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Biodegradable Foam (Bio-foam) from Banana Weevil as an Environmentally Friendly Styrofoam Generation

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Abstract

A review has been carried out on the development of Biodegradable Foam (Bio-foam) with the main ingredient of Kepok banana weevil starch as a breakthrough in environmentally friendly food and beverage packaging while providing innovative solutions for the use of post-harvest banana weevil waste. Banana weevil bio-foam has some advantages that styrofoam does not have, the properties in question are biodegradable, strong against pressure, resistant to water and fire, smooth surface structure, and smaller pores and anti-microbial. Bio-foam is processed by the thermos-pressing method at the best temperature of 160°C with a pressure of 60 bar for 10 minutes. The best composition of bio-foam was obtained from several kinds of literature, including the ratio of banana cob starch and sepiolite fibre used of 60:40 with the addition of 10% v/v of PVA which was able to produce a smaller pore size of 0.2-1.0 m, strong pressure >4.02 MPa, melting point 166.50°C with a heat flow of -12.38 MW. The addition of 10% oregano essential oil in the pre-bio foam sample has lower water solubility and better mechanical resistance, as well as having a more effective ability to resist Salmonella (gram-negative bacteria) and L. Monocytogenes (gram-positive bacteria). Banana weevil bio-foam can be completely degraded after two months faster than styrofoam which takes approximately 80 years.

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1. INTRODUCTION

The practical lifestyle of humans encourages the need for various industries, especially the food and beverage industry in creating single-use packaging in the form of styrofoam [1]. One of the food and beverage containers that are often used by the public is Styrofoam, a type of plastic (polymer) made from a mixture of 90-95% polystyrene and 5-10% gas by using a blowing agent such as Freon which has the potential to deplete the ozone layer [2]. The main component of styrofoam, namely styrene, is a carcinogen that can interfere with body health such as nervous system and brain disorders in humans [3-4].

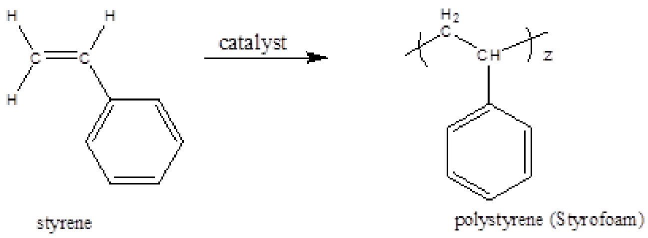

Figure 1. Chemical structure of styrofoam content [5].

The continuous use of Styrofoam has a high impact on the global environment. Styrofoam is difficult to degrade naturally in the soil so it takes approximately 80 years to decompose [6]. Based on data from The Environmental Protection Agency (EPA), the styrofoam waste produced is almost 2.6 million tons and the EPA categorizes the styrofoam manufacturing process as the fifth largest producer of hazardous waste in the world [2]. One thing that can be done to reduce these negative impacts is to replace the use of styrofoam packaging with biodegradable foam packaging products or bio-foam that are more environmentally friendly [7]. Bio-foam can be made from starch or natural composite materials [8-9]. A series of studies have shown that starch is the main ingredient in the manufacture of bio-foam. Various types of starch that can be used in the manufacture of bio-foam include cassava starch [10-11], sweet potato starch [12], potato starch [13-14], corn starch [15], and banana cob starch [16].

Banana weevil starch was chosen as the main ingredient in the development of bio-foam. This material was chosen because the banana weevil was not used optimally and was even left to rot without any effort in its utilization and was considered waste by the community after the harvest took place [17]. The utilization of banana weevil waste can be a long-term right solution as a raw material for making bio-foam. The banana weevil has many types, one type of banana weevil that is widely studied is the kepok banana weevil. The kepok banana weevil type was chosen in the development of this bio-foam because it has some advantages, including a starch content of 64.20%[18], a low water content of 0.98%, and a high absorption capacity of 253.33% compared to plantain weevil starch, mahulu, milk, and Ambon [19] and has the greatest antibacterial activity compared to the stem or midrib [20].

Bio-foam to be developed must have some advantages that styrofoam does not have, the properties in question are biodegradable, strong against pressure [1], [11], [21-23], resistant to water [1], [14], [24] and fire [14], smooth surface structure and smaller pores [15-16] and anti-microbial [12]. Based on the description above, it is hoped that this paper will be able to provide information on developing superior bio-foam with the properties described previously in overcoming the problem of styrofoam waste while providing innovative solutions in the utilization of banana weevil which is considered post-harvest waste.

2. MATERIALS AND METHODS

The writing method used is a literature study method, the data and information needed are obtained by conducting a study through accredited National journals and International Journals which are accessed online from trusted sites.

2.1 Banana Weevil as a Source of Bio-foam Starch

Banana weevil is the brown (outer skin) and white (inner) raised part of the banana plant which is located on the banana stem tuber [25-26]. Banana weevil contains starch. The starch on the banana cob looks like starch from sago flour and tapioca [28]. Substances contained in the banana weevil are starch as much as 76%, water 20% [6], carbohydrates 66% [27], protein, minerals, water [28], vitamin B as much as 0.01 mg, vitamin C as much as 12 mg [29]. Indonesia is a country that has various types of bananas. Each type of banana has starch content with different percentage levels. The difference in the value (%) of carbohydrate content (starch) contained in various types of banana weevil can be seen in Table 1. In addition, the carbohydrate content of dried banana weevil reaches 66.2 grams while of banana weevil that is fresh (fresh) reaches 11.6 grams in every 100 grams of weight of banana weevil [30], which can be seen in Table 2.

Table 1. The content of carbohydrates in starch in various types of banana weevil [31].

Banana Type	Carbohydrate Content (%)
Kapas	29,74
Raja	28,95
Tanduk	27,94
Lempeneng	25,68
Mas	24,38
Susu	23,97
Siam	23,66
Ambon	22,05
Palembang	21,86
Kepok	20,53
Ampyang	20,29
Gembor	18,56

Table 2. The composition of the banana weevil [32]

Component	Wet	Dry
Starch (%)	96	76
Calories (%)	43	425
Proteins (%)	0,6	3,4
Carbohydrates (%)	11,6	66,2
Ca (%)	60	150
P(%)	0,5	2
Fe (%)	0,11	0,04
Vitamins (%)	12	4
Water (%)	86	20

Of the several types of banana weevils listed in Table 1, according to Nafiyanto (2019), the kepok banana weevil is a good banana weevil for making bio-foam. Kepok banana weevil has a high water absorption capacity of 253.33% and a lower water content of 0.98% compared to the starch of plantain weevil, mahulu, milk, and Ambon, as well as the greatest anti-bacterial activity compared to the stem or midrib. This is also reinforced by research conducted by Saragih (2013) which shows that the kapok banana weevil has a fibre content of 29.62%, water content of 1.09%, ash content of 0.67%, yield of 12.56%, and water absorption. 260.0%. In the research of Irawan et al. (2018), bio-foam was developed from banana cobs and Nagara sweet potato using a ratio of 60:40, 70:30, and 80:20 with the addition of PVA (Polyvinyl Alcohol) as much as 10%v/v where PVA is a polymer used as a blending material in increasing mechanical and thermal stability. Some advantages were obtained from bio-foam made from banana weevil and Nagara sweet potato from the characteristic test results, namely the composition ratio of 60:40 has a hardness value of 4.02 Mpa. The hardness value of this bio-foam is higher than that of commercial styrofoam which ranges from 1.3 Mpa-1.39 Mpa.

2.2 Supporting Materials in Creating Superior Bio-foam

The effect of the PVA coating material obtained from the results of the literature study showed that the TPS foam micrograph with 6% w/v PVA coating seemed to fill the foam. The foam layer becomes thicker and the interior blanks are filled with PVA, which appears to make the foam denser. The PVA coating significantly reduces the water absorption of the TPS foam. The results obtained from the study of Bergel et al. (2018) were associated with the hydrophobicity of the PVA layer. The water absorption of samples coated with 2%, 4%, and 6% w/v PVA was about 113, 79, and 56 g water/100 g solids, respectively, in 40 min. Based on these data, it can be seen that increasing the concentration of PVA decreases water absorption in the sample. Meanwhile, the uncoated foam absorbs 224 g more water than the 6% PVA-coated foam [13]. In the research of Darder et al. (2016), the microfiber clay mineral sepiolite material is used as a filler for bio-foam reinforcement, the sepiolite material is made by lyophilization. The mechanical properties of the foam showed an increase in the compression modulus from 7.3 MPa to 29 MPa in the foam containing 10% starch, 40% sepiolite, and 50% alginate. Through a horizontal combustion test carried out for the initial evaluation of the role of sepiolite fibres on the fire-retardant properties of bionanocomposite foams, it was revealed that bionanocomposite foams with a sepiolite content of >25% behaved as an auto-extinguishing material. The addition of 50% sepiolite to alginate or potato starch increases the value of the compression modulus to about twice the value measured for pure polymer foams [14].

Research conducted by Tirado et al. (2020) used oregano essential oil as a bioactive ingredient in bio-foam with the selected thermopressing technique as the foaming process was carried out at 160 pressure 60 bar for 10 minutes. During the thermoforming process, essential oil microdrops can be encapsulated in gelatin starch or starch with polymer blends, to prevent the oil from completely evaporating during foam drying. The results of the antimicrobial analysis showed that the foam with the addition of 10% essential oil gave a greater antimicrobial effect because more essential oils were dispersed into the environment. Foams with 10% OEO showed a larger inhibition zone due to the greater presence of phenolic compounds such as carvacrol, thymol, terpinene, and p-cymene in the foam, as previously reported by Hashemi and Mousavi Khaneghah (2017). Based on these data, information was obtained that foam with 10% OEO completely inhibited Salmonella (gram-negative bacteria) and L. Monocytogenes (gram-positive bacteria) [12].

2.3 Thermopressing Method as a Bio-foam Making Technique

In the process of making bio-foam there are various methods carried out such as the printing technique method [33], extrusion method [34], baking process [35], recommendation technique [3], wet–milling [36], a mixing method [37], process self-catalyzing/rising[38], a coating method, melt extrusion method [39] and thermopressing method[40] Thermopressing method is a technique that is more flexible in making bio-foam than other methods or techniques. The use of the thermopressing technique is done by simultaneously printing the bio-foam dough at a certain temperature and pressure [41-42]. can be adjusted to get the best results. Thermopressing has good foaming ability due to the even distribution of the material in the mould [3]. In addition, the advantages of using thermopressing techniques are in the form of simple technology, faster processing time, and lower costs [43].

The best results of bio-foam processing using this thermopressing technique were obtained at a temperature of 160 with a processing time of 10 minutes at a pressure of 60 bar [30].

3. RESULTS AND DISCUSSION

Through a literature review that has been carried out, information is obtained that the best banana weevil which is suitable as the main ingredient in the manufacture of bio-foam, namely the kepok banana weevil, was chosen because of its starch content of 64.20%, low water content of 0.98% and good absorption. 253.33% higher than plantain weevil, mahulu, milk and Ambon. In addition to the main ingredients, many supporting materials are needed to produce superior bio-foam, namely biodegradable, strong against pressure, resistant to water and fire, smooth surface structure, and smaller pores, and anti-microbial. The best composition for making bio-foam uses a ratio of 60:40 banana cob starch and sepiolite clay, sepiolite clay is used to strengthen the bio-foam. For a sepiolite content of more than 25%, the foam is resistant to fire, so it can be extinguished automatically. Meanwhile, the addition of 50% sepiolite can increase the compression modulus to 2 times that of pure polymer foam. The use of 10% v/v PVA as a blending material can increase mechanical, and thermal stability and reduce water absorption in bio-foam samples. The pre-bio foam material resulting from mixing the recommended composition is then added with 10% oregano essential oil to have lower water solubility and better mechanical resistance. And can be more effective against Salmonella (gram-negative bacteria) and L. Monocytogenes (gram-positive bacteria). The pre-bio foam produced can be processed by the thermopressing method at the best temperature of 160 with a pressure of 60 bar for 10 minutes. Bio-foam which is processed with the composition of natural ingredients and the selected method can produce smaller pore sizes, namely 0.2-1.0 m, pressure strength > 4.02 MPa, melting point 166.50 with heat flow - 12.38 MW, can be completely degraded after two months compared to Styrofoam which takes approximately 80 years.

Figure 2. Thermopressing device [44].

Figure 3. Bio-foam results from the thermopressing technique [43].

The results of the literature study that have been carried out can provide solutions in the development of bio-foam packaging into food packaging with some advantages. The presentations obtained based on literature studies from 44 journals that have been collected show that 41% of the use of banana weevil is applied as food packaging in the form of edible film, and only 2% is applied as bio-foam packaging. Meanwhile, 57% use cassava, potato, corn and sweet potato starch as bio-foam manufacture. Thus, this information can provide opportunities in the form of contribution to the application of natural resources in the form of banana weevil in creating food and beverage packaging in the form of bio-foam that can replace Styrofoam packaging.

4. CONCLUSION

The results of the literature study that have been carried out show that the utilization of banana weevil starch for bio-foam is still very small, only 2% and 41% are used as edible films. Meanwhile, 57% of the total reviewed journals use other starches such as cassava, potato, corn, and sweet potato in the manufacture of bio-foam. The information obtained that the best composition for making bio-foam using a ratio of banana cob starch and sepiolite clay used is 60:40 with the addition of 10% v/v PVA capable of producing a smaller pore size of 0.2-1.0, strong pressure >4.02 MPa, melting point 166.50 with -12.38 MW heat flow. The addition of sepiolite fibre can reduce water adsorption in hydrophilic polysaccharide chains. The sepiolite content of more than 25% makes the foam resistant to fire while the addition of 50% sepiolite increases the compression modulus to 2 times that of pure polymer foam. The percentage of oregano essential oil, which is 10% added to the pre-bio foam mixture, was able to inhibit Salmonella (gram-negative bacteria) and L. Monocytogenes (gram-positive bacteria). Bio-foam can completely degrade after two months compared to Styrofoam which takes approximately 80 years.

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