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Synthesis of Biofoam from Cassava Peel Starch, Banana Peel Starch and Chitosan as Additives

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Abstract

Biodegradable Foam (Biofoam) material has been made for application of styrofoam substitute food packaging material from a mixture of starch with chitosan as an additive. The purpose of this study was to determine the effect of molding temperature on biofoam products and to determine the effect of chitosan addition on the physical, mechanical, and biodegrability properties of biofoam made from cassava peel starch (a) and banana peel starch (b) which is close to commercial biofoam standards. The production of biofoam uses variations in molding temperature of 125, 150 and 175 °C and variations in chitosan weight with variations of 0, 1, 2 and 3 grams. The resulting biofoam product was then tested for density, water absorption, compressive strength, biodegradation and functional groups with *Fourier Transform Infrared* (FTIR). Based on the results of the study, it is known that biofoam that is close to commercial standards is found in the addition of 3 gr chitosan weight with a molding temperature of 125 °C with a density value of 0.423gr/cm^3, water absorption of 42.54% and compressive strength of 0.0045 Mpa. As for biodegradation, biofoam products will decompose 55.17% for 55 days in 0 g chitosan weight with a thermopressing temperature of 175 °C. The spectrum results obtained on biofoam have C-H, C-O, C-N, N-H, C=O and O-H functional groups.

INTRODUCTION

The existence of waste is a problem that has not been resolved until now. Indonesia is the second plastic waste contributor after China (Richana, 2013). Based on data from the Ministry of Environment, the average amount of plastic waste production in Indonesia reaches 175.000 tons per day, its equivalent to 64 million tons per year (Saleh, 2014).

One of the materials that make plastic packaging is Polystyrene or most known as Styrofoam. Styrofoam is a plastic packaging that has a long time to decompose, which is around 100 to 500 years to be perfectly decomposed (KLHK, 2015). Therefore, efforts are needed to find a replacement for Styrofoam as an alternative food packaging that is more environmentally friendly and easily degraded naturally. The solution to the problem is to make biofoam as food packaging from natural materials, namely starch. Starch has properties that are renewable, abundantly available and cheap (Bourtoom & Chinnan, 2018). Starch can be obtained from plants that contain carbohydrates such as cassava, bananas, corn, potatoes and others. Waste from these plants can be taken to be utilized as raw material for making biofoam, especially cassava peel and banana peel waste. The starch content in cassava peels ranges from 44-59% and the fiber content ranges from 17.5-27.4% (Purwaningrum, 2016). Meanwhile, banana peels can contain about 18.50% starch (Jambeck, 2015).

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The characteristics of biofoam can be seen from its physical, mechanical and chemical properties consisting of density, water absorption, tensile strength, biodegradation and *Fourier Transform Infrared* (FTIR). But if only use with starch as a raw material, it does not make the characteristics of biofoam better. This is evidenced in research conducted by Saleh with raw materials of sago starch, cassava peel and banana peel producing biofoam products with high water absorption and low mechanical properties (Iriani, 2016). Characteristics of a biofoam that has good standards which is based on standard synbra technology which has a density value of 0.66 gr/cm^3, water absorption value of < 2%, compressive strength value of 0.2 Mpa. Therefore, to improve the characteristics of biofoam products, it is necessary to add additives in the form of chitosan or polyvinyl alcohol (PVOH) (Dallan et all, 2007). Chitosan is a biopolymer that has a hydrophilic functional group so that it is reactive because it can form interchain hydrogen bonds with amylose and amylopectin in starch (Munadjim, 1983). Chitosan is used as an additive in making biofoam because chitosan has functional groups of amines, primary and secondary hydroxyl which are very reactive because they can form hydrophobic hydrogen bonds which cause lower water absorption in biofoam. Chitosan contains NH3 groups which can bind to OH from starch so that the biofoam becomes stronger (dense) and is not easily degraded by microbes. In this study, Sodium bicarbonate ($NaHCO_3$) was also added which functioned as a *blowing agent* that would make the product lighter. Because the blowing agent has the working principle of being able to release carbon dioxide gas during the decomposition reaction and produce air cavities to increase the swelling power value of the resulting biofoam (Soykeabkaew et al, 2004).

Based on this study, further research is needed to improve the physical, mechanical, and biodegradability characteristics of biofoam products using the thermopressing method. Thermopressing uses a principle similar to making wafers by burning the dough at a certain temperature. Dough with 70-80% humidity is placed in hot molds. The steam formed on the dough will form as a blowing agent to form foam. The product in the form of a tray produced in this process has a light weight and has the ability to withstand good temperatures (Lawton, 2004). The purpose of this research is to determine the effect of thermopressing temperature variations and to determine the effect of chitosan addition on the physical, mechanical and biodegradability properties of biofoam products made from cassava peel starch and banana peel starch.

RESEARCH METHODS

This research was conducted at the Applied Chemistry Laboratory of the Department of Chemical Engineering, Faculty of Engineering, University of Lampung. The tools used in this research, were analytical balance, beaker glass, measuring cylinders, spatula, hotplate, magnetic stirrer, thermopressing, Mechanical Universal Testing Machine (AND MCT-2151), Spectrum Two FT-IR Spectrometer. While the raw materials used in this research are Chitosan 98% (CM), Sodium bicarbonate 99% (Malan) , aquadest, acetic acid 99% (Merck) , cassava peel starch and banana peel starch obtained from Karang Anyar, Gedong Tataan District, Pesawaran Regency, Bandar Lampung.

The variables used in this study were thermopressing temperature of 125 °C, 150 °C and 175 °C and chitosan weight of 1 gr, 2 gr and 3 gr with total mass per sample of 10 gr, Sodium bicarbonate ($NaHCO_3$) mass of 1.2 gr, banana peel starch to cassava peel starch ratio of 1:1.

Starch Preparation

Cassava peels and banana peels were extracted to obtain starch. The first step was to cut the cassava peel and banana peel into small pieces. Each material was blended separately with water in a 2:1 ratio. After obtained the pulp, each material was squeezed by using a filter cloth. Then the filtrate was decanted 24 hours for cassava peel and 48 hours for banana peel filtrate. Next, the starch was dried under the sun and was sieved using a 100 mesh sieve to get a uniform starch size.

Procedure of Biofoam Production

Chitosan was weighed and dissolved in 2% acetic acid, mass ratio 1:40 (gr/gr) with variations of chitosan weight of 1 gr, 2 gr and 3 gr. Meanwhile, cassava peel starch and banana peel were weighed in a ratio of 1:1. Then the two ingredients were mixed and dissolved using aquadest with a ratio of 2:4. The starch mixture was then heated on a hot plate until it reached the material gelatinization

temperature of 78 °C. During the stirring, solution of chitosan and Sodium bicarbonate ($NaHCO_3$) were added alternately until the dough was homogeneous. Next, the dough was molded using a thermopressing equipment for 7 minutes. The molded bio foam was cooled for 15 minutes and then stored in a zip bag lock and put into a desiccator.

Density Test

Density is a measurement of the mass of an object per unit volume. The procedure in density testing refers to ASTM D 792-08. Samples of a certain size were calculated in volume (length x width x height) in cm^3. Then the biofoam was weighed (gr). Density calculation was done by using equation (1):

$$\rho = \frac{m}{V} \qquad (1)$$

Where, ρ is the density (gr/cm^3), m is the sample mass (gr) and V is the volume (cm^3).

Water Absorbency Test

The water absorption test refers to ASTM E 96. The sample was weighed and the mass was recorded. Then the sample was then soaked with water for 1 minute and then it was removed and dried. Re-weighing was recorded as the final mass. Calculation of water absorption was done using equation (2):

$$\text{Water Absorbency } (\%) = \frac{W - W_0}{W_0} \qquad (2)$$

Where, W_0 is the initial sample weight (gr) and W is the sample weight after dipping (gr)

Compressive Strength Test

The compressive strength test used a Mechanical Universal Testing Machine (AND MCT - 2151). The compressive strength test procedure refers to ASTM D 882. The calculation of the compressive strength test was carried out using equation (3):

$$\sigma = \frac{F_{maks}}{A} \qquad (2)$$

Where, σ is the compressive strength (N/mm^2), F_{max} is the Maximum stress (N) and A is the surface area (mm^2)

Biodegradation Test

The degradability test was conducted based on ENI 13432 using the soil burial test method, which is a method of burying biofoam in the soil for a certain time. Calculation of mass reduction was carried out using equation (4):

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

Where, M_0 is the sample mass before biodegradation process (gr) and M_1 is the mass of sample after biodegradation process (gr)

The degradation of the sample was obtained by dividing the percent mass reduction by the length of time of burial, the calculation of equation (5) as follows:

$$\%\ Degradation = \frac{\%\ mass\ reduction}{burial\ time} \qquad (4)$$

FTIR (Fourier Transform Infrared) Analysys

FTIR (*Fourier Transform Infrared*) is a method that uses infrared spectroscopy. The working principle of FTIR spectroscopy is the interaction of energy with matter. In infrared spectroscopy, infrared radiation is passed through the sample. Some of the infrared radiation is absorbed by the sample and some is passed through. The result of the spectrum is the amount of molecular absorption and transmission that forms the molecular fingerprint of a sample. The benefits of information that can be known from FTIR (*Fourier Transform Infrared*) are identifying an unknown compound, can analyze the functional groups of a compound with better analytical capabilities than conventional IR systems, including in terms of sensitivity, speed and increased data processing (Thermo Nicolet, 2001).

RESULTS AND DISCUSSION

From the research that has been done, the results of biofoam products can be visually observed. The observation results are shown in Figure 1 and Table 1.

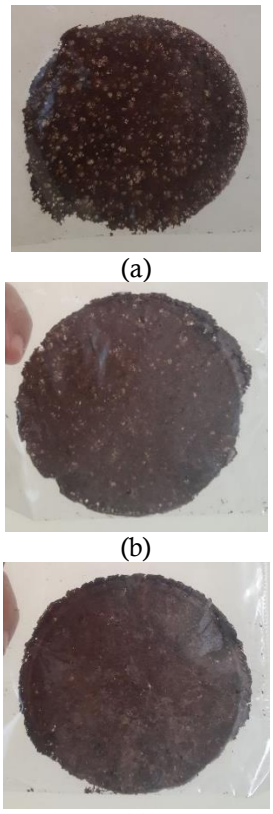
From Table 1, it is known that the higher the temperature of the thermopressing process used, the harder the texture of the biofoam produced. This is Because there are fewer cavities in the biofoam resulting in a solid biofoam structure. As for the color of biofoam products, it is more

(3)

dominant in dark color because it uses ingredients from banana peel starch which is blackish brown.

Table 1. Visual Appearance of Biofoam

Thermopressing Process Temperature (°C)	Biofoam Visual Appearence
125	Slightly blackish brown color, slightly solid texture (a)
150	Slightly blackish brown color, moderately solid texture (b)
175	Blackish brown color, solid texture (c)



(a) (b) (c)

Figure 1. Biofoam Visual Appearance, (a) at 125 °C, (b) at 150 °C, (c) at 175 °C.

Density Test

Density testing is done to determine the density of the atoms that make up the material that are interrelated or interact between one atom and another. Density is a physical property of a polymer. The density of a material affects the mechanical properties of the material, the higher density value of material then the more it increases its mechanical properties, so that the resulting biofoam has a good tensile strength value. The following is a graph of the calculation results of the biofoam product density test.

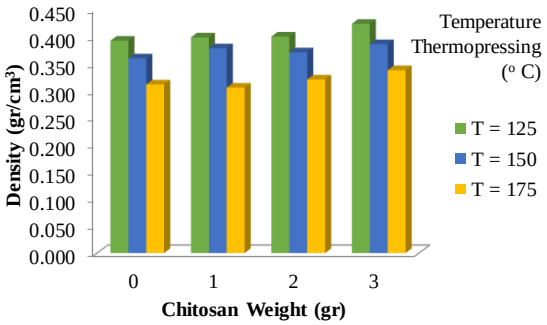


Figure 2. Effect of Thermopressing Temperature and Chitosan Addition on Biofoam Density

Figure 2 shows that the data that is closest to the biofoam standard with a mixture of cassava peel starch and banana peel starch using the thermopressing method is found in biofoam with a chitosan variation of 3 grams and a process temperature of 125 °C which has a density value of 0.423 gr/cm^3. When compared to the standard biofoam from *synbra technology* which has a density value of 0.66 gr/cm^3, this research still has a lower density value.

When viewed from the graph, it is concluded that the higher the molding temperature, the lower the density. This is because the higher the molding temperature, the water contained in the dough will evaporate, then encourage starch to produce a hollow structure so that the mass of biofoam decreases, as a result the density value becomes low. In addition, the density value of biofoam is also influenced by the addition of chitosan weight. Chitosan functions as a filler that can fill empty cavities in biofoam so that as the chitosan weight increases, the density value will be higher. Based on the calculation that have been done the higher density value can also be caused because there is still a liquid substance in the form of acetic acid that has not evaporated in biofoam.

WATER ABSORBENCY TEST

Water absorption testing aims to determine the amount of water absorbed by biofoam and determine biofoam's resistance to water. This is because biofoam products will be used as food packaging containers so that the expected water absorption has a low value. Water absorption testing is done by calculating the change in biofoam

mass before and after entering water for 1 minute and then dividing by the mass of biofoam before being put into water. The following is a graph of the results of the water absorption test on biofoam products.

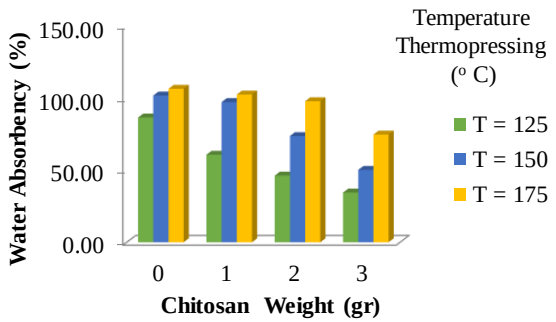


Figure 3. Effect of Thermopressing Temperature and chitosan on Biofoam Water Absorbency

Figure 3 shows that the data that is closest to the biofoam standard with a mixture of cassava peel starch and banana peel starch using the thermopressing method is found in biofoam with a process temperature of 125 °C and a chitosan variation of 3 grams, which has a water absorption value of 34.5%. When compared to the biofoam standard from *synbra technology* which has a water absorption value of < 2%, this research still has a high water absorption value.

The water absorption capacity of the biofoam produced increases as the temperature of the thermopressing process increases. This is because the water contained in the dough will evaporate, then encourage starch to produce a hollow structure so that the cavity formed is more and more, therefore water will more easily enter to fill the cavity formed, as a result the value of water absorption becomes more and more. This is in line with the research of Miladinov & Hanna (2001) which states that the more cavities formed, the surface area will also increase and this will affect the water absorption.

Water absorption is also affected by the addition of chitosan weight, it can be seen in Figure 3 as the chitosan weight increases, the water absorption is getting lower. This is because the addition of chitosan can increase the mass density of biofoam and cause the amount of water absorbed to be smaller. Empty cavities will be filled by chitosan which has hydrophobic properties so that the resulting biofoam will be tighter and reduce water absorption (Dallan et al., 2007). Research by Hendrawati et al (2017) showed similar results where the addition of chitosan had an effect on water absorption which became lower with increasing levels of chitosan. Based on further research by Hendrawati et al (2019), the addition of chitosan causes the presence of an amine group (NH_2^-) in acetic acid solution to protonate to NH_3^+. So that a strong hydrogen bond is formed between NH_3^+ from chitosan and OH from starch. This hydrogen bonding occurs when an O or N atom molecule contained in chitosan interacts with an H atom from amylose, amylopectin or from chitosan itself. Therefore, strong hydrogen bonds make biofoam not easy to absorb water.

Compressive Strength Test

Compressive strength testing aims to determine how much maximum strength can be held by biofoam which will later be used as food packaging. Therefore, it is expected that biofoam has a high compressive strength value so that when used biofoam is not easily damaged and broken (Iriani, 2013). The tool used in this test is the Mechanical Universal Testing Machine (AND MCT - 2151). The following is a graph of the calculation results of the compressive strength test on biofoam products.

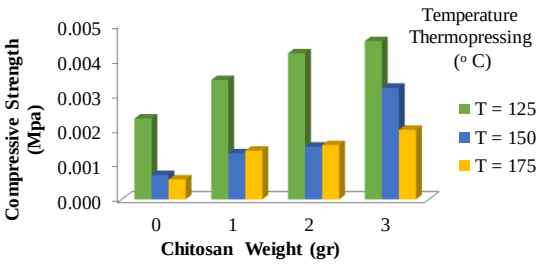


Figure 4. Effect of chitosan and thermopressing temperature on the compressive strength of biofoam.

Figure 4 shows that the data that is closest to the biofoam standard with a mixture of cassava peel starch and banana peel starch using the thermopressing method is found in biofoam with a chitosan variation of 3 grams and a process temperature of 125 °C which has a compressive strength value of 0.00452 Mpa. When compared to the biofoam standard from *synbra technology* which has a compressive strength value of 0.2 Mpa, this study still has a lower compressive strength.

The compressive strength of the biofoam produced experienced a low value as the temperature of the thermopressing process

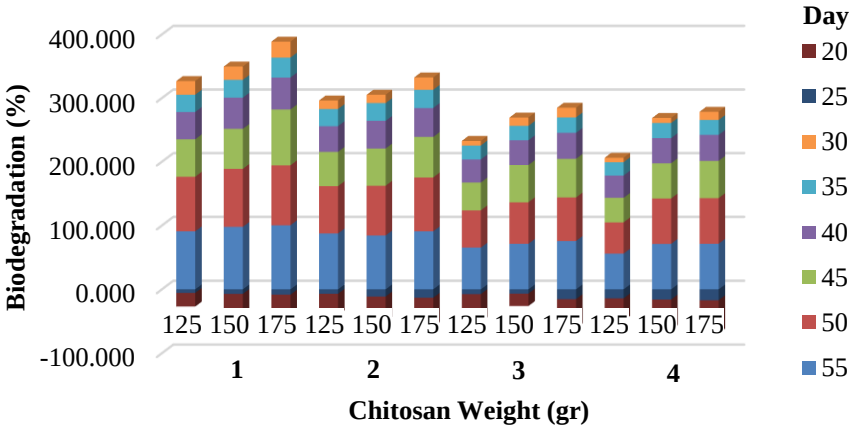


figure 5. Effect of chitosan and thermopressing temperature on biofoam biodegradation

increased. The increase in temperature causes the water in the dough to evaporate, which will encourage the starch to produce a hollow structure, the more cavities formed, the compressive strength of the biofoam will decrease because nothing can withstand the amount of pressure exerted on the surface of the biofoam. This is in line with the research of Soykeabkaew *et al.* (2004) which states that hollow structures generally have low compressive strength because the cavities that are formed generally have thin cell walls so that they will be easily destroyed when pressurized.

The compressive strength is also influenced by the addition of chitosan weight, biofoam with the addition of chitosan tends to have higher compressive strength results compared to biofoam without the addition of chitosan, it can be seen in Figure 4 that as the chitosan weight increases, the compressive strength value gets higher. This is due to the tight structure of chitosan and the ability to form hydrogen bonds between chains, namely NH_3^+ from chitosan and OH from starch. This causes the distance between the molecules in the biofoam to become denser and affects the compressive strength value (Setiawan et al, 2015). Chitosan also has a linear polymer chain structure, which tends to form a crystalline phase because it is able to arrange polymer molecules in a more orderly manner. So that the crystalline phase can provide strength, stiffness, and hardness to the resulting product (Agustin & Padmawijaya, 2016).

Biodegradation Test

The biodegradation test aims to determine the level of decomposition of biofoam samples by microorganisms in the soil. This test is carried out by the soil burial test method, namely by burying the sample into the ground for a certain time. In this study conducted for 55 days. The following is the calculation data from the biodegradation test on biofoam products.

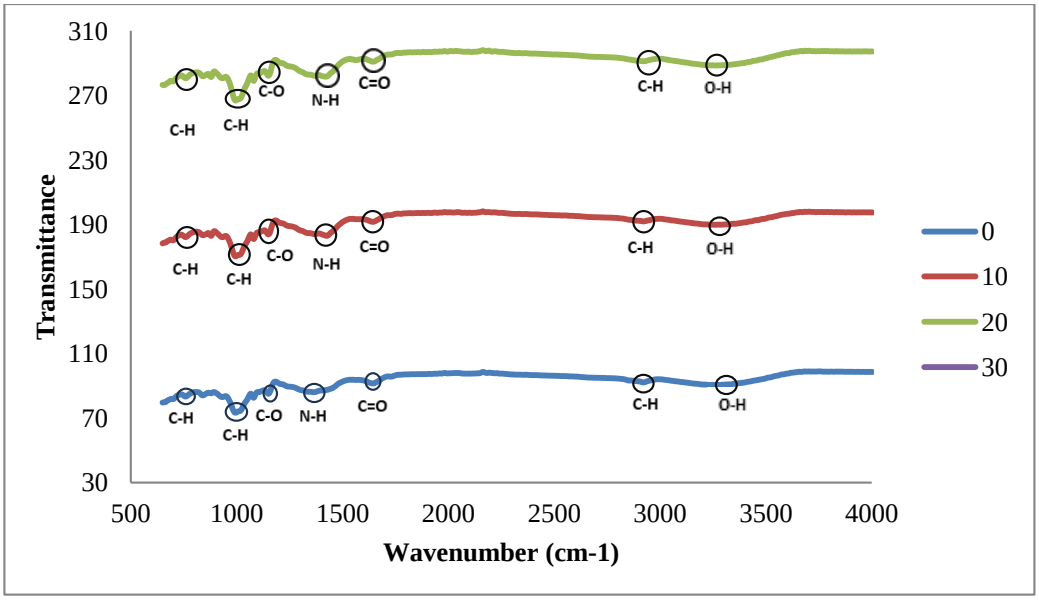
Figure 5 shows that the highest level of biodegradation in biofoam with a variation of 0% chitosan and a thermopressing temperature of 175°C degraded 55.17% for 55 days and the lowest level of biodegradation occurred with the addition of 30% chitosan.

From the results of the biofoam biodegradation test, it was found that the higher the temperature of the thermopressing process, the higher the biofoam degradation value, it can be said that biofoam is easier to decompose when the process temperature is high. High process temperatures cause many cavities to form in biofoam so that bacteria will more easily enter and grow into the surface of biofoam and over time biofoam will decompose faster.

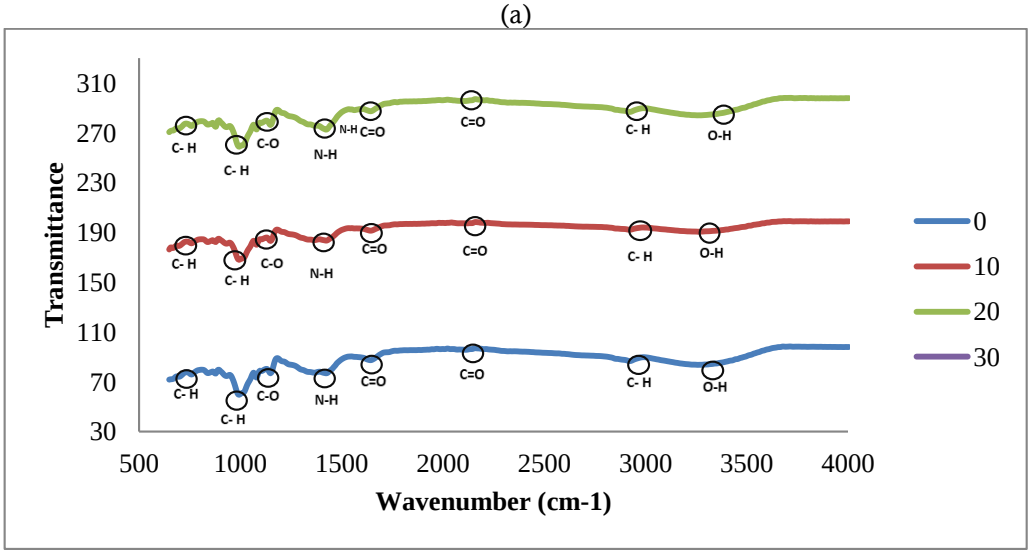
Bioegradability of biofoam is also affected by the addition of chitosan concentration. The more concentration of chitosan added to the biofoam, the more difficult it will be for the biofoam product to decompose. Chitosan has anti-bacterial properties which cause the formation of strong hydrogen bonds between NH_3^+ from chitosan and OH^- from starch. The value of NH_3^+ will increase as the amount of chitosan increases so that the biofoam becomes stronger and is not easily degraded by microorganisms in the soil (Bourtoom & Chinnan, 2008).

Analysys Functional Groups

Functional group analysis using Fourier-transform infrared spectroscopy (FTIR) was conducted on biofoam from cassava peel starch and



(a)



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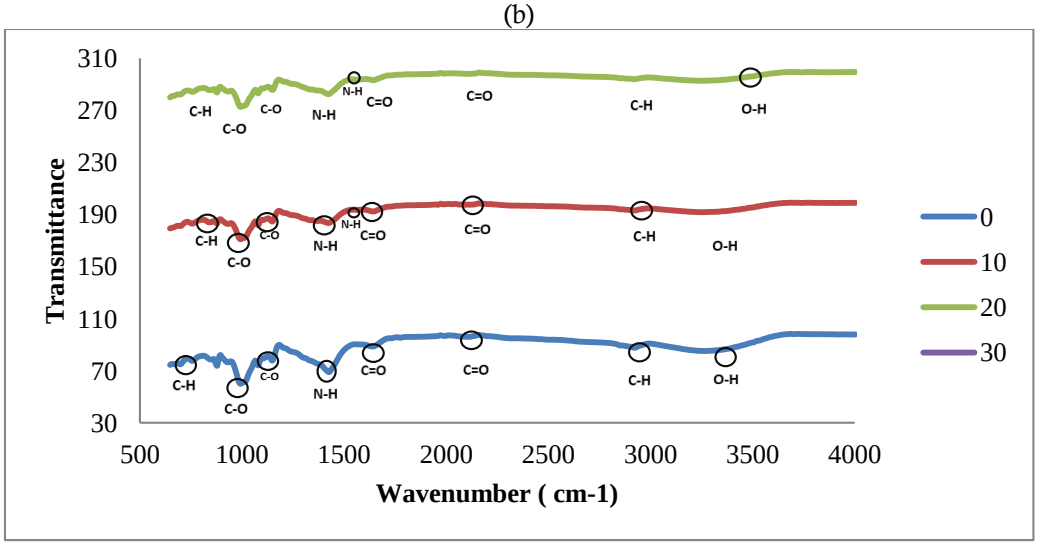

(c)

Figure 6. Relations graph of chitosan weight to biofoam characteristics (a) at 125 °C, (b) at 150 °C, (c) at 175 °C.

banana peel starch with the aim of identifying the functional groups contained in biofoam products. The FTIR functional group testing method uses infrared spectroscopy equipped with Fourier Transform calculation and data processing to obtain higher resolution and sensitivity. You can see the graph in the figure below which is the result of FTIR analysis of the relationship between chitosan weight and biofoam characteristics at each temperature.

Figure 6 shows that the spectrum results obtained on biofoam with temperatures of 125 °C, 150 °C and 175 °C have C-H, C-O, C-N, N-H, C=O and O-H functional groups. This is evidenced by the presence of absorption band peaks at 760.4 cm^{-1}, 834.9 cm^{-1}, 842.4 cm^{-1}, 998.9 cm^{-1}, 2922.2 cm^{-1} which are typical of the C-H functional group of alkane compounds. In addition, there is an absorption at wave number 1148 cm^{-1} which is typical of C-O functional groups and absorption at wave numbers 1640 cm^{-1}, 1647.5 cm^{-1} which is typical of C=O functional groups. O-H functional groups derived from the constituent components of starch, namely amylose and amylopectin at wave numbers 3250.2 cm^{-1}, 3257.7 cm^{-1}, 3265.1 cm^{-1}, 3266.1 cm^{-1} and 3272.6 cm^{-1}.

Based on the results of the functional group analysis, there is no difference in functional groups in each thermopressing temperature variation. In each run there are O-H and C-O groups that indicate the degradability of biofoam and N-H functional groups that indicate the presence of amine groups due to the addition of chitosan. The OH group comes from the constituent components of starch, namely amylose and amylopectin. O-H functional group which is one of the functional groups that affect the biodegradation properties of biofoam in soil. This is because the O-H and C-O groups are hydrophilic groups so that water molecules can cause microorganisms in the environment to enter the biofoam matrix. The hydrogen bond between the O-H group in starch and the N-H group in chitosan causes the mechanical properties of the resulting biofoam to be higher so that the biofoam becomes tight and stiff compared to biofoam without the addition of chitosan (Sofia et al., 2017).

CONCLUSION

Based on the results of the study it is concluded that Biofoam products produced from cassava peel starch and banana peel starch raw materials have approached the standard of commercial biofoam from *synbra technology*. The characteristics of biofoam products that are close to the standard value are in the addition of 3 grams of chitosan weight, 125 °C thermopressing temperature with a density value of 0.423 gr/cm^2, 34.5% water absorption and compressive strength of 0.005 Mpa. The suggestion from this study is to use an additional material, namely Sodium Metabisulfite ($Na_2S_2O_5$) which functions as an browning prevention agent and the addition of cellulose so that the resulting biofoam product is more robust and strong so that it can increase the value of the physical and mechanical properties of the biofoam product.

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REFERENCES

Agustin, Y. E., Padmawijaya, K. S. 2016. Sintesis Bioplastik Dari Kitosan-Pati Kulit Pisang. Jurnal Teknik Kimia. 10 (2): 42 - 48

Berghuis, N. T., Zulfikar, M. A., Wahyuningrum, D. 2020. Sintesis Membran Komposit Berbahan Dasar Kitosan dengan Metoda Sol-Gel sebagai Membran Fuel Cell Pada Suhu Tinggi. Al Kimiya: Jurnal Ilmu Kimia dan Terapan. 7(1): 35-46.

Bourtoom, T., Chinnan, M. S. 2018. Preparation and properties of rice starch chitosan blend biodegradable film. Food Science and Technology. 41(9) :1633 – 1641.

Dallan, P. R. M., Moreira, P. D. L., Petinari, L., Malmonge, S. M., Beppu, M. M., Genari, S. C., Moraes, A. M. 2007. Effects of chitosan weight concentration and incorporation of chitin and glycerol on dense chitosan membrane properties. Journal of Biomedical Materials Research Part B: Applied Biomaterials. 80(2): 394-405.

Hendrawati, N., Yulia I., Putri A. W. 2017. Pengaruh Penambahan Kitosan Terhadap Sifat Biodegradable Foam Berbahan Baku Pati. Jurnal Rekayasa Kimia dan Lingkungan. 12(1): 1-7.

Hendrawati. N., Dewi, E. N., Santosa, S. 2019. Karakterisasi Biodegradable Foam dari Pati Sagu Termodifikasi dengan Kitosan Sebagai Aditif. Jurnal Teknik Kimia dan Lingkungan. 3(1): 47-52

Iriani E. S., Richana, N., Sunarti, T. C. 2016. Pengembangan Biodegradable Foam Berbahan Baku Pati. Report. Buletin Teknologi Pasca Panen. Fakultas MIPA Institut Pertanian Bogor. Bogor Agricultural University. Bogor.

Jambeck, J. R., Andrady, A., Geyer, R., Narayan, R., Perryman, M., Siegler, T., Wilcox, C., Lavender, L. K. 2015. Plastic waste inputs from land into the ocean. Science. 347(6223): 768-771.

KLHK. 2015. Rangkaian Hari Lingkungan Hidup 2015- Dialog Penanganan Sampah Plastik. http://kanalkomunikasi.pskl.menlhk.go.id/rangkaian-hlh-2

Lawton, J. W., Shogren, R. L., Tiefenbacher, K. F. 2004. Aspen fiber addition improves the mechanical properties of baked cornstarch foams. Industrial Crops and Products. 19(1): 41 – 48.

Miladinov, V. D., Hanna, M. A. 2001. Temperatures and ethanol effects on the properties of extruded modified starches. Industrial Crops and Products.13(1): 21-28

Munadjim. 1983. Teknologi Pengolahan Pisang. PT Gramedia Pustaka Utama. Jakarta

Purwaningrum, P., 2016. Upaya Mengurangi Timbulan Sampah Plastik Di Lingkungan. Indonesian Journal of Urban and Environmental Technology. 8(2): 141-147.

Richana, N. 2013. Menggali Potensi Ubi Kayu dan Ubi Jalar. Nuansa Cendikia. Bandung.

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. Proceedings of the National Science and Technology Seminar, Jakarta. 12 November 2014, 1–4.

Setiawan, Heru., Reza, F., Aziz, A. 2015. Penentuan Kondisi Optimum Modifikasi Plasticizer Sorbitol PVA pada Sintesa plastic Biodegradable Dasar Pati Sorgum dan Chitosan Limbah Kulit Udang. Journal of Science and Technology. 13 (1): 29 – 38.

Sofia, A., Prasetya, A. T., Kusumastuti, E. 2017. Comparison of pumpkin-chitosan skin bioplastics with plasticizers from various glycerol sources. Indonesian. Journal of Chemical Science. 6(2), 110– 116.

Soykeabkaew, N., Supaphol, P., Rujiravanit. R., 2004. Preparation and characterization of jute and flax reinforced starch-based composite foams. Carbohydrate Polymers. 58(1): 53-63

Thermo Nicolet. 2001. Introduction to Fourier Transform Infrared Spectrometry. Thermo Nicolet Inc., Madison, USA.