermopressing method) and alatex truder [4] [12].

Research on the effect of the proportion of tapioca flour: yellow soybean hull flour with the addition of glycerol on biofoam is not yet known. Therefore, in this study, research was conducted on the effect of the proportion of tapioca flour: and yellow soybean hull flour with the addition of glycerol on the characteristics of the biofoam produced.

### *1.2. Literature Review*

Research on biofoam using starch and fiber as basic ingredients has been carried out by several researchers. According to [5] explained that biofoam is made from natural materials, making it easier for biofoam to decompose naturally in the soil. The material that is widely used in making biofoam is starch, however, biofoam produced from starch still absorbs water easily and is fragile. Therefore, biofoam products need to be added with other ingredients such as crude fiber and plasticizers.

The starch in tapioca flour contains amylose and amylopectin. Amylose has a smaller size with an unbranched structure. Meanwhile, amylopectin is a large molecule with a many-branched structure and forms a double helix. During the gelatinization process of heated starch, some of the double helix of the amylopectin fraction stretches and falls apart when hydrogen bonds are broken. when a higher temperature is applied, more hydrogen bonds will be broken, causing water to be absorbed into the starch granules. In this process, amylose molecules are released into the water phase that surrounds the granules, so that the structure of the starch granules becomes more open, and more water enters the granules, causing the granules to swell and their volume to increase. The water molecules then form hydrogen bonds with the sugar hydroxyl groups of the amylose and amylopectin molecules. In the outer part of the granule, the amount of free water decreases, while the amount of released amylose increases. Amylose molecules tend to leave granules because they are shorter and dissolve more easily. This mechanism causes biofoam produced from starch to still absorb water easily and be brittle. Therefore, the use of biofiller in the form of fiber in making biofoam is very necessary.

The addition of biofiller in the form of fiber improves the mechanical properties of the biofoam, where with the addition of this fiber, the surface area will be greater and the interaction or adhesion power between the two materials will be greater so that the mechanical properties will be better, such as increasing tensile strength and reduce the water absorption capacity of biofoam. The crude fiber in yellow soybean hull flour has a high cellulose content. This makes yellow soybean hulls flour a suitable biofiller for making biofoam.

The cellulose fiber in yellow soybean hull flour is composed of a bond structure of aromatic C=C functional groups which have water-resistant properties and hydrophilic C=O carbonyl which binds water molecules in the environment so that degradation occurs easily [13]. In research conducted by Ref. [14] it was also explained that the addition of tea dregs as a source of crude fiber showed that the density value obtained increased. This is because fiber from tea dregs as a filler can fill empty spaces in the matrix thereby increasing the density of the biofoam. Therefore, this study used a comparison of the proportions of tapioca flour: yellow soybean hull flour with the addition of glycerol.

Previous research has previously developed biofoam products, such as biofoam made from cassava starch and empty palm fruit bunch fiber by Ref. [5], biofoam made from sago starch and sugarcane bagasse by Ref. [6], biofoam made from starch durian seeds and tea dregs nanocellulose by Ref. [7]. In this study, researchers used tapioca flour as a source of starch and soybean hull flour as a source of fiber

The addition of glycerol to biofoam products functions as a plasticizer. This plasticizer will be located between the biopolymer chains so that the distance between starch and cellulose will increase. This reduces the hydrogen bonds between starch-cellulose and is replaced by hydrogen interactions between starch-glycerol and glycerol-cellulose so that the biofoam will be more elastic. The addition of glycerol resulted in a decrease in the tensile strength value of biofoam. This is due to the space that occurs because the bonds between polysaccharides are broken by glycerol and causes the bonds between molecules in the biofoam to weaken. Glycerol will increase the molecular mobility of the polymer chain which is indicated by the biofoam becoming more elastic. The greater the proportion of glycerol used, the more elastic the biofoam, but if too little glycerol is added, the resulting biofoam will be less elastic.

Glycerol and starch have hydrophilic properties so they can bind water. Water is a growth medium for most bacteria and microbes, so high moisture content causes biofoam to degrade more easily. This is because glycerol is the simplest glyceride compound with hydroxyl which is hydrophilic and hygroscopic so it easily binds with water. Glycerol does not bind to starch molecules but interacts with water molecules through hydrogen bonds which causes a decrease in the compactness of the starch matrix and crude fiber. This has an impact on increasing the solubility of biofoam. Increasing the concentration of glycerol can increase the solubility of biofoam because of the nature of glycerol as a plasticizer [15]. Supported by [16] in their research, they explained that the phenomenon of decreasing tensile strength due to the influence of increasing plasticizer concentration can be explained by the role of plasticizers which reduce the strong molecular attraction between starch and encourage the formation of hydrogen bonds between starch molecules and plasticizer. The weakening of hydrogen bonds between starch chains causes a decrease in the tensile strength of biofoam. Research by [17] showed that using glycerol concentrations of 5%, 10% and 15% in making biofoam can increase the water content, solubility, and expansion of the resulting biofoam. The use of 10% glycerol is the best treatment, producing characteristics of a thickness of 78.52nm, water content of 18.84%, and a tensile strength of 4.65Mpa.

The procedure for making biofoam in this research uses the oven method based on research conducted by Ref. [18], namely making biofoam using a baking process using an oven system at a temperature of 100°C for 60 minutes. A lot of research has been done on biofoam, but the ones that are commercial and marketed are still limited. This is because biofoam products still have several weaknesses, such as leaking easily and low mechanical properties. For this reason, this research was carried out using starch sources from tapioca flour, crude fiber from yellow soybean bran flour, and plasticizer from glycerol. The addition of yellow soybean hull flour and glycerol as biofiller is expected to produce biofoam products that can compete with commercial styrofoam

### *1.3. Research Objective*

This research aims to determine the effect of the proportion ratio of tapioca flour and yellow soybean hulls with the addition of glycerol on the characteristics of the biofoam produced and determine the best treatment for the proportion ratio of tapioca flour and yellow soybean hulls flour with the addition of glycerol which can produce biofoam with good characteristics.

## 2. MATERIALS AND METHODS

### *2.1. Material and Tools*

The main ingredients for making biofoam are aquadesh, tapioca flour, soybean hulls flour and glycerol. Materials for analysis are distilled water, 10% alcohol, 25% HCL, 45% NaOH, 95% ethanol, acetic acid, iodine solution, H2SO4, NaOH, luff schrool solution, 10% KI solution, and K2SO. These chemicals were obtained from a chemical shop in the Surabaya area. The fertilizer used for the biodegradable test is soil fertilizer from UD. Sami Jaya.

The tools used in this research include 80 mesh sieve, stove, cabinet dryer, analytical balance, blender, glassware, desiccator, dropper pipette, electric oven, water bath, Shimadzu Ag-X 50kN UTM (Universal Testing Machine), FTIR (Fourier Transform Infra-Red) and SEM (Scanning Electron Microscope).

### *2.2. Design of Experiment and Analysis*

This research used a Completely Randomized Research Design with 2 factorials, namely the comparison of the proportion of tapioca flour with soybean hulls flour, namely (70:30, 50:50, 30:70) and the difference in the proportion of glycerol, namely 5%, 10%, and 15%. Each treatment was repeated 2 times so that the total number of treatments was 18 experimental units.

**Table 1.** Research Experimental Treatment

| Comparison of tapioca flour and yellow soybean hulls | Glycerol | | |
|---|---|---|---|
| | $B_1$ : 5% | $B_2$ : 10% | $B_3$ : 15% |
| $A_1$ (70 : 30) | $A_1B_1$ | $A_1B_2$ | $A_1B_3$ |
| $A_2$ (50 : 50) | $A_2B_1$ | $A_2B_2$ | $A_2B_3$ |
| $A_3$ (30 : 70) | $A_3B_1$ | $A_3B_2$ | $A_3B_3$ |

The data obtained will be processed and analyzed using the Microsoft Excel computer. Data will be analyzed using the One-Way ANOVA test and Duncan's advanced test with significant difference values (P<0.05).

Data processing and analysis was carried out using Microsoft Excel software. Data were entered into a 2-factor completely randomized design. Then the responses used are water content, starch content, density, water absorption capacity, biodegradability, and strength of biofoam

### *2.3. Yellow Soybean Hulls Manufacturing*

Yellow Soybean hulls are washed until clean and then steamed for 30 minutes to remove the unpleasant odor. Steamed soybean hulls are dried using a cabinet dryer for 10 hours at 65oC and ground then sieved using an 80mesh sieve

### *2.4. Biofoam Manufacturing*

The first stage is mixing the dry ingredients in the form of tapioca flour and soybean shellfish flour then mixing with distilled water and glycerol. The next process is printing. The finished dough is molded into the prepared biofoam mold. After printing, the dough is placed in the oven at 100oC for 60 minutes in the oven

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### 2.5. Analytical

The parameters used in this research were analyzed using the following: water content, starch content, amylose content, amylopectin content, crude fiber content using the AOAC method, Density using ASTM D792-91 (1991), biodegradable using SNI-01-2891-1992 and tensile strength using ASTM D638-02-2002

## 3. RESULT AND DISCUSSION

### 3.1. Analisa Bahan Baku

Analysis of raw materials in this research was carried out on soybean bran flour and tapioca flour. The results of the tapioca flour analysis can be seen in Table 2

**Table 2**. Result of analysis of tapioca flour

| Composition | Tapioca Flour | |
|---|---|---|
| | Analysis Result | Literature |
| Moisture Content (%) | 11.26 | Max. 15[a] |
| Starch Content (%) | 86.88 | 86.86-86.88[b] |
| Amylose Content (%) | 31.43 | 30[c] |
| Amylopectin Content (%) | 55.5 | 50[c] |

Keterangan Sumber: [a]) SNI 01-3451-1994, [b]) Wijayanti and Rahmadhia (2021), [c]) Aryani (2010)

The amylose and amylopectin levels in tapioca flour (Table 2) used as raw material for biofoam showed test results of 31.43% and 55.45%, while the amylose and amylopectin levels of tapioca flour according to [19] were 30% and 50%. Differences in test results with the literature can be caused by the variety of materials used. According to [20] ingredient varieties can influence the physicochemical characteristics and functional properties of tapioca flour.

Table 3 shows that the test results for the water content of yellow soybean hulls flour obtained were lower when compared to the literature by [21], namely 4.42%, while the literature shows the test results for the water content of yellow soybean hulls flour at 4.75%. The crude fiber content of yellow soybean hulls flour used as raw material for biofoam is 25.67%, which is a difference from the literature by [22], namely 24.84%. Differences in test results with the literature can occur due to several factors such as differences in the type of raw material used, differences in time and temperature in the drying process, and differences in the mesh size used during the sieving process. Following Utomo's statement [13]. The drying and sieving process of soybean epidermis in this study used an oven at 65°C for 10 hours using a 100 mesh sieve

Table 3. Result of analysis of yellow soybean hulls flour

| Composition | Tapioca Flour | |
|---|---|---|
| | Analysis results | Literature |
| Moisture Content (%) | 4,42 | 4,75[22] |
| Crude Fiber (%) | 25,67 | 24,84[23] |

### 3.2. Moisture Content Biofoam

Table 3 shows that the higher the proportion of tapioca flour the lower the proportion of yellow soybean hulls flour and the higher the proportion of glycerol, the higher the biofoam moisture content value. This is because the proportion of tapioca flour is higher than the proportion of yellow soybean hulls flour, where tapioca flour has hydrophilic properties, following literature [24] explains that biofoam with tapioca starch as a raw material is hydrophilic, so the molecules of water can easily fight the hydrogen bonds in starch.

The addition of yellow soybean hull flour can also increase the fiber content in biofoam, where the fiber content has water-binding properties (hydrophilic). This strong binding of water makes it difficult for water to evaporate and causes the moisture content to decrease further. This is following research by [23] and [25] that the decrease in moisture content is thought to be related to the high fiber content in the material used, where fiber has the property of binding water with a fairly strong bond. So the more fiber in the material, the more difficult it is for the water in the material to evaporate and cause the moisture content to be lower. Research by [26] and [27] also shows a decrease in the percentage of biofoam moisture content as the weight ratio of pineapple leaf fiber increases.

The addition of glycerol also has the effect of increasing the moisture content value in biofoam because glycerol itself is an additional ingredient in the form of a liquid that is easily dissolved by water and is a simple glyceride compound that is hydrophilic and hygroscopic. This is supported by research by [28] which states that adding glycerol to making biofoam can increase the moisture content value of biofoam products

### 3.3. Starch Content

Table 3 shows that the higher the proportion of soybean hulls flour and the lower the proportion of tapioca flour and the more glycerol added, the lower the biofoam starch content. This is because tapioca flour has a higher starch content, namely 86.88%, while the content of soybean hulls flour is fiber, so the more addition of tapioca flour can increase the starch content of biofoam. In research [21] said that the content of a product is influenced by the ingredients used, if more ingredients contain starch in the ingredients added, the starch content in the product will also increase. This is supported by [29] that the greater the starch added, the higher the starch content of the product produced. The addition of glycerol can reduce the starch content, this is because the more the percentage of glycerol added, the percentage of starch in the material decreases

**Table 3**. Analysis results of Biofoam

| Analysis | Sample | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A1B1 | A1B1 | A1B1 | A1B1 | A1B1 | A1B1 | A1B1 | A1B1 | A1B1 |
| Moisture Content (%) | 17.92 | 18.11 | 18.18 | 16.33 | 16.84 | 17.26 | 15.10 | 15.37 | 15.76 |
| Starch Content (%) | 27.42 | 26.97 | 26.31 | 24.51 | 22.30 | 21.08 | 19.71 | 18.26 | 17.53 |
| Crude Fiber (%) | 5.41 | 5.17 | 5.01 | 9.86 | 9.71 | 9.33 | 14.49 | 14.46 | 14.25 |
| Densitas (gr/cm$^3$) | 0.75 | 0.54 | 0.45 | 1.08 | 0.93 | 0.82 | 1.31 | 1.26 | 1.13 |
| Water Adsorbtion Capacity (%) | 15.48 | 16.17 | 16.49 | 15.29 | 15.13 | 14.75 | 13.88 | 14.50 | 14.67 |
| Biodegradable (%) | 15.12 | 16.61 | 18.08 | 7.88 | 9.94 | 13.84 | 3.13 | 5.45 | 8.14 |
| Tensile Strength (Mpa) | 8.55 | 8.17 | 7.73 | 10.75 | 9.84 | 9.26 | 11.83 | 11.34 | 11.03 |

### *3.4. Crude Fiber*

Table 3 shows that the higher the proportion of soybean shellfish flour the lower the tapioca flour and the lower the proportion of glycerol, the lower the crude fiber content of the biofoam. The increase in the crude fiber content of bio-foam is due to the greater proportion of soybean hull flour. Soybean hulls have a higher crude fiber content, namely 25.67% (Table 2) than tapioca flour, namely 0.4 [30]. Therefore, the greater the proportion of soybean hull flour, the crude fiber content of biofoam increases. This is following research by [31] that the greater the proportion of ingredients containing crude fiber that is added, the crude fiber content of the product can be increased. Their research, it shows that the use of 3% and 4% carrageenan can increase the crude fiber content by 0.17 because carrageenan is an ingredient containing fiber.

The increase in glycerol concentration is also associated with a decrease in crude fiber content in biofoam. This is because as the glycerol concentration ratio increases, the crude fiber content decreases. Research by [32] and [31] that by increasing the concentration of added glycerol, the crude fiber content in the product can decrease because an increase in the glycerol ratio can reduce the crude fiber content. The glycerol content mostly consists of stearic acid, not the crude fiber fraction, so the change in added glycerol does not result in an increase in fiber, but the addition of glycerol can reduce the ratio of crude fiber contained in the product.

### *3.5. Density*

Table 3 shows that the lower the proportion of tapioca flour the higher the proportion of yellow soybean hull flour and the lower the proportion of glycerol, the higher the density value of the biofoam produced. A higher density value indicates that the biofoam produced is dense, and vice versa, a low density value indicates that the biofoam produced is increasingly hollow. This is influenced by the concentration of tapioca added, tapioca flour has a high starch content, where starch can gelatinize when exposed to water (when kneading biofoam) and heat, and can make the starch granules expand. This development increases the product volume and can reduce the density value of the biofoam. This follows the statement of [33] that the process that occurs in gelatinization is that when starch granules are given water and heat, the starch granules will expand.

Density can also be influenced by the fiber content in the soybean hulls flour used. The higher the fiber content in the material used, the resulting density will increase. This is because the fiber can fill empty spaces in the matrix, so that the resulting biofoam is denser. This was also shown by research by [34] that the more the mixture of paper and orange peel was added, the greater the density of the biofoam. Berutu's experiment also explained in their research that, in the process of making biofoam, the gelatinization process that occurs will produce biofoam with a hollow structure. However, if cellulose fiber is added to the dough, the cavities formed will become smaller because the expansion process is hampered. The inhibition of the expansion process produces dense biofoam with an increasingly higher density [35].

The addition of glycerol also affects the density of the biofoam produced. The density of biofoam will decrease as more glycerol is added. This is because glycerol, which is a plasticizer, bonds with starch to form a starch-plasticizer polymer, replacing the bonds between starch, so that the thickness of the biofoam increases along with increasing glycerol concentration, so that the thicker the biofoam produced, the lower the density value. This is following research by [36] that with the addition of 15% to 45% glycerol, the density value of biofoam decreases. The decrease in density is related to the decrease in biofoam volume. The more the volume of biofoam increases, the lower the resulting density. Bourtoom [37] said that the added plasticizer can bind with starch to form a starch-plasticizer polymer. The bonds between starch are replaced by these bonds so that the thickness increases. In their research also stated that the increase in the thickness of edible film occurs because the glycerol molecules form a matrix with the main component of the edible film which causes the distance between the polymers to be closer so that the thickness of the biofoam increases [38].

### *3.6. Water Adsorption Capacity*

Table 3 shows that the lower the proportion of tapioca flour the higher the proportion of yellow soybean hulls flour and the lower the additional proportion of glycerol, the lower the water absorption capacity. Increasing the proportion of tapioca flour can increase the starch content in the product because tapioca flour has a higher starch content, namely 86.88%, where the starch content has higher -OH bonds than the -OH bonds in


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yellow soybean hulls flour fibers, where the -OH is hydrophilic (has the property of binding water). This is supported by research by [35] that in making biofoam, the higher the fiber ratio added, the lower the water absorption capacity of the biofoam. This is because fiber has a greater cellulose content, whereas cellulose does not like water (hydrophobic). According to Agustin and [39], materials have lots of -OH groups can bond with water through hydrogen interactions and have high water absorption values. Increasing the number of hydrophilic components causes an increase in the percentage of water absorption capacity.

The addition of the proportion of glycerol in making biofoam affects the water absorption value, where the greater the proportion of glycerol added, the higher the water absorption value. This can happen because glycerol breaks the hydrogen bonds in starch causing the intermolecular distance to increase, in the intermolecular distance or space water can enter when soaked in water which causes high water absorption. This is following research conducted by [40] regarding research on the physical and mechanical properties of biodegradable plastic from cassava starch with variations in the addition of bagasse and glycerol, that the addition of bagasse and glycerol increases the water absorption value of biofoam plastic, the strength value The resulting water absorption is between 2.61 – 10.64%.

### 3.7. Biodegradable

Table 3 shows that the lower the proportion of tapioca flour the greater the proportion of soybean hulls and the smaller the proportion of glycerol added, the lower the biodegradability value of the biofoam. Increasing the proportion of soybean hull flour can increase the fiber content of the product because soybean hull flour is a material with a high fiber content, namely 25.67%. The increasing presence of fiber can slow down the degradation process of biofoam because cellulose is difficult to water. Where water can become a place for microbes to grow as biofoam decomposers. This is following research by [35] that the more fiber added to the manufacture of biofoam, the longer the degradation will take because the fiber has properties that are resistant to water (hydrophobic). The order of decomposition from the fastest to the slowest decomposition is sugar, starch, simple protein, complex protein, hemicellulose, cellulose, fat and lignin.

Glycerol also affects the biodegradability of biofoam, the more glycerol added, the higher the level of biofoam decomposition, so that biodegradability increases. This is related to the water absorption capacity of biofoam, the more glycerol added, the water absorption capacity of biofoam increases. Water is a place for microbes to grow which can decompose biofoam. This is following research by [41] which states that glycerol as a plasticizer also plays a role in degradation. Glycerol, which is hydrophilic, contributes OH groups to help absorb water in the soil. The decomposition phenomenon is closely related to water and soil microbial action. In other words, the degradation rate increases along with the biofoam's ability to absorb water. Several factors such as fungi, bacteria microorganisms, or other biological factors play an important role in material decomposition. Initially, the polymer begins to decompose as microbial organisms interact with the biodegradable polymer. Then the polymer is transformed through an enzymatic process by microbes which results in the polymer breaking down into smaller compounds that have a low average molecular weight. This process of complete decomposition of materials is known as mineralization [42].

### 3.8 Tensile Strength

Table 3 shows that the tensile strength value increased along with the lower proportion of tapioca flour and the higher proportion of yellow soybean hulls flour as well as the higher proportion of glycerol. This occurs because there is space due to the bonds between polysaccharides in starch being broken by glycerol, so that the bonds between molecules become weaker. The function of adding glycerol is as a plasticizer to provide elastic properties which cause a decrease in intermolecular forces along the polymer chain, thereby increasing flexibility [43]. According to [44] in their research, they explained that with the addition of 20%, 25%, and 30% glycerol, the tensile strength test results decreased further. This happens because the glycerol in the solution experiences excess or excess, thereby breaking hydrogen bonds and weakening the chemical structure.

The addition of the proportion of yellow soybean hulls flour increased the tensile strength value of the biofoam. This is because the function of adding crude fiber to biofoam is to improve the mechanical characteristics and one form of improving the characteristics of starch-based biofoam is to improve the tensile strength of the biofoam. Increasing the fiber concentration it can increase the tensile strength value, in the fiber there is cellulose content which has high tensile strength characteristics, cellulose is formed from crystalline and amorphous structures as well as the formation of microfibrils and fibril structures. fibrous and strong hydrogen bonds [45]. supported by research by [43] because cellulose as a reinforcing component in composite materials can increase its mechanical strength. The increase in the tensile strength value due to the addition of cellulose is caused by an increase in the attractive force interactions between the constituent molecules.

### 3.9 Best Treatment Analysis

Based on the results of the analysis of the decision on the best treatment using the Zeleny method, it shows that the best treatment is known to be biofoam with the proportion of tapioca flour as the basic ingredient: yellow soybean hulls flour (30:70) and the addition of 15% glycerol with analysis results of 15.76% water content, starch content. 17.53%, density 1.13 gr/cm3, water absorption 14.67%, biodegradability 8.14% (±8 weeks) and tensile strength 11.03Mpa. The SEM results of the best-treated biofoam can be seen in Fig.1.

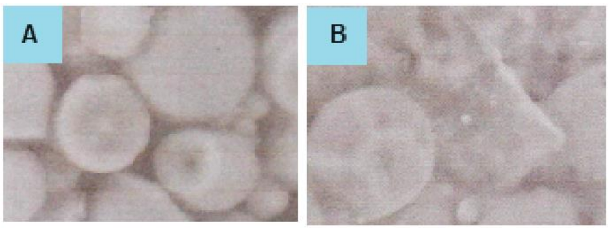


**Fig. 1.** Biofoam best treatement (A) and commercial biofoam (B)

When compared with commercial biofoam (Figure 1), it can be seen that there are fewer visible lumps and indentations or the resulting morphology is more even. The morphology results show that the starch and fiber have not been completely dissolved, thus showing an uneven morphology. This follows the statement by

[13] that the white lumps and indentations in the SEM analysis results are caused by the starch and fiber not being completely dissolved, apart from that it can also be caused by the long stirring time, the longer the stirring time, the better the solubility of the starch and fiber. . Gresita's research [46] also showed that the results of SEM analysis on biofoam based on canna starch and straw waste with a magnification of 2000x and 180x, bubbles were found which indicated that the mixing of the ingredients was not homogeneous in all biofoam samples. In research by [9] analyzing the morphology of pineapple leaf fiber biofoam with a magnification of 500 times, the biofoam produced had holes formed due to the gelatinization process. The gelatinization process can occur by adding water to the starch and adding the heating process, the water that comes out of the biofoam mixture will leave holes.

The results of the analysis of the best-treated biofoam produced a cavity size that was smaller and denser than the literature biofoam based on sago starch and pineapple fiber, so it can be said that the research best treated biofoam had a higher tensile strength value. The tensile strength value of the research best-treated biofoam is 11.03Mpa, while the literature biofoam has a tensile strength of 1.66Mpa. This is following the statement of [4] and [47] that the morphology of biofoam has an influence on the compressive strength and tensile strength values, where biofoam that has a large cavity size and is porous indicates that the biofoam formed has low compressive strength and tensile strength value

## 4. CONCLUSION

There is a real interaction between the treatment ratio of tapioca flour: soybean hull flour and the addition of glycerol on water content, starch content, density, water absorption capacity, biodegradability, and tensile strength of biofoam. The best treatment based on the physicochemical assessment was found in sample A¬3¬¬B¬3 with a ratio of tapioca flour: soybean hulls flour (30:70) and the addition of 15% glycerol with analysis results of water content of 15.76%, starch content of 17, 53%, density 1.13 gr/cm3, water absorption 14.67%, biodegradability 8.14% (±8 weeks) and tensile strength 11.03Mpa

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