



Effect of Chitosan Variation in Starch and Cellulose Based Biofoam

Ayu Lintang Cahyani, Vidrika Linda, Dody Guntama*, Mubarakah N. Dewi, Lukmanul Hakim

Faculty of Industrial Technology, Jayabaya University, Jl. Raya Jakarta-Bogor no. Km 28, Pekayon, Cimanggis, East Jakarta 16452, Indonesia.

*dodyguntama@jayabaya.ac.id

Abstract. Styrofoam's using as packaging is increasing. Styrofoam is difficult to decompose so alternatives such as biofoam are needed. This study explores the creation of eco-friendly packaging material by varying cellulose (0%, 3%, 5%, and 7%) and chitosan concentrations (0%, 2%, 4%, 6%, 8%, and 10%) in biofoam, aiming to replace non-biodegradable Styrofoam. Production is carried out by delignifying sugarcane bagasse and corn cobs with 10% NaOH, making tofu pulp starch and biofoam. The research focuses on tensile strength, absorption capacity, biodegradation, and morphology of the biofoam. Results indicate that chitosan concentration affects water absorption and biodegradation, while cellulose impacts tensile strength. The findings highlight the potential of biofoam made from tofu dregs, corn cobs, and sugar cane bagasse, offering a promising alternative to Styrofoam

Keywords: Styrofoam, bagasse, corn cobs, and biofoam.

(Received 2023-10-06, Accepted 2023-10-22, Available Online by 2023-10-26)

1. Introduction

The use of Styrofoam as food and drink packaging has become a practical part of human lifestyle in recent years. The application of styrofoam as a packaging material is because styrofoam has the advantages of being practical, light and economical. Based on information provided by the Ministry of the Environment and Forestry (KLHK) on the website karet6.com published on February 16 2021, the increase in packaging material waste, especially plastic and styrofoam, jumped to 27-36% during the pandemic to the new normal era. The increase in the number of Styrofoam users is caused by people's new habits of preferring to buy food and take it home to avoid the spread of the covid-19 virus.

An increase in the amount of styrofoam waste will cause many problems for the environment due to the nature of styrofoam which is difficult to decompose naturally and if burned it will produce dioxin compounds which are carcinogens [1]. One alternative that can be used as a substitute for styrofoam is biodegradable foam (biofoam). Biodegradable foam is an alternative packaging material that can be made from starch and cellulose [2]. One of the studies on biofoam was carried out by Nanik who used



sago starch with the addition of chitosan. Research shows that the addition of chitosan can provide biofoam characteristics that are stronger and do not easily absorb water. This is because chitosan has amine, primary, and secondary hydroxyl functional groups [2]. Apart from that, research on biofoam has been carried out by Bangkit using tea dregs waste. This research shows that the addition of pulp fiber causes an increase in tensile strength and an increase in water absorption capacity. This is caused by individual fibers and fiber length in the composition of biofoam [3].

Biodegradable foam (Biofoam) is an alternative replacement for Styrofoam packaging using the main raw material in the form of starch so that the alternative packaging can decompose naturally [4]. The main ingredient that is widely used in making biodegradable foam is starch. The use of starch as an alternative main ingredient for making biofoam is because starch has several advantages, namely that it can be renewed, is an abundant raw material in nature and is easily degraded. Starch also has special properties such as the ability to expand and is easily modified. However, biofoam made from pure starch still has shortcomings, namely that it is brittle and easily absorbs water. To increase the strength and flexibility of starch-based biofoam, additives can be added including plasticizers, modified starch, synthetic polymers, and fibers [5].

The process of making biofoam can be done using several methods, including using thermopressing technology and a baking process where starch, fiber and other additives are mixed with a certain composition. Biofoam can be made with a main mixture of starch and fiber. Starch is used in its manufacture because it is cheap and easy to obtain, low in toxicity and easily decomposed. However, the use of starch alone will greatly reduce the strength value of the product produced and has a very low resistance value to water absorption so to increase the strength and flexibility properties of the product, fiber is added to improve its mechanical properties [3].

2. Methods

2.1. Design Process for Making Biofoam

The design process for making biofoam, it begins with making cellulose, followed by making starch and then the stage of making the biofoam itself. Cellulose was prepared from sugar cane bagasse and corn cobs. Tofu dregs were used for starch. Biofoam was made with varying cellulose (0%, 1%, 3%, 5%, 7%) and chitosan (0%, 2%, 4%, 6%, 8%, 10%) concentrations. Testing included tensile strength, absorption capacity, biodegradation, and SEM analysis.

2.1.1. Materials

In the process of preparing the materials and making the biofoam, the main ingredients were tofu dregs obtained from the tofu production center in the Kelapa Dua area of Depok, sugar cane dregs obtained from the Tumpah Pesona Square market, Depok, and corn cobs. The material used to make starch is distilled water. The materials used to make cellulose are Sodium Hydroxide (NaOH), Aquadest, and Hydrochloric Acid (HCl). The material used to make biofoam is Polyvinyl Alcohol (PVA); Magnesiumstearate and chitosan

2.1.2. The Process of Making Cellulose

In the process of making cellulose, the dried sugar cane bagasse and corn cobs are then chopped to reduce the fiber surface. The bagasse and corn cobs that had been chopped and dried were each weighed at 1 Kg and carried out a delignification process with 1 L of 10% Natrum Hydroxide (NaOH) and heated at a temperature of 121°C while stirring for 15 minutes. The resulting cellulose is then washed with distilled water until it is clean and neutral. The cellulose was then dried in an oven at 100°C for 5 hours [6].

2.1.3. Starch Manufacturing Process

In making starch, tofu dregs obtained from tofu production centers are cleaned. Tofu dregs are added with water 1:1. The tofu dregs that have been added to water are then filtered using a filter cloth to take

the filtrate. Then leave the tofu dregs filtrate for 24 hours until a starch precipitate forms which is then separated from the filtrate. The tofu dregs are then dried and mashed [7].

2.1.4. Process of Making Biofoam

In the process of making biofoam, the prepared cellulose is then weighed according to variations of 0%, 1%, 3%, 5% and 7%. Starch is added as much as 85% of the total weight of the dough assuming the total weight of the dough is 100 grams. The starch and cellulose mixture was weighed and 5% of the weight of the dough was added with magnesium stearate. Polyvinyl Alcohol (PVA) is added as much as 10% by weight of the total mixture. Aquadest is added to as much as 40% of the total dough weight. Chitosan was added according to variations of 0%, 2%, 4%, 6%, 8%, and 10% of the dough weight. After obtaining the perfect mixture of ingredients, stir until the dough expands. The finished dough is then molded and heated in the oven at 120 °C for 1 hour jam [2]. The following is a flow diagram of the biofoam making process.

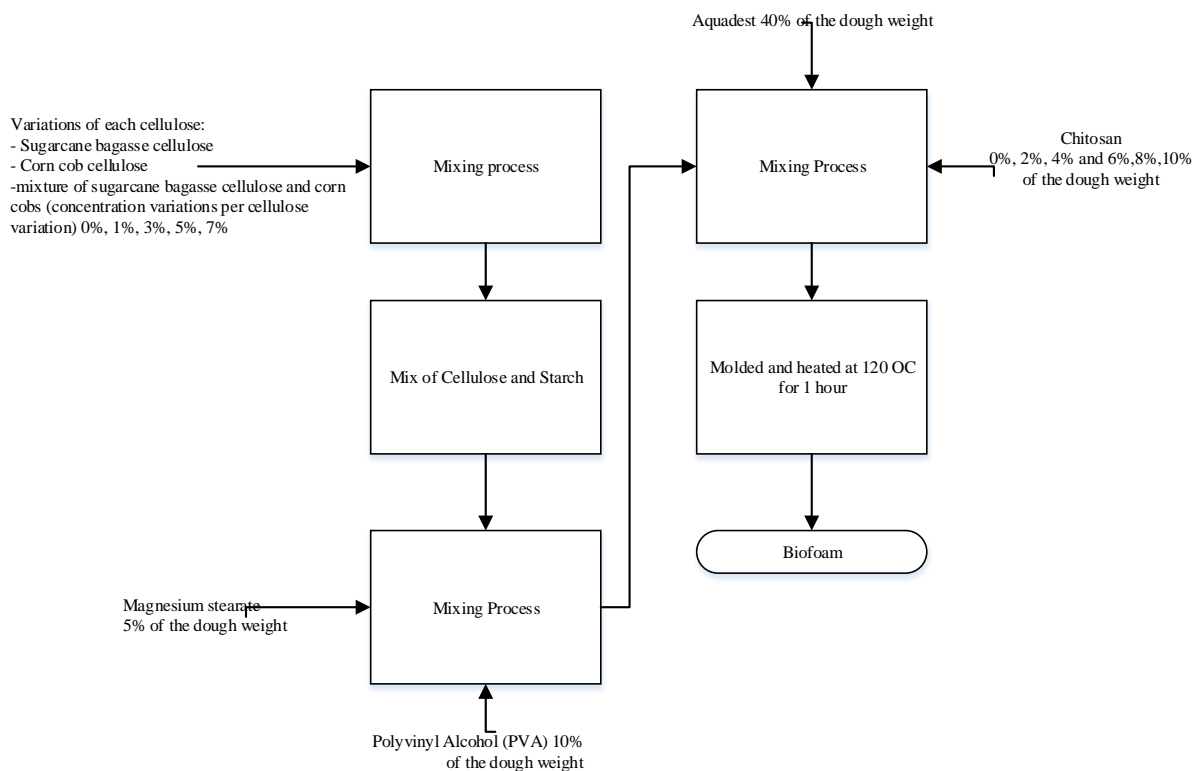


Figure 1 Research Metodology

2.2. Sample Testing Procedure

2.2.1. Tensile Strength Test

The biofoam to be tested is adjusted to size. The size of the biofoam is adjusted to the standard size that will be used. Standard ASTM D-638 size type 1 with a maximum length of 16 cm and thickness < 7 mm. The customized biofoam sample is then clamped at both ends to the grip. The biofoam sample was then tested by pulling it until it broke with a tensile strength tool. The test results in the form of maximum break were recorded as the tensile strength of the biofoam [6].

2.2.2. Absorption Test

The biofoam that was tested was adjusted to a size of 2.5 cm x 5 cm. The biofoam was then dried in the oven for 5 minutes at a temperature of 40-50 °C. Biofoam is weighed as an initial weight. The 500 mL glass cup that has been prepared is then filled with distilled water to ¼ volume. The biofoam to be tested for absorption is placed in a glass cup filled with water for 1 minute. After one minute, remove the biofoam and dry the surface a little. The dried biofoam is then weighed as the final weight [6].

2.2.3. Biodegradation Rate Test

The Biofoam to be tested is adjusted to a size of 2.5x5 cm. The biofoam that has been adjusted to size is then weighed as the initial weight. The biofoam samples were then planted in the soil for 21 days. Checks are carried out every 7 days by weighing the biofoam to determine the level of degradation. After 21 days the sample was then removed and cleaned then weighed again as the final weight [6].

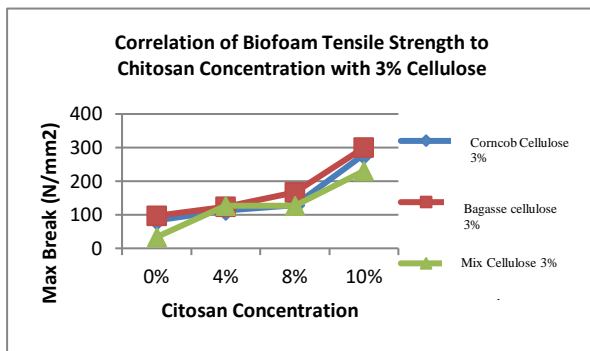
2.2.4. Biofoam Morphology Test using SEM

The Biofoam to be tested is adjusted to a size of 3x3 cm. Biofoam that has been adjusted to size is then placed in the sample compartment. Biofoam was read using Prisma E SEM ThermoFisher Scientific at 100x and 1000x magnification.

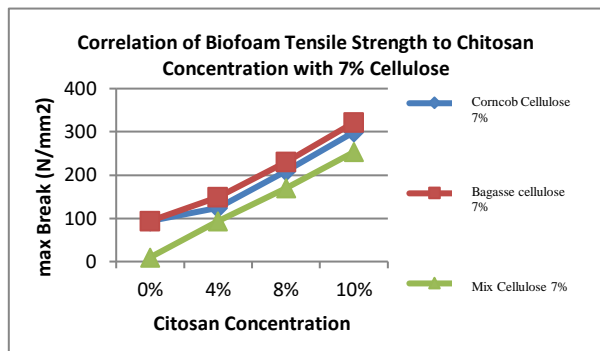
3. Results and Discussion

3.1. Tensile Strength Test

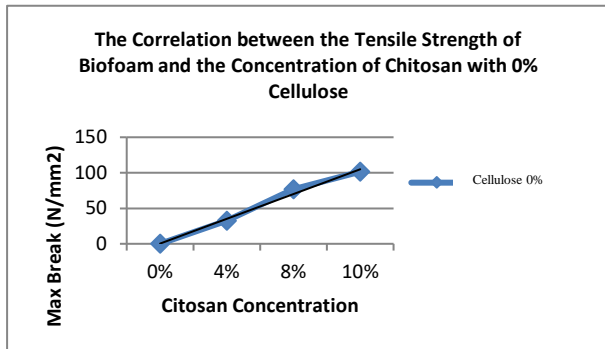
Tensile strength testing was carried out on biofoam both with the addition of cellulose from bagasse, corn, mixtures and without the addition of cellulose. The greater the tensile strength value of a material means a greater force is needed to pull the material. The effect of the composition ratio of cellulose and chitosan on the tensile strength of biofoam as in Figure



(a)



(b)



(c)

Figure 2. Graph of the correlation between the tensile strength of biofoam and the concentration of chitosan (a) The correlation between the tensile strength of biofoam and the concentration of chitosan with 3% cellulose (b) The correlation between the tensile strength of biofoam and the concentration of chitosan with cellulose 7% (c) The correlation between the tensile strength of biofoam and concentration chitosan with 0% cellulose

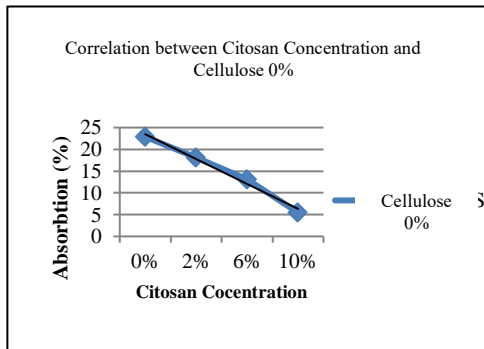
The graph shows biofoam's strength increased with higher cellulose. Cellulose concentration was tested at concentrations of 0%, 3%, and 7%. The increasing amount of cellulose will increase the strength between the phases of biofoam. The strength between these phases provides a biofoam effect that can withstand tension so that the tensile strength increases [3]. This increase in tensile strength value is in accordance with research conducted by Nanik Hendrawati (2017) that increasing the amount of chitosan will increase the tensile strength of biofoam [4].

The graph shows that biofoam's strength increased with higher cellulose concentrations, with bagasse cellulose showing superior results (graph with orange line). The tensile strength value of bagasse cellulose is caused by the crude fiber component that dominates bagasse cellulose, which is 36.75% [8]. Long fiber size as a filler will increase the biofoam's resistance strength which will make the tensile strength value greater [3].

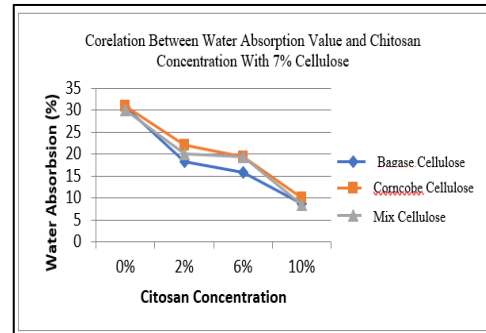
Based on data from Product Information Commercial regarding the mechanical properties of styrofoam, the mechanical strength of styrofoam is 0.1 MPa or 1 N/mm². Based on the results obtained from this research, the tensile strength value was obtained at a value of more than 0.1 MPa [3]. Based on this data, the biofoam produced from the application of tofu dregs, sugar cane bagasse and corn cobs meets the tensile standards of commercial Styrofoam.

3.2. Water Absorption Test

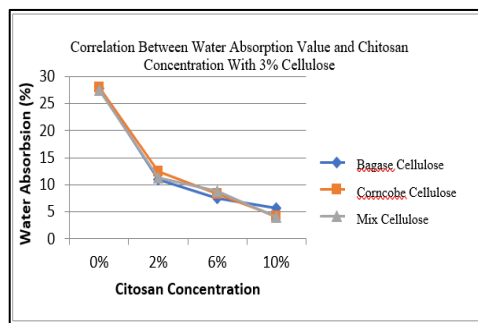
Water absorption capacity is the ability of a material to absorb water. The water absorption test is an important parameter to find out whether biofoam can easily absorb water or not. This parameter can be used as an indication of the suitability of biofoam in its application as a food packaging material. The following is Figure 3 which presents the correlation between variations in biofoam concentration and the ability of biofoam to absorb water with 0% cellulose.



(a)



(b)



(c)

Figure 3. (a) Graphic image of the correlation between water absorption values and the concentration of chitosan with 0% cellulose. (b) Graphic image of the correlation between water absorption values and the concentration of chitosan with 7% cellulose. (c) Graphic image of the correlation between water absorption values and chitosan concentration with a cellulose concentration of 3%

The graph above shows the effect of chitosan concentration on the ability of biofoam to absorb water. Based on the graphs presented in Figure 3 it appears that chitosan reduced water absorption, especially at higher concentrations. Corn cobs displayed high water absorption due to their hydrophilic nature. The large amount of cellulose in corn cobs 41%, is one of the reasons why corn cobs can absorb more water [9].

Based on the data presented in Figure 3 regarding the comparison graph between cellulose concentration and chitosan concentration, the percentage of water absorption decreases with an increase in the amount of chitosan concentration. The decrease in the amount of water absorbed is caused by the hydrogen bonds formed by chitosan so that it is more hydrophobic. Hydrogen bonds in chitosan are formed due to the presence of amine groups and hydroxy groups. The amine group (NH_2) in chitosan will be protonized to become NH_3^+ which will form hydrogen bonds with OH^- , making the biofoam bond stronger and not easily absorbing water [4].

3.3. Biodegradation Test

Biodegradation testing of biofoam produced from research, both with and without the addition of chitosan, aims to find out how much biofoam can decompose naturally when compared to packaging that is widely used, such as styrofoam or plastic. The effect of the comparison of cellulose composition from corn cobs, sugar cane bagasse, and the mixture on the biodegradation value can be seen in the following graph.

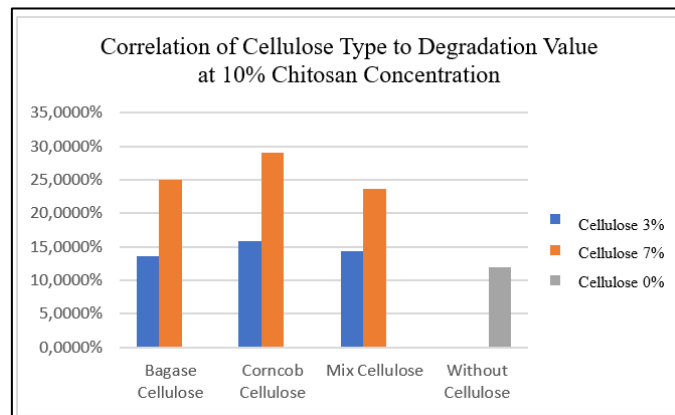


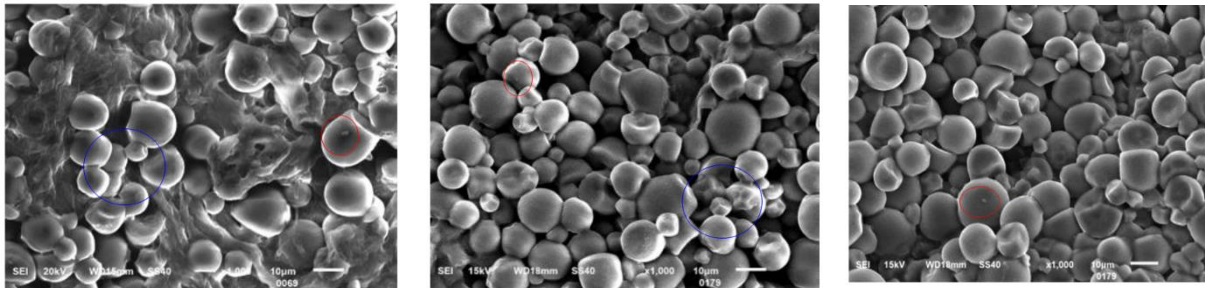
Figure 4. Graph of the correlation between cellulose type and biofoam degradation value

Figure 4. above shows a graph of the correlation between cellulose type and degradation value at a chitosan concentration of 10%. In the graph it can be seen that corn has the highest degradation value among other types of cellulose with a percentage of 15.8820% at a cellulose concentration of 3% and a percentage of 28.9818% at a concentration of 7% under conditions where the chitosan concentration for both is 10%. Corn cellulose exhibited the highest biodegradation rates. Increasing chitosan hindered biodegradation, making the biofoam more resistant. The high biodegradation value of corn cobs is because corn cob cellulose has a fairly high water content of 5.39% [10]. The biodegradation test was carried out under aerobic conditions with the help of microorganisms in the soil using the soil burial test method [13]. The water content in the supporting specimen will increase the ability of bacteria to decompose the specimen. Thus, the biodegradation value of corn cobs is higher than the value of other cellulose.

In this research, chitosan was used as an additive to increase the strength of biofoam and as a coating to reduce the ability of biofoam to absorb water in its environment [4]. The degradation value decreased along with increasing chitosan concentration. A decrease in biodegradation value indicates that biofoam will be increasingly difficult to decompose. The addition of chitosan causes the formation of hydrogen bonds between NH_3^+ from chitosan and OH from starch. The NH_3^+ value will increase with the addition of chitosan and make the biofoam stronger and not easily degraded. Apart from increasing the strength of biofoam, the addition of chitosan can also act as an anti-microbial agent [12]. Based on biodegradation results data, it refers to the Synbra Technology biofoam standard which degrades in less than 48 days. The results obtained in the biodegradation test process for 21 days were in the highest range of 40% - 57%. The biodegradation value will continue to increase if continued until the 48th day. Based on SNI, the biodegradation standard is 89.8% - 90% for less than 180 days. Thus, based on the test reduction interval of 21 days, the biofoam based on tofu dregs, corn cobs, sugar cane bagasse with chitosan as an additive meets the established standards.

3.4. Biofoam Morphology Test with Scanning Electron Microscope (SEM)

Characterization using a scanning electron microscope (SEM) aims to see the morphological structure and determine the interactions that occur between the filler material and the biofoam matrix. Characterization of biofoam with a composition without chitosan, plus 4% chitosan, and 6% chitosan with 5% mixed cellulose can be seen in the following picture



(a)

(b)

(c)

Figure 5. 10. Morphological characteristics of biofoam (a) Composition 0% chitosan 5% cellulose mixture (b) Composition 4% chitosan 5% cellulose mixture (c) Composition 10% chitosan 5% cellulose mixture

SEM analysis indicated denser biofoam with increased chitosan, showcasing improved interfacial bonding. Figure 5 (a) shows the morphology of biofoam with a composition of 0% chitosan 5% cellulose mixture at 1000x magnification. You can see a rough, dense surface with fibers that dominate and don't look perfectly distributed. In Figure 5 (b) and (c) you can see the density between the starch bound by chitosan. In Figure 5 (a), the interaction of uniformly distributed cellulose in the matrix can improve mechanical properties, but the higher the cellulose concentration, the easier it will be for the biofoam to absorb water. The nature of cellulose which tends to be hydrophilic or prefers water causes cellulose to absorb water from its environment. This will have an effect on microbial activity in biofoam.

Figures 5 (b) and (c) show the morphology of biofoam with concentrations of 4% chitosan and 5% mixed cellulose and 10% chitosan and 5% mixed cellulose, respectively. Figures 5 (b) and (c) show that there has been good inter-phase bonding between chitosan, starch, PVA and cellulose. In picture (b) there are still voids which cause the biofoam to be less impermeable to water. Figure 5 (c) shows the morphology of the denser biofoam. The tighter the bonds between chitosan, the more impermeable the chitosan is to water. The OH bonds formed between chitosan and acetate make the biofoam stronger and does not absorb water.

Magnesium stearate is used as a demolding agent which aims to make the biofoam less sticky when released from the mold. Magnesium stearate is a magnesium compound with a mixture of solid organic acids obtained from fat, its physical form is smooth, shiny white and does not easily dissolve in water so it remains in the form of lumps [11] . In the image above, the morphology of magnesium stearate can be seen in the area marked with a red circle.

4. Conclusion

This study highlights the significant impact of chitosan and cellulose concentrations on biofoam properties. Low chitosan concentrations enhance biodegradation, while higher concentrations improve water resistance. Bagasse cellulose strengthens biofoam, offering promising alternatives to non-biodegradable packaging materials. Further research could explore optimizing these variables for diverse applications, contributing to eco-friendly packaging solutions.

Acknowledgements

The author thank to the Faculty of Industrial Technology, Jayabaya University for the fund has been given

References

- [1] H. Nanik, E. N. Dewi and S. Santoso, "Karakteristik Biodegradable Foam dari Pati Sagu Termodifikasi dengan Kitosan Sebagai Aditif," *Jurnal Teknik Kimia dan Lingkungan*, vol. 3, no. 1, pp. 47-52, April 2019.
- [2] N. Hendrawati, E. N. Dewi and S. Santosa, "Karakteristik Biodegradable Foam dari Pati Sagu Termodifikasi dengan Kitosan Sebagai Aditif," *Jurnal Teknik Kimia dan Lingkungan*, vol. 3, no. 1, pp. 47-52, April 2019.
- [3] B. K. Syahputra, "Pembuatan Biodegradable Foam dari Biji Durian dan Nano Serat Ampas Teh dengan Proses Pemanggangan," Sumatera Utara, 2019.
- [4] N. Hendrawati, Y. I. Lestari and P. A. Wulansari, "Pengaruh Penambahan Kitosan Terhadap Sifat Biodegradable Foam Berbahan Baku Pati," *Jurnal Rekayasa Kimia dan Lingkungan*, vol. 12, no. 1, pp. 1-7, Juli 2017.
- [5] F. Z. Rasdiana and C. W. Weldi, "Kajian Teknologi Produksi Biodegradable Foam Berbasis Pati dan Selulosa Sebagai Kemasan Ramah Lingkungan," *Jurnal Sains dan Teknologi Pangan*, vol. 6, no. 3, pp. 3947-3954, Mei 2021.
- [6] Y. Ruscahyani, S. Oktorina and A. Hakim, "Pemanfaatan Kulit Jagung sebagai Pembuatan Biofoam," *Jurnal Teknologi Technosciantia*, vol. 14, no. 1, pp. 25-30, 2021.
- [7] I. Nurfitasari, "Pengaruh Penambahan Kitosan dan Gelatin Terhadap Kualitas Biodegradable Foam Berbahan Baku Biji Nangka," Makassar, 2018.
- [8] R. A. E. H. and D. Febrina, "Nilai Nutrisi Ampas Tebu yang Defermentasi Menggunakan Starbio Pada Level yang Berbeda," *Jurnal Peternakan*, vol. 13, no. 2, pp. 59-65, September 2016.
- [9] R. E.S, A. Subhan and A. Darmawan, "Pemanfaatan Jenggel Jagung Sebagai Pakan Ternak Sapi," Bogor, Puslitbang Peternakan, 2006, pp. 9-10.
- [10] T. C. Sunarti and N. Richana, "Produksi Selulase Oleh *Trichoderma viride* pada Media Tongkl Jagung dan Fraksi Selulosanya," *Jurnal Pascapanen*, vol. 4, no. 2, pp. 57-64, 2007.
- [11] A. U. M. Ritonga, "Pembuatan dan Karakterisasi Biofoam Berbasis Komposit Serbuk Daun Keladi yang Diperkuat Oleh Polivinil Asetat," Medan , 2019.
- [12] F. I. Muharam, "Penambahan Kitosan Pada Biofoam Berbahan Dasar Pati," *EJournal UPI*, vol. 5, no. 2, 2020.