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The Use of Sodium Alginate with Starch to Make Biodegradable Sachet and Wrap Products as an Alternative Substitute of Plastic

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Abstract:

Biodegradable plastic can be an alternative to reduce conventional plastics which is an environmental problem because it is easy to decompose. This research aims to obtain formulas and produce of wraps and sachets from biodegradable products made from sodium alginate and to know the comparison of their quality with conventional plastics. There was five formula, the first and fifth used sodium alginate, the second until the fourth used sodium alginate mixed with cassava, corn or glutinous starch. These formulas produced thin, transparent, clear to slightly yellowish bioplastics sheets which were then made sachets and wraps. These bioplastics had a tensile strength value of 0.006-0.028 MPa, elongation of 4-55%, the thickness of 0,07-0,12 mm, and water absorption of 53-63,36%. The antioxidant tests showed that bioplastics require the addition of antioxidants and cannot yet encase water-containing or hygroscopic materials. The Biodegradability tests showed that bioplastics would decompose within 1-10 day when exposed to water, or within 30 days in moist soil or sand.

Keywords: Biodegradable plastic, sodium alginate, starch, sachet, wrap

1. Introduction

Plastic is a packaging material that is widely used and developed in the market. According to the Indonesian Association of Aromatic Olefins and Plastics Industry (INAPLAS), in 2015, plastic consumption in Indonesia reached 17 kg/capita/year. If total population of Indonesia in the first half of 2017 was around 261 million people, then nationally, plastic usage reached 4.44 million tons (Kamsiati, Herawati, and Purwani, 2017).

Apart from China, Indonesia was the largest country who dump plastic waste into the sea (Kamsiati, et al., 2017). 90% of plastic waste was dumped into the sea and 70% of this waste comes from food and beverage packaging. It is estimated that there will be a more plastic waste in the sea compared to fish in 2050. Plastic waste causes 25% fish in Indonesian market contaminated because plastic that made these day, even though it was already degraded, it was still in the form of nanoparticles and the fish are mistaken these as their food (Evoware, 2016).

In 2019, 855 billion sachets were sold in the global market, with Southeast Asia holding around 50% market share. It predicted that the number of sachets that sold will reach 1.3 trillion in 2027. When the industry is growing, the quantities of plastic waste will also increasing, because the industry still relied on plastic as packaging. The government's efforts to reduce plastic waste by implementing paid plastic bags are not a solution yet to solved the problem of plastic waste in Indonesia (Qodriyatun, 2018)

One solution for this whole problem is to make environmentally-friendly plastics (biodegradable plastics). Biodegradable plastics/bioplastics are plastics that can be degraded by microorganisms (Haryanto dan Saputri, 2016). Biodegradable plastics are alternative plastics which whole or almost every components come from renewable raw materials. Biodegradable plastics have the same uses as synthetic or conventional plastics (Nisah, 2017).

In this study, a formulation experiment will be carried out to make biodegradable sachets and wraps from sodium alginate (from seaweed) as an alternative beside plastic.

2. Research Method

2.1. Tools and Materials

The tools ware scales, pans, stoves, spoons, plates (molding tools), bowls, mixers, measuring cups, hairdryers, basins, spoons, spatels, ovens, INSTRON H1324 (tensometer), and Teclock Thickness tester.

The materials were sodium alginate (Subur Kimia Jaya), water, glycerin (source: Subur Kimia Jaya), cassava starch (Subur Kimia Jaya), corn starch (source: Subur Kimia Jaya), glutinous rice starch (source: Rose Brand), sand beach (taken from Mambruk Beach, Anyer, Banten, Indonesia), building sand, Lembang soil, red soil, rice field mud, sugar, salt, pepper, and coffee.

2.2. The Formula

Formula	Materials	Quantity
1	Sodium Alginate (g)	5
	Glycerin (mL)	1
	Water (mL)	150
2	Sodium Alginate (g)	5
	Cassava Starch (g)	5
	Glycerin (mL)	2
	Water (mL)	200
3	Sodium Alginat3 (g)	5
	Corn Starch (g)	5
	Glycerin (mL)	2
	Water (mL)	200
4	Sodium Alginate (g)	5
	Glutinous Rice Flour (g)	5
	Glycerin (mL)	2
	Air (mL)	200
5	Sodium Alginate (g)	5
	Glycerin (mL)	3
	Water (mL)	150

Table 1: The Formula

2.3. The Procedure of Manufacturing Biodegradable Wraps and Sachets

The ingredients weighed according to the formula. Sodium alginate dissolved in 100 ml hot water $\pm 300^{\circ}\text{C}$ with a mixer. Starch heated in a saucepan with 100 ml of hot water, stirring constantly until thick. The two ingredients mixed in a hot state of $\pm 400^{\circ}\text{C}$, then stirred until homogeneous with a mixer. Leave the mixture for ± 15 minutes until the foam was gone. Biodegradable plastic was printed on a plate, then dried using a hairdryer. Furthermore, biodegradable plastic that already dried was taken and tested.

2.4. Test

The tests that performed were:

2.4.1. Organoleptic Test

This test was done by observing the appearance of the product (color, smell, taste, and shape).

2.4.2. Tensile Strength Test

This test was aimed to determine the resistance of a material to load at the most bending point and also to determine the level of elasticity of a material. This test was performed using a tensometer.

2.4.3. Thickness Test

This test was carried out to determine the thickness of the bioplastic produced. This test performed using a thickness tester.

2.4.4. Water Absorption Test

This test was carried out to determine the occurrence of bonds in the polymer as well as the level of regularity of the bonds in the polymer which was determined by the addition of polymer weight after experiencing swelling.

2.4.5. Antioxidant Test

The antioxidant test was carried out by wrapping materials that were easily damaged or changed mechanically (apples for plastic wrap and salt, sugar, pepper, coffee for plastic sachets). Observation of changes was carried out every 2 days for a period of up to 30 days.

2.4.6. Biodegradability Test

The biodegradability test was the most important test in determining the decomposition time of plastic in the soil. This test is carried out by burying the plastic in the soil and observing the time of change or decomposition once every 5 days (Safitri, et. al., 2016).

3. Results and Discussion

3.1. The Organoleptic Test

In this study, 5 formulas were made. 1st and 5th formula used sodium alginate, while 2nd – 4th formulas used a mixture of sodium alginate with cassava starch, corn starch, or glutinous starch. Bioplastics produced from this study were in the form of thin sheets, clear or yellowish color, and did not rigid. This bioplastic then used to make sachets and wraps. When made sachets, the adhesive for it must use these formula, could not use plastic adhesive tools or burned with fire.

Information	F1	F2	F3	F4	F5
Colour	Transparent	Transparant	Whitish	Yellowish White Spots	Transparant
Odor	Odorless	Odorless	Odorless	Sour	Odorless
Flavor	Salty	Salty	Salty	Sweet	Salty, Sweet
Texture	Dry, Smooth	Moist, Smooth	Moist, Smooth	A little moist, Smooth	Moist, Smooth

Table 2: The Organoleptic Test Result

The organoleptic test results (Table 2) showed that there were no significant changes during the test (30 days), meaning that the five formulas were stable in the testing process. The best bioplastic in the organoleptic test was shown by 1st formula because it was the driest and not much affected by moisture, while the other formulas were more moist than 1st formula, so when stored, they would slightly stuck to the container or to each other over time and affected the inner plastic when used.

3.2. The Tensile Strength Test

The tensile strength test was done by applying a certain load to the sample, then a tensometer will pull it off. The results obtained (Figure 1) show that the more glycerin plasticizer was added, the lower the tensile strength, it could be seen in 1st and 3rd formulas. The addition of starch affected tensile strength, where the type of starch used will affect the test results. At the time of manufacture, the thickest was a mixture of sodium alginate and cassava starch, so the test time required a heavier load than the other formulas. When viewed from the average percent yield, the strongest bioplastic was shown by 3rd formula. The addition of starch made the bioplastic stronger than the bioplastic from sodium alginate only.

Figure 1: The Tensile Strength Test Result Chart

When compared with the SNI standard for plastics, the average tensile strength produced by this bioplastic has not met the requirements and was still very far away. When compared with biodegradable plastic standards, the average tensile strength test results still did not meet the 1-10 MPa requirements. However, if it used to make sachets containing dry powder (such as pepper and coffee), this bioplastic could be use.

3.3. The Thickness Test

Figure 2: The Thickness Test Result Chart

The result of the thickness test had an influence on the tensile strength test. The thicker the sample was, the greater the tensile strength, but if bioplastic was too thick, it was not good for making bioplastic wrap because it was too stiff. Thickness also affects elongation or elasticity. The thicker the bioplastic, the lower the elongation. However, this was also influenced by the amount of plasticizer used. In this test, the result showed bioplastic has thickness of 0.076-0.118 mm.

3.4. The Elongation Test

Figure 3: The Elongation Test Result Chart

The elongation test also called a test to measure elasticity, elongation was also known as creep. In the results of the elongation test (Figure 3.) it showed that the more glycerin plasticizer used, the higher the percentage of elongation obtained. However, in different cases when there was an addition of starch, it affected the elongation yield, it could be higher or lower. In 3rd formula, the addition of corn starch increased the percentage of elongation better than 1st formula which only used sodium alginate and 1 ml of glycerin. However, in 2nd formula, where cassava starch was added, the percentage of elongation was the smallest among other formulas. When compared with the SNI plastic standards in table 2.2, the formula that met the percent elongation requirements (21-220%) was shown by 1st, 3rd, and 5th formulas, while 2nd and 4th formulas had not met the requirements, could be said that it was too stiff or less elastic.

3.5. The Comparison of Elongation with Tensile Strength

The results of this elongation test were opposite to the tensile strength, where the higher the percent elongation, the lower the tensile strength (Figure 4). This was because the high elasticity made the strength of the bioplastic diminish (more flexible). This high elongation yield also affected the dry rate of the bioplastics produced. The higher the moisture was in bioplastic; then stickier the bioplastics were when stacked and packed. When they have separated again, it could

cause the bioplastics to easily damaged or perforated. If it was too humid, it would cause the products that are packaged when used as sachets to easily changed or damaged.

Figure 4: The Comparison of Percentage of Elongation and Percentage of Tensile Strength Chart

3.6. The Swelling Test

Figure 5: The Swelling Test Result Chart

The water absorption test was carried out by weighing the initial weight of the sample and placing it in a container filled with 30 ml of water for 30 seconds. The soaked sample was then removed and then dried with a tissue so that no excess water was weighted. The test results (Figure 5) showed that the average yield was around 53-63.36% of the water that could be absorbed by bioplastics. This was influenced by the thickness of the bioplastic. The thicker the bioplastic, the greater the percentage of water absorbed. When compared with the SNI plastic standard (25% at 25oC), the absorption of this bioplastic to water was very high. The water absorption test showed that the higher the water absorption, the lower the bioplastic resistance level, and the greater the level of damage. However, this was not a problem if the sachet bioplastic will be made in a soluble package and consumed with its contents.

3.7. The Antioxidant Test

Formula	4	5	Buffer (Wrap Plastic)
Apple condition	The apples rot on the 3rd day	The apples rot on the 3rd day	The apples rot on the 14th day

Table 3: The Antioxidant Test Results for Wrap Formulas 4 and 5 for 30 Days

In the antioxidant test, humidity was very influential in bioplastic testing, where the bioplastic that was used as a sachet for wrapping apples becomes easily damaged because it absorbed water from apples and apples were easier to rot and dry (Table 3), in contrast to plastic wrap (cling wrap) commonly found on the market. From the test results, it showed that the plastic wrap on the market was able to wrap apples well so that the apples only turned brown and took longer to rot.

However, the bioplastic wrap produced from this experiment could not be used to wrap apples properly, so that within 3 days the apples had rotted and began to dry. This could be overcome by reducing the moisture content and by adding antioxidants to formulas for bioplastics making.

In this test, each bioplastic was made into sachets and included coffee and spices, namely pepper, salt, and sugar. If you looked at the results (Table 4), 1st, 2nd, and 4th formulas could not be used to wrap hygroscopic materials such as salt, because the hygroscopic nature of salt caused the sachet to become damp and the salt became liquefied. 3rd Formula also could not be used for hygroscopic ingredients, but the sugar wrapped in this formula's bioplastic was also slightly moist but did not make the sugar melt and decrease. Meanwhile, 5th formula which produced the most humid bioplastic compared to the others could only be used for wrapping coffee, because the humid condition made the pepper moist and sticks a lot to the sachet, the salt became moist and melt faster, as well as sugar. So, bioplastics that were made into sachets did not need additional antioxidants when used to wrap dry materials, it was different if it was used to wrap materials that were slightly moist or hygroscopic, adding antioxidant was necessary.

Formulas	Sugar	Salt	Pepper	Coffee
1	No changes	Salt melts, height is reduced by 0.7 cm	No changes	No changes
2	No changes	Salt melts, height is reduced by 0.4 cm	No changes	No changes
3	No changes	Salt melts, height is reduced by 0.4 cm	No changes	No changes
4	No changes	Salt melts, height is reduced by 0.3 cm	No changes	No changes
5	Moist sachets, sticking sugar, reduced height by 0.1 cm	Salt melts, height is reduced by 0.8 cm	The sachet is moist, the pepper sticks, the height is reduced by 0.5 cm	No changes

Table 4: The Antioxidant Test Result for Sachet Formulas 1-5 for 30 Days

Formulas	Lembang Soil	Red Soil	Field Mud	Building Sand	Sand Beach
1	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day
2	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 10 day
3	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 5 day
4	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 5 day
5	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 1 day	Decompose within 5 day

Table 5: The Biodegradability Test Result in Wet Media for 30 Days

The biodegradability test was carried out by stockpiling bioplastics in Lembang soil, red soil, building sand, and beach sand in wet and dry conditions, also placed on the rice field mud. The results of the biodegradability test (Table 5) showed that the more bioplastics were exposed to water, the faster the bioplastics were destroyed. This was very good when the weather were rainy because bioplastics would quickly degrade when they were disposed of in nature so that they could protect the environment. When exposed to water, bioplastics would disintegrate within 1 day. When buried in Lembang soil, red soil, and building sand would also be destroyed within 1-10 when backfilled with wet beach sand. However, if it was not exposed to water or soil and sand in a dry state, within 30 days this bioplastic had not been destroyed. This was not a problem considering conventional plastics were destroyed within 200-1000 years to decompose because during the rainy season these bioplastics would soon be destroyed. When viewed from the results of biodegradability testing, 2nd formula (sodium alginate with cassava starch) took the longest to disintegrate when buried in wet soil and sand. This was because 2nd formula produced the driest and strongest bioplastics among the others.

4. Conclusion

1st – 5th formulas can be used as a substitute for plastic sachets because it does not cause changes to the packaged product, but it is not optimal when used as a plastic wrap because it cannot pack materials containing water. Sachets produced from 1st, 2nd, and 4th formulas can be used to wrap dry, non-hygroscopic seasonings or ingredients. 3rd formula cannot cover the sugar and hygroscopic ingredients 5th formula can only be used to wrap coffee. This

bioplastic will decompose within 1-10 days if exposed to water and will blend with moist soil or sand and form lumps within 1 month. The resulting bioplastic had a water absorption capacity of 53-63.36% and a tensile strength value of 0.006-0.028 MPa but for tensile strength (1-10 MPa) it had not fulfilled the SNI for bioplastics (plastic bags). Bioplastics from 1st, 3rd, and 5th formulas show 13-55% elongation test results and had met the SNI plastic for elongation percent (21-220%).

5. Further Research Flow

Further research flow that can be done:

- To get maximum results on the tensile strength test, it is necessary to change and modify the formula.
- Maximizing wrap and sachet bioplastic to make it waterproof.
- To test the shelf life, food safety test, heat resistance test (thermal test), and functional group analysis with FTIR as a continuation stage of this research.
- Applying the manufacture of bioplastics by machine so that they can be produced in industry on a large scale.

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