



## Synthesis of Biofoam Based on Starch Mixture to Improve Mechanical and Physical Characteristics

Yuli Darni<sup>1\*</sup>, Ghea Maulidaco Anandati<sup>1</sup>, Eva Mayanti<sup>1</sup>, Lia Lismeri<sup>1</sup>, Herti Utami<sup>1</sup>, Azhar<sup>1</sup>, Ichsanul Abidin<sup>2</sup>

<sup>1</sup> Department of Chemical Engineering, Lampung University, Jl. Prof. Dr. Ir. Sumantri Bojonegoro No. 1 Bandar Lampung.

<sup>2</sup> Department of Mechanical Engineering, Lampung University, Jl. Prof. Dr. Ir. Sumantri Bojonegoro No. 1 Bandar Lampung.

\*E-mail: yuli.darni@eng.unila.ac.id

### Article History

Received: 12 September 2022; Received in Revision: 21 January 2023; Accepted: 12 February 2023

### Abstract

Biodegradable foam (biofoam) is a type of bioplastic to be used as an alternative packaging to replace styrofoam that is safe and environmentally friendly. This study aims to determine the effect of adding chitosan on the characteristics of biofoam made from cassava peel starch (A) and banana peel starch (B). In the manufacture of biofoam, various A/B ratios used are 1:0; 3:2; 1:1 (w/w). While the chitosan content added was 0%, 15%, and 30% by weight of starch, as well as NaHCO<sub>3</sub> blowing agent with a content of 12% by weight of starch. The production of biofoam was carried out using the thermopressing method with a printing temperature of 125°C, and a printing time of 7 minutes. The results of biofoam were characterized based on density, water absorption, compressive strength, biodegradation, and FTIR functional groups. Based on the research results, it is known that biofoam is close to commercial biofoam standards, namely biofoam with an A:B ratio of 3:2, and the addition of 15% chitosan with a water absorption capacity of 33.68%, a compressive strength value of 5.05 MPa, and a decomposition power of 17.44%. This variation has the functional groups N-H, O-H, C-H, C=O, C-N, and C-O.

Keywords: banana peel starch, biofoam, cassava peel starch, chitosan, thermopressing

### 1. Introduction

Plastic waste is a major problem that has not been properly resolved to date. The National Waste Management Information System states that types of plastic waste contribute 182% of the total types of waste in Indonesia (SIPSN, 2021). One of the plastic packagings in Indonesia that is widely used is styrofoam. However, the effect of styrofoam is environmental pollution because it is difficult to decompose and is harmful to health (Hendrawati et al., 2017). Therefore, efforts are needed to replace styrofoam as food packaging by making biofoam from starch as raw materials. Apart from being renewable, starch has low density, low toxicity, is easily degraded into environmentally friendly compounds, and is inexpensive (Thakur et al., 2019).

To optimize the use of agricultural waste, especially cassava peels and banana peels, these wastes can be used as raw materials for making biofoam. The starch content of cassava peels is in the range of 44–59%

(Lestari et al., 2019), while the starch content of kepok banana peels is 11.48% (Albaasith, 2014). Based on research conducted by Adil et al. (2020), it showed that biodegradable packaging made from cassava peel starch had an effect on improving the characteristics of biodegradable packaging made such as tensile strength, water resistance and biodegradability.

Saleh et al. (2014) showed that starch-based biofoam still has some drawbacks, such as high water absorption and low mechanical properties. One way to improve the characteristics of biofoam is by adding additives, namely PVOH (Darni et al., 2021) or chitosan (Hendrawati et al., 2017). Chitosan is a biopolymer that functions as a filler with hydrophilic functional groups so it is very reactive because it can form hydrogen bonds (Berghuis, 2020).

This is also supported by research conducted by Hendrawati et al. (2017) and Muharram (2020) who agreed to explain that the biofoam containing high content of chitosan means

that biofoam does not easily absorb water and has a greater tensile strength value.

In addition, biofoam is expected to have a light product mass so that in the manufacturing process sodium bicarbonate ( $\text{NaHCO}_3$ ) is added as a blowing agent. The blowing agent has the working principle of releasing  $\text{CO}_2$  gas when the pressure is released during the decomposition reaction, resulting in air cavities or foam that increases the swelling power value of the resulting biofoam (Gultom, 2016).

According to Hendrawati et al. (2020), the addition of blowing agent  $\text{NaHCO}_3$  also functions as a pore former in biofoam so that it will affect the porosity of biofoam which is getting bigger. This large porosity will accelerate the biofoam degradation process because it makes it easier for microbes to enter.

Therefore, to improve the characteristics of biofoam that has been carried out from previous studies, this study used various amounts of chitosan and starch ratios from cassava peels and kepok banana peels.

## 2. Methodology

### 2.1 Materials

Materials used in this study were chitosan (CM) 98%,  $\text{NaHCO}_3$  (Malan) 99%, NaCl (Pudak) 99.5%, acetic acid (Merck) 99%, distilled water, cassava peel starch (A), and starch from Kepok banana peel (B) obtained from Karang Anyar Village, Gedong Tataan District, Pesawaran Regency, Lampung.

### 2.2 Extraction of Cassava Peel and Kepok Banana Peel

The process began with the extraction of raw materials from cassava peels and kepok banana peels. The first step was to clean the skin of the cassava and kepok banana, and cut them into small pieces. Then, each cassava peel and kepok banana peel were blended with the addition of water in a 1:2 ratio. Dregs of cassava peel and kepok banana peel obtained were filtered and squeezed. The filtrate obtained was decanted for 24 hours for cassava peels, and 48 hours for kepok banana peels. After that, the starch precipitate was dried.

### 2.3 Preparation of Biofoam

Cassava peel starch and kepok banana peel starch with a ratio of 1:0 were dissolved using

10 ml distilled water (sample 1). Then, the chitosan was weighed according to the experimental variables, and dissolved in acetic acid. The starch solution was heated on a hot plate at 185 rpm speed until it reached a gelatinization temperature of  $75^\circ\text{C}$ , while stirring,  $\text{NaHCO}_3$  and chitosan solutions were added until homogeneous. After that, the dough was printed using a thermopressing tool for 5 minutes. The printed biofoam was cooled for 30 minutes. Then, the biofoam was stored using a zip bag lock and put in a desiccator.

### 2.4 Density Measurement

Density was a measurement of the mass of an object per unit volume. The higher the density, the greater the mass of each volume. The density test referred to ASTM D 792-08 standard. A 2 cm x 2 cm specimen was cut, and the thickness of the biofoam was measured to determine the volume. Then, the sample was weighed to determine its mass. The density value was calculated using Equation 1.

$$\rho = \frac{M}{V} \quad (1)$$

Where:

$\rho$  = density (g/ml)

M = sample mass (g)

V = volume (ml)

### 2.5 Water Absorption

The water absorption test aimed to determine the resistance of biofoam to water (Izzak et al, 2013). The water absorption test procedure referred to ASTM E 96. A sample measuring 2 cm x 2 cm was weighed, and its initial mass was recorded. Then, the sample was immersed in water for one minute to determine the percentage of water absorption. Then, the surface of the sample was dried using a tissue and weighed again to determine the final mass. The water absorption value was calculated using Equation 2 below.

$$\text{Water Absorption (\%)} = \frac{W_1 - W_0}{W_0} \times 100\% \quad (2)$$

Where:

$W_0$  = mass of test object before immersion (g)

$W_1$  = mass of the test object after immersion (g)

### 2.6 Compressive Strength Test

The compressive strength test aimed to determine how much maximum strength the biofoam can withstand. The compressive

strength test procedure referred to ASTM D 882 where the tool used was the Mechanical Universal Testing Machine (AND MCT-2151). The compressive strength test was carried out in stages by placing the sample on a flat surface, and placing a compressive load in the middle until the sample broke. The compressive strength value was calculated using Equation 3.

$$\sigma = \frac{F_{\max}}{A} \quad (3)$$

Where:

$\sigma$  = compressive strength (N/mm<sup>2</sup>)

$F_{\max}$  = maximum stress (N)

$A$  = surface area (mm<sup>2</sup>)

## 2.7 Biodegradation Test

The biodegradation test aimed to determine the level of decomposition of biofoam samples by microorganisms in the soil. The biodegradation test was carried out according to EN13432 standard with the soil burial test method. The biofoam sample measuring 2 cm x 2 cm was weighed first, and buried in the soil to a depth of 10 cm for 14 days. Then, changes in the biofoam were observed in a matter of days, and the final weight was weighed again. The difference between the initial and final biofoam masses was recorded as the degraded sample mass. The percent reduction in mass was calculated using the following equation:

$$\% \text{ Mass reduction} = \frac{M_0 - M_1}{M_0} \times 100\% \quad (4)$$

Where:

$M_0$  = Mass of sample before biodegradation (g)

$M_1$  = Mass of sample after biodegradation (g)

## 2.8 Functional Group Analysis

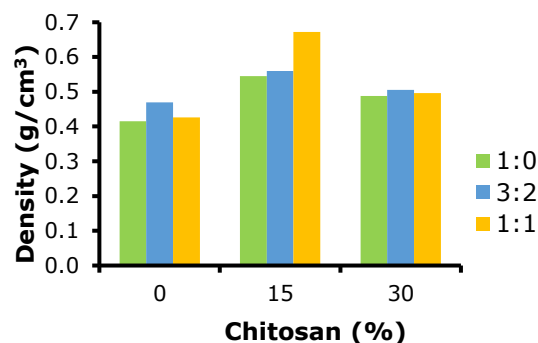
FTIR functional group analysis aimed to determine the functional groups contained in biofoam because the infrared spectra of a compound could provide an overview and molecular structure of the compound. The way FTIR spectroscopy worked was by passing infrared light on the biofoam sample placed on the set holder (where some of the frequencies would be absorbed by the sample while some other frequencies would be transmitted) (Sipatuhutar, 2020).

## 3. Results and Discussion

### 3.1 Density

The effect of the addition of chitosan on the density of biofoam is shown in Figure 1,

biodegradable foam has a density value in the range of 0.415–0.672 g/cm<sup>3</sup>. Referring to the commercial biofoam density standard with a value of 0.8 g/cm<sup>3</sup>, it can be seen that the biofoam that approaches the standard is a starch ratio of 1:1, and the addition of 15% chitosan with a density value of 0.672 g/cm<sup>3</sup>. This variation is not only seen from the physical and mechanical properties but also from an economic perspective, where biofoam with the addition of 15% chitosan is considered more capable of reducing costs than biofoam with the addition of 30% chitosan.

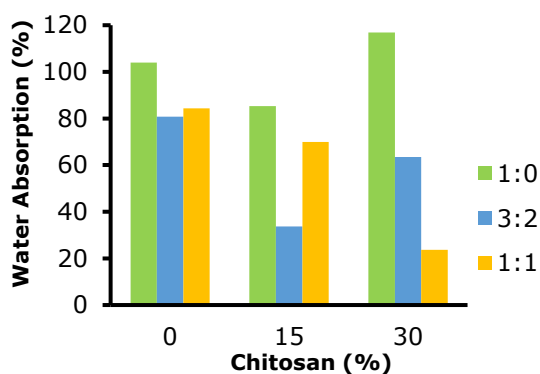


**Figure 1.** The relationship between chitosan and the density of biofoam

The addition of chitosan affects the density of the resulting biofoam, where the more chitosan is added, the higher the density value will be. However, based on Figure 1, it is known that in each of the same ratios, when 30% chitosan was added, the density value of the resulting biofoam decreased. This is because the more filler that is added, the interaction between the filler and the matrix will be more uneven so that some of the filler does not bind to the matrix because it has reached its optimum point (Sipahutar, 2020).

### 3.2 Water Absorption

The effect of the addition of chitosan on the water absorption capacity of biofoam is shown in Figure 2, biodegradable foam has a water absorption value in the range of 23.68–116.81%. Referring to the standard for water absorption in commercial biofoam with a value of less than 2%, it can be seen that biofoam made from cassava starch and banana peel starch still has a water absorption capacity that exceeds the standard. Biofoam with a water absorption capacity close to standard is biofoam with an A/B ratio of 1:1 with the addition of 30% chitosan, and an A/B ratio of 3:2 with the addition of 15% chitosan with a water absorption capacity of 23.68% and 33.68%, respectively.



**Figure 2.** Relationship between chitosan and biofoam water absorption

Biofoam with the highest water absorption is found in the A:B ratio of 1:0 with the addition of 30% chitosan. This is because the weak bond of cassava peel starch causes high water absorption. Meanwhile, the bonds of banana peel starch tend to be stronger than cassava peel starch making it difficult to stretch (Febriyantoro et al., 2019).

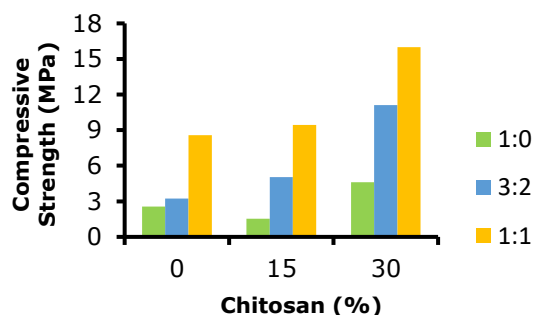
Figure 2 also shows that the absorption of water in the biofoam sample is inversely proportional to the concentration of chitosan added. Biofoam without the addition of chitosan tends to have a higher water absorption capacity than biofoam with the addition of chitosan. This is because biofoam made from starch without the addition of chitosan is more hydrophilic so that water absorption is greater, and makes biofoam not resistant to water (Kaisangri et al., 2014). Based on research by Hendrawati et al. (2019), the presence of the  $\text{NH}_2^-$  group in chitosan will protonate to  $\text{NH}_3^+$  in an acetic acid solution. Furthermore,  $\text{NH}_3^+$  causes molecules to bind  $\text{OH}^-$  through hydrogen bonds, making it difficult for biofoam to absorb water.

### 3.3 Compressive Strength

The effect of the addition of chitosan on the compressive strength of biofoam is shown in Figure 3, biodegradable foam has compressive strength values in the range of 1.520–16.003 MPa. Referring to the standard compressive strength of commercial styrofoam with a value of 0.12 MPa, and the standard compressive strength of commercial biofoam with a value of 4 MPa, it can be seen that biofoam that is close to the standard has a compressive strength value of 5.05 MPa, namely at a starch ratio of 3:2 with the addition of chitosan 15%. This is not only seen from the physical and mechanical properties, but also from an economic perspective where biofoam with the addition of 15% chitosan is considered more

capable of reducing costs compared to biofoam with the addition of 30% chitosan.

Based on Figure 3, it can be seen that biofoam with a starch ratio of 1:1 has a higher compressive strength value than biofoam with a starch ratio of 1:0 and 3:2. This is because of the presence of functional groups and more cellulose content in banana peel starch. The presence of this cellulose compound is influential in providing a strong and hard bond structure. Cellulose forms a wide conformation while starch forms a helix (Febriyantoro et al., 2019).



**Figure 3.** The relationship between the addition of chitosan to the compressive strength of biofoam

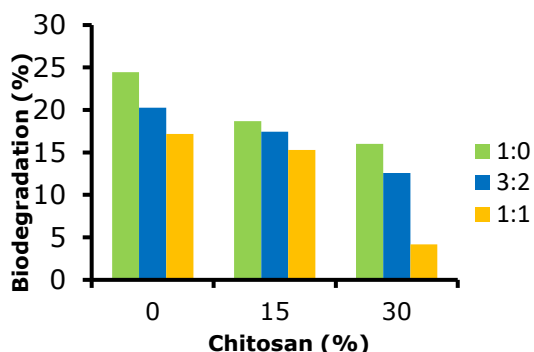
Figure 3 also shows the results in the form of compressive strength of biofoam that is directly proportional to the concentration of chitosan added. Biofoam with the addition of chitosan tends to have a higher compressive strength than biofoam without the addition of chitosan. This is because the dense structure of chitosan can form hydrogen bonds among chains, causing the distance between molecules in biofoam to get closer, as well as affecting high compressive strength values (Setiawan et al., 2015). Chitosan also has a linear polymer chain structure, and tends to form a crystalline phase that can provide strength, stiffness, and hardness to the resulting product (Agustin et al. 2016).

### 3.4 Biodegradation

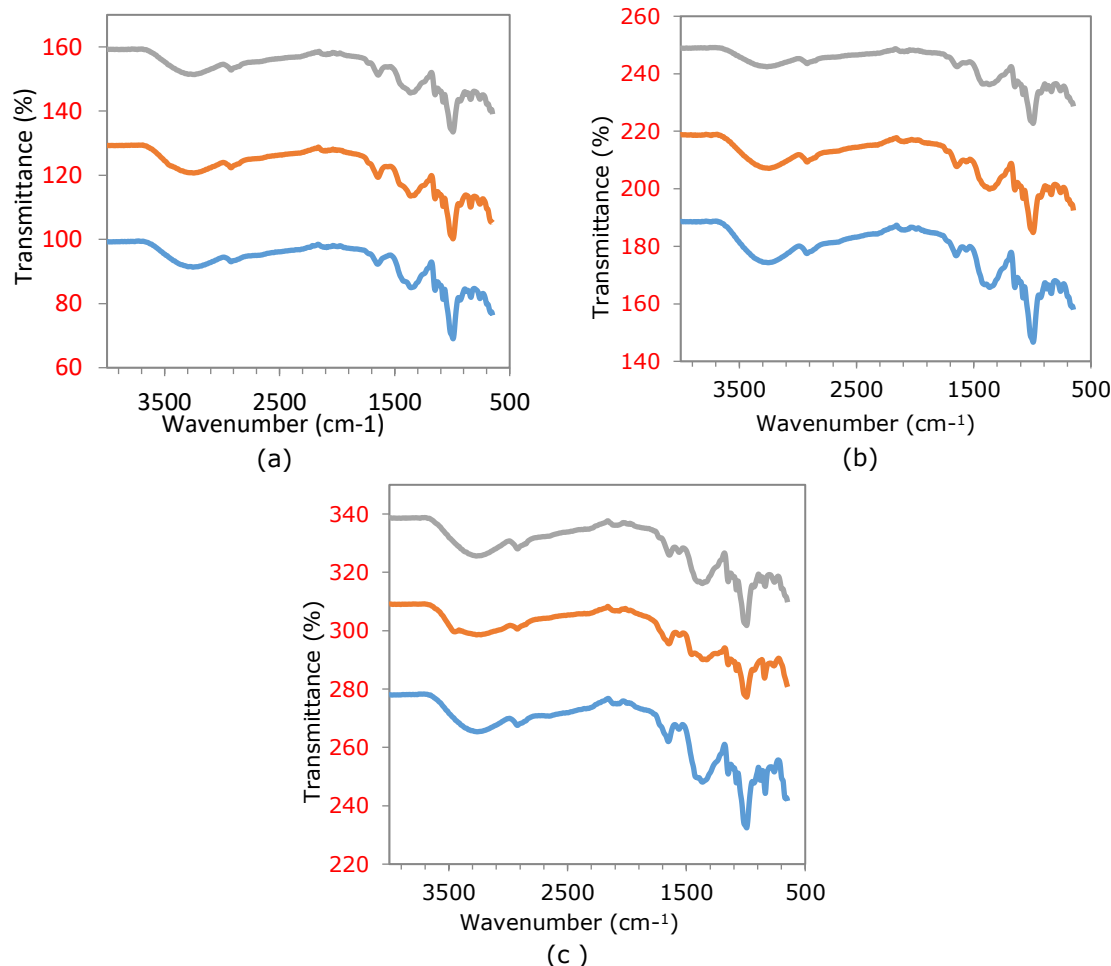
The effect of the addition of chitosan on biodegradation is shown in Figure 4, biofoam has a decomposition value in the range of 4.17–24.45%. Biofoam with a starch ratio of 3:2 with the addition of 15% chitosan has a decomposition value of 17.44%. This value includes aspects of sufficient biodegradation, so this condition also supports other characteristics.

Based on this study, it can be seen that the decomposition value is inversely proportional to the concentration of chitosan, where the

more chitosan is added, the more difficult it will be for biofoam to decompose. This is because chitosan has antibacterial properties and can cause the formation of strong hydrogen bonds between  $\text{NH}_3^+$  from chitosan and  $\text{OH}^-$  from starch. The  $\text{NH}_3^+$  value will increase with the increasing amount of chitosan so that the biofoam becomes stronger, and is not easily degraded by microorganisms (Bourtoom et al, 2018).



**Figure 4.** The relationship between the addition of chitosan and the decomposition of biofoam



**Figure 5.** Functional groups of biofoam made from cassava peel starch and banana peel starch in a) 0% chitosan addition, b) 15% chitosan addition, c) 30% chitosan addition

### 3.5 Functional Group Analytical

Figure 5 (a, b, c) below shows that in each biofoam, there are several absorption peaks that can indicate a compound group so that it becomes a characteristic of that compound. Without the addition of chitosan and with the ratio A:B 1:0, 3:2, and 1:1, it is known that biofoam has the functional groups O-H, C-H, C=O, C-N, and C-O. This is evidenced by the presence of peaks at wave numbers 3250.2  $\text{cm}^{-1}$  and 3235.3  $\text{cm}^{-1}$ , which indicate overlapping vibrations in the stretching O-H group range. The O-H groups are amylose and amylopectin compounds in starch that are the main constituents of biofoam. The presence of OH groups is also a sign that biofoam easily absorbs water and can be degraded in the soil (Ruscahyani et al, 2021). In addition, on biofoam with A:B ratios of 1:0, 3:2, and 1:1, absorptions appears at wave numbers 2922.2  $\text{cm}^{-1}$ , 2922.2  $\text{cm}^{-1}$ , and 2922.2  $\text{cm}^{-1}$  that are the C-H functional groups from alkanes. Furthermore, absorption appears at wave numbers 2094.8  $\text{cm}^{-1}$ , 2087.3  $\text{cm}^{-1}$ , and 2094.8  $\text{cm}^{-1}$ , which indicate the range of C=O groups.

The next peaks with wave numbers 1356.8  $\text{cm}^{-1}$ , 1364.2  $\text{cm}^{-1}$ , and 1364.2  $\text{cm}^{-1}$  show typical regions of the C–N group. Wave numbers 1148.0  $\text{cm}^{-1}$ , 1148.0  $\text{cm}^{-1}$ , and 1148.0  $\text{cm}^{-1}$  indicate the C–O functional group.

Comparison of absorption bands on biofoam with the addition of 0%, 15%, and 30% chitosan with A:B ratios of 1:0, 3:2, and 1:1 is presented in Tables of 1–3.

**Table 1.** Functional groups on biofoam without the addition of chitosan

| Wavenumber ( $\text{cm}^{-1}$ ) |        |        | Absorption Range ( $\text{cm}^{-1}$ ) | Functional Group |
|---------------------------------|--------|--------|---------------------------------------|------------------|
| 1:0                             | 3:2    | 1:1    |                                       |                  |
| 3250.2                          | 3250.2 | 3235.3 | 3100–3500                             | O–H              |
| 2922.2                          | 2922.2 | 2922.2 | 2850–3000                             | C–H              |
| 2094.8                          | 2087.3 | 2094.8 | 2087–2117                             | C=O              |
| 1647.5                          | 1647.3 | 1640.0 | 1640–1690                             | C=O              |
| 1356.8                          | 1364.2 | 1364.2 | 1150–1460                             | C–N              |
| 1148.0                          | 1148.0 | 1148.0 | 1025–1160                             | C–O              |
| 998.9                           | 998.9  | 998.9  | 960–1080                              | C–H              |
| 834.9                           | 842.4  | 842.4  | 885–895                               | C–H              |
| 760.4                           | 760.4  | 760.4  | 735–770                               | C–H              |

**Table 2.** Functional groups on biofoam with the addition of 15% chitosan

| Wavenumber ( $\text{cm}^{-1}$ ) |        |        | Absorption Range ( $\text{cm}^{-1}$ ) | Functional Group |
|---------------------------------|--------|--------|---------------------------------------|------------------|
| 1:0                             | 3:2    | 1:1    |                                       |                  |
| 3250.2                          | 3250.2 | 3265.1 | 3100–3500                             | O–H              |
| 2922.2                          | 2922.2 | 2922.2 | 2850–3000                             | C–H              |
| 2094.8                          | 2094.8 | 2094.8 | 2087–2117                             | C=O              |
| 1647.5                          | 1647.5 | 1640.0 | 1640–1690                             | C=O              |
| 1565.5                          | -      | 1423.8 | 1420–1650                             | N–H              |
| 1364.2                          | 1364.2 | 1371.7 | 1150–1460                             | C–N              |
| 1148.0                          | 1148.0 | 1148.0 | 1025–1160                             | C–O              |
| 998.9                           | 998.9  | 998.9  | 960–1080                              | C–H              |
| 834.9                           | 834.9  | 834.9  | 885–895                               | C–H              |
| 760.4                           | 760.4  | 760.4  | 735–770                               | C–H              |

Biofoam with A:B ratios of 1:0, 3:2, and 1:1 with the addition of 0% chitosan when compared to biofoam with the addition of 15% and 30% chitosan showed many similarities in functional groups. The N–H group is an amine compound derived from chitosan. Hydrogen bonds between the O–H groups in starch and the N–H groups in chitosan cause the

mechanical properties of the resulting biofoam to be higher so that the biofoam becomes denser and stiffer than biofoam without the addition of chitosan (Sofia et al., 2017).

**Table 3.** Functional groups on biofoam with the addition of 30% chitosan

| Wavenumber ( $\text{cm}^{-1}$ ) |        |        | Absorption Range ( $\text{cm}^{-1}$ ) | Functional Group |
|---------------------------------|--------|--------|---------------------------------------|------------------|
| 1:0                             | 3:2    | 1:1    |                                       |                  |
| -                               | 3444.1 | -      | 3400–3500                             | NH               |
| 3265.1                          | 3265.1 | 3265.1 | 3100–3500                             | O–H              |
| 2922.2                          | 2922.2 | 2922.2 | 2850–3000                             | C–H              |
| 2087.3                          | 2102.2 | 2102.2 | 2087–2117                             | C=O              |
| 1654.9                          | 1647.5 | 1640.0 | 1640–1690                             | C=O              |
| 1565.5                          | 1558.0 | 1565.5 | 1420–1650                             | NH               |
| 1364.2                          | 1326.9 | 1371.7 | 1150–1460                             | C–N              |
| 1148.0                          | 1148.0 | 1148.0 | 1025–1160                             | C–O              |
| 998.9                           | 998.9  | 998.9  | 960–1080                              | C–H              |
| 834.9                           | 842.4  | 834.9  | 885–895                               | C–H              |
| 760.4                           | 760.4  | 760.4  | 735–770                               | C–H              |

#### 4. Conclusion

Biofoam has been prepared from starch from cassava and banana peels that are close to commercial biofoam standards, namely with a variation of the starch ratio of 3:2 and the addition of 15% chitosan. The biofoam produced in this variation has a water absorption of 33.68%, a compressive strength value of 5.05 MPa, and a biodegradability of 17.44%. The higher the chitosan content added as a filler, the lower the absorption capacity of the biofoam, the higher the compressive strength of the biofoam, and the more difficult it is for the biofoam to decompose. Biofoam with ratios of cassava peel starch and banana peel starch of 1:0, 3:2, 1:1, and the addition of 15% chitosan has the functional groups N–H, O–H, C–H, C=O, C–N, and C–O.

#### Acknowledgement

The authors express their deepest gratitude to the Directorate General of Higher Education, Research, and Technology (Ditjen Dikristek) via notification letter No.2489/E2/KM.05.01/2022 that has provided research funds through the Exact Research Student Creativity Program (PKM-RE) 2022, Department of Chemical Engineering that provided facilities for this research, and all parties who were directly or indirectly involved and assisted in the implementation of this research.

## References

- Adil. P. and Sukainah, A., 2020. Synthesis of cassava peel (*Manihot esculenta*) as a basic material for making biodegradable packaging. *J Agric Educ* 6(1), 55-64. <https://doi.org/10.1016/j.indcrop.2014.11.054>
- Agustin, Y. E. and Padmawijaya, K. S., 2016. Synthesis of bioplastics from chitosan-starch of banana peels with the addition of additives. *J Chem Eng* 10(2), 40-48. <https://dx.doi.org/10.33005/tekkim.v10i2.537>
- Albaasith Z., Lubis, R. N., Tambun R., 2014. Enzymatic preparation of glucose syrup from kepok banana peels (*Musa acuminatabalbisianacolla*). *J Chem Eng* 3(2), 15-18. <https://doi.org/10.32734/jtk.v3i2.1607>
- Berghuis, N. T., Zulfikar, M. A., Wahyuningrum, D., 2020. Synthesis of composite membrane based on chitosan using sol-gel method as a fuel cell membrane at high temperatures, *Al-Kimiya* 7(1), 35-46. <http://dx.doi.org/10.15575/ak.v7i1.6614>
- Bourtoom, T. and Chinnan, M. S., 2018. Preparation and properties of rice starch-chitosan blend biodegradable film. *J Food Sci Technol* 41(9), 1633-1641. <https://doi.org/10.1016/j.lwt.2007.10.014>
- Darni, Y., Aryanti, A., Utami, H., Lismeri, L., Haviz, M., 2021. Preliminary study on the production of biofoam made from a mixture of starch and sorghum stems. *J Technol Manag Innov* 2(2), 13-19. <https://doi.org/10.23960/jtii.v3i2.49>
- Febriyantoro, I., Nuriyah, L., Iswarin, S. J., 2019. The effect of starch composition of plantain peel and cassava peel as bioplastic raw materials and measurement of their characteristics. *Brawijaya Phys Student J* 2(1), 10-16.
- Gultom, F., 2016. Preparation and characterization of polyurethane foam nanocomposites with the addition of Sarulla natural nanozeolite filler. *PhD Dissertation*. Sumatera Utara University, Medan. <https://www.jurnal.darmaagung.ac.id/index.php/jurnaluda/article/download/377/351>
- Hendrawati, N., Lestari, Y. I., Wulansari, P. A., 2017. The effect of chitosan addition in the production of biodegradable foam made from starch. *J Environ Chem Eng* 12(1), 1-7. <https://doi.org/10.23955/rkl.v11i2.5002>
- Hendrawati, N., Wibowo, A. A., Chrisnandari, R. D., 2020. Biodegradable foam from acylated sago starch with the addition of blowing agent NaHCO<sub>3</sub>. *J Environ Chem Eng* 4(2), 186-19. <https://dx.doi.org/10.33795/jtkl.v4i2.168>
- Izzak, F. D., Rauf, F. A., Lumintang, R. C. A., 2013. Analysis of mechanical properties and water absorptivity of rattan fibre composite materials. *Jurnal Poros Teknik Mesin Unsrat* 2(2). <https://ejournal.unsrat.ac.id/v3/index.php/poros/article/view/2988>
- Kaisangsri, N., Kerdchoechuen, O., Laohakunjit, N., 2014. Characterization of cassava starch based foam blended with plant proteins, kraft fiber, and palm oil. *Carbohydr Polym* 110, 70-77. <https://dx.doi.org/10.1016/j.carbpol.2014.03.067>
- Lestari, T., Apriyadi, R., Ferdiaz, F., 2019. Utilization of cassava peel waste as compost with various activators on the growth and production of lettuce (*Lactuca sativa* L). *J Agricult Econ Agribus*, 124-133. <http://repository.ubb.ac.id/id/eprint/2282>
- Muharram, F. I., 2020. Addition of chitosan to starch-based biofoam. *J EDUFORTECH*, 5(2), 118-127. <http://dx.doi.org/10.17509/edufortech.v5i2.28814>
- National Waste Management Information System., 2021. *Garbage Composition Graph*. <https://sipsn.menlhk.go.id/sipsn.2022.01.11>
- Ruscahyani, Y., 2021. Utilization of corn peel as material for making biodegradable foam. *Undergraduate Thesis*. UIN Sunan Ampel, Surabaya. <https://doi.org/10.34151/technoscientia.v14i1.3295>
- Saleh, E. R. M, Assagaf, M., Rodianawati, I., Warsiki, E., Wulandari, N., 2014. Determining the best process conditions

- for biofoam production from local agricultural waste in North Maluku. *Proc Natl Sci Technol*, Jakarta. 12 November 2014, 1–4.  
<https://jurnal.umj.ac.id/index.php/semnastek/article/view/309>
- Setiawan, D. A., Argo, B. D., Hendrawan, Y., 2015. The effect of membrane concentration and preparation on the characterization of chitosan membranes. *J Trop Agric Biosystem* 3(1), 95–99.  
<https://jkptb.ub.ac.id/index.php/jkptb/article/view/260>
- Sipahutar, B. K. S., 2020. Making biodegradable foam from durian seed starch (*Durio zibethinus*) and cellulose nanofiber the dregs (*Camellia sinensis*) by roasting process. *Undergraduate Thesis*. University of North Sumatra, Medan.  
<http://repositori.usu.ac.id/handle/123456789/25568>
- Sofia, A., Prasetya, A. T., Kusumastuti, E., 2017. Comparison of pumpkin-chitosan skin bioplastics with plasticizers from various glycerol sources. *Indonesian. J Chem Sci* 6(2), 110–116.  
<http://dx.doi.org/10.33394/hjkk.v8i1.2559>
- Thakur, R., Pristijono, P., Scarlett, C. J., Bowyer, M., Singh, S. P., Vuong, Q., 2019. Starch-based films: major factors affecting their properties. *Int J Biol Macromol* 132, 1079–1089.  
<https://doi.org/10.1016/j.ijbiomac.2019.03.190>