Production of Biodegradable Straw from Banana Peel

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Abstract

This study aims to determine the effect of enhancement in stirring temperature (75°C, 80°C, 85°C) and type of plasticizer (glycerol and sorbitol) on the characteristics of biodegradable straw from ambon banana peel waste and to compare them with the characteristics of conventional boba's straws. Methods used in this study were tensile strength, elongation, biodegradation, and water uptake tests. The result showed enhancement of stirring temperature and type of plasticizer did not significantly affect the characteristics of biodegradable straws from ambon banana peel waste ($p > 0.05$). Enhancement of stirring temperature will increase the tensile strength and water resistance value, but decreased elongation and biodegradation value because enhancement of stirring temperature will decrease the water content and increase the molecular density. In addition, plasticizer will increase elongation value and level of biodegradation, but decrease tensile strength and water resistance values. Plasticizer has the ability to increase the elasticity of polymers, as well as increase water absorption because it has hydrophilic hydroxyl groups. Biodegradable straw that have been developed has a colour of black, being rigid, with a length of 13 cm and an external diameter of 1.2 cm. The colour and external diameter of biodegradable boba's straw looks similar with conventional boba's straw but shorter in length. Therefore, ambon banana peel waste was promising to be used as an alternative material for biodegradable straw in the future.

Keywords: *Ambon banana peel waste; biodegradable straw; plasticizer; starch; stirring temperature*

1. INTRODUCTION

Plastic products are becoming a global environmental issue, according to Plastics Europe (2020), global plastic production in 2019 was 368 million tons. The Directorate General of Waste, Waste and B3 Management, Ministry of Environment and Forestry of the Republic of Indonesia (2020) released data that the composition of plastic waste in Indonesia in 2020 reached 5.6 million tons or 17.1% of the total waste production. One of the most common types of plastic waste is plastics straw. Data compiled by Divers Clean Action in Fatia & Sugandi (2019) shows that in Indonesia at least 93 million plastic straws are used by the public in one day. This number causes Indonesia to be ranked 4th in the world in terms of producing plastic straw waste.

One of the uses of plastic straws is for *boba* drinks, where *boba* drinks are tea-based drinks mixed with fruit or milk flavors, as well as the addition of a topping of chewy balls made of tapioca flour and sugar (Veronica dan Ilmi, 2020). *Boba* drink must be consumed using a straw with a large hole to be able to suck the *boba* from the bottom of the glass and cannot be replaced by other objects (Nerissa, 2020). Conventional *boba's* straw has different characteristics from other plastic straws, namely, it is stiffer, thicker, and has a larger hole of diameter. Therefore, there is a potential for development of *boba's* straws that are more environmentally friendly using biodegradable plastics from natural waste.

On the other hand, banana production in Indonesia in 2020 reached 8.18 million tons, increased by 11.02% from banana production in 2019 which only reached 7.28 million tons (Central Agency on Statistics, 2020). One type of banana is the ambon banana. The Agency for Agricultural Research and Development (2007) explained that ambon banana are often used as consumption fruit, or processed into chips, juice, and "*salé pisang*". The utilization of ambon banana produces banana peel which is generally discarded and usually was throw away as waste in garbage production.

Ambon banana is known to have a starch content of 29.37%, while banana peel waste

ISSN 2252-6137 (print), ISSN 2302-3848 (online), doi: 10.22146/aij.v9i1.77148

(especially green ones) contains ± 15% starch (Musita, 2012; Hassan *et al.*, 2018). The starch content is possible and potential to be used as a material for making biodegradable straws. Regarding to the production of biodegradable straws, this study has objectives to know the characteristic of biodegradable straw from ambon banana peel waste based on enhancement of stirring temperature (75°C, 80°C, and 85°C) and different types of plasticizers (glycerol and sorbitol).

2. MATERIAL AND METHODS

This research was conducted in September-December 2021 in Agroindustrial Process Engineering Laboratory, Vocational College, Universitas Gadjah Mada, and Process Engineering Laboratory, Faculty of Agricultural Technology, Universitas Gadjah Mada.

2.1 Materials

The materials used in this study were ambon banana peel waste, water, distilled water, glycerol, sorbitol, chitosan, 1% acetic acid solution, and conventional *boba's* straws (as control variables) (Adisurya, 2022).

2.2 Methods

2.2.1 Experimental Design

The treatment in this study was enhancement of stirring temperature with a variation of 75°C, 80°C, and 85°C and different types of plasticizers, namely glycerol and sorbitol. The replication of experiment is 4 times which calculated using Federer formula based on the number of group treatments (Wahyuningrum & Probosari, 2012). Each sample uses 3 g of ambon banana peel starch, 3 g of chitosan, and 1 ml of plasticizer. Data were analyzed using a two-tailed test. If there is a significantly difference, then data analysis is continued with duncan test. The experimental design listed in Table 1 (Adisurya, 2022).

Table 1. Experimental Design of Production of Biodegradable Straw

Starch	Chitosan	Plasticizer	Stirring Temperature	Sample Code
Conventional Boba Straw				Control
3 g	3 g	Glycerol (1 ml)	75°C	GT_1
			80°C	GT_2
			85°C	GT_3
		Sorbitol (1 ml)	75°C	ST_1
			80°C	ST_2
			85°C	ST_3

Sources: (Sari, 2016; Melani, Putri dan Robiah, 2019; Azzahra, 2020)

2.2.2 Starch Extraction

The ambon banana peel cut into pieces until it reaches a weight of 500 g, afterward added 1 liter of water and mash it using a blender. After that filter it using a filter cloth. The solution was precipitated for 12 hours, then the water was removed to obtain wet starch. The wet starch was dried in the oven at 70°C for ± 12-24 hours, then mashed using a blender and sieved through a 100-mesh sieve (Made Heni Epriyanti, Admadi Harsojuwono dan Wayan Arnata, 2016; Melani, Putri dan Robiah, 2019; Azzahra, 2020).

2.2.3 Production of Biodegradable Straw

The starch solution for 1 sample of biodegradable straw was made by weighing 3 g of starch, then dissolved it in 20 ml of distilled water and stirred for 30 minutes at 80°C. On the other hand, 3 g of chitosan was dissolved in 100 ml of 1% acetic acid and stirred for 30 minutes without heating to obtain chitosan solution. Put the chitosan solution into the starch solution and stirred until homogeneous by heating at various stirring temperatures of 75°C, 80°C, and 85°C using digital oven—temperature was controlled by manage the number of samples heated in 1 batch and also carry out periodic checks every 1 hour. After that, add 1 ml of plasticizer according to treatment (glycerol or sorbitol), then stirred for 1 hour using a magnetic stirrer. The solution was then poured on an acrylic plate and dried in the oven at 70°C for 5 hours. Biodegradable film was rolled using an acrylic rod with a diameter of 1 cm and then dried again in the oven at 70°C for 5 hours (Nurfauzy dan Farhah, 2017; Azzahra, 2020)

2.2.4 Sample Testing

Tensile strength, elongation, biodegradation, and water uptake test was conducted to measure the properties of the straw. Tensile strength is the test used to determine how much force that sample can withstand until it breaks, while elongation test to find out the elongation created on the sample from the initial condition to broken off (Safitri et al., 2016 & Suparno et al., 2013). Both of tests using universal testing machine with a speed of 10 mm/min (Rosid et al., 2019). Moreover, biodegradation test is the test to determine level of degradation by looking at the percentage loss of sample mass (Rahmawati, 2018). The technique used was a soil burial test, sample with a long of 4 cm was weighted its initial mass, then planted in humus soil at a depth of 2 cm for 7 days at the room conditions. The moisture content of sample is not be calculated in this study, percentage loss of mass focused on alteration of sample mass. The percentage loss of mass is calculated using the formula in notation 1 (Rifaldi et al., 2017).

$$\%W = \frac{W_0 - W}{W_0} x\ 100\% \quad (1)$$

Explanation:
%W : percentage loss of mass (%)
W_0 : initial mass (g)
W : final mass (g)

The level of resistance of biodegradable straws to water determined using water uptake test. The higher of water absorption capacity, the lower level of its resistance to water (Wahyuni, 2018). Sample with a long of 4 cm was weighted its initial mass, then soaked in distilled water for 30 minutes. After that, sample was weighted its final mass. The percentage of water uptake is calculated using the formula in notation 2 (Rifaldi et al., 2017).

$$\%WU = \frac{W - W_0}{W_0} x\ 100\% \quad (2)$$

Explanation:
%WU : percentage of water uptake (%)
W_0 : initial mass (g)
W : final mass (g)

3. RESULTS AND DISCUSSION

Prototype of biodegradable straw from ambon banana peel waste and conventional *boba's* straw as control variable are attached as below. Biodegradable straw has a length of 13 cm and an external diameter of 1.2 cm.

(a) (b) (c)

Figure 1. Prototype of Biodegradable Straw form Ambon Banana Peel Waste: (a) Front View; (b) Above View; (c) Conventional *Boba*'s Straw

3.1.1. Tensile Strength

Tensile strength test using universal testing machine with a speed of 10 mm/min. The data that presented as a graphic below is an average of tensile strength value of each treatment from 4 times of replication.

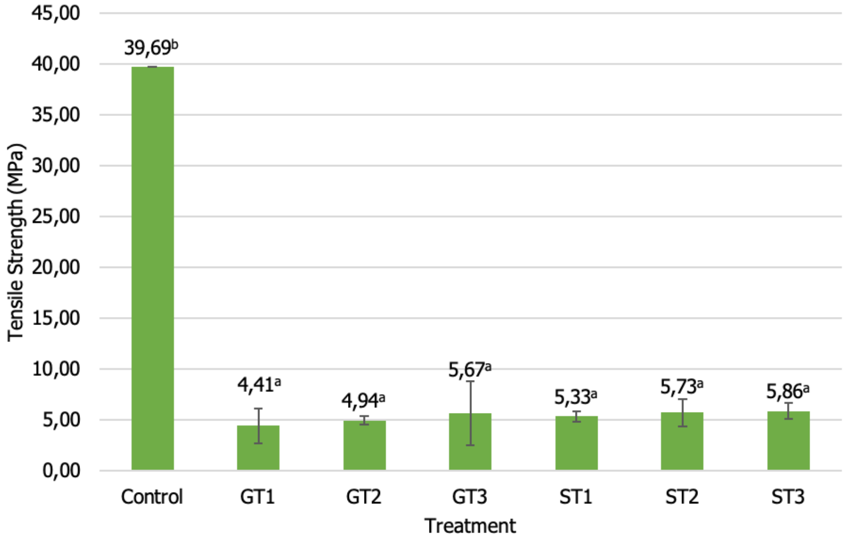

Figure 2. Results of Tensile Strength Test

Explanation:

Control : Conventional *boba's* straws
GT_1 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 75°C.
GT_2 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 80°C.
GT_3 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 85°C.
ST_1 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 75°C.
ST_2 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 80°C.
ST_3 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 85°C.

Based on Fig.2, the control sample has the highest tensile strength value (39.69 MPa), while the GT_1 sample has the lowest tensile strength value (4.41 MPa). In terms of the type of plasticizer, biodegradable straws with sorbitol as plasticizer were generally have a higher tensile strength value than biodegradable straws with glycerol as plasticizer. Sorbitol has a larger molecular weight than glycerol which results in stronger intermolecular bonds that inhibit water penetration, so the resulting of biodegradable straws become tougher (Azizaturrohmah, 2019; Cheng et al., 2006).

Besides that, the enhancement of stirring temperature increased the tensile strength values. The enhancement of stirring temperature causes water content in the biodegradable film solution to decrease, therefore the molecular structure is getting closer which results in enhancement of the tensile strength values (Hartatik, 2014). Futhermore, the process of heating the solution causes starch gelatinization and affect the amylose bonds which it is getting close together one another so that it will increase the tensile strength (Ginting et al., 2014).

Based on two-tailed test, the enhancement of stirring temperature and different type of plasticizers did not affect the tensile strength value of biodegradable straws from ambon banana peel waste ($p > 0.05$). Otherwise, comparison test results showed that the tensile strength value of biodegradable straws was significantly different against of conventional *boba's* straw ($p < 0.05$), so it needs to proceed with duncan test The results of duncan test showed that the tensile strength value of all biodegradable straw samples was significantly different to the conventional *boba's* straw It can be said that the tensile strength value of all the biodegradable straw samples are not close to conventional *boba's* straw.

3.1.2. Elongation

Elongation test also using universal testing machine with a speed of 10 mm/min. The graphic below is an average of elongation value of each treatment from 4 times of replication.

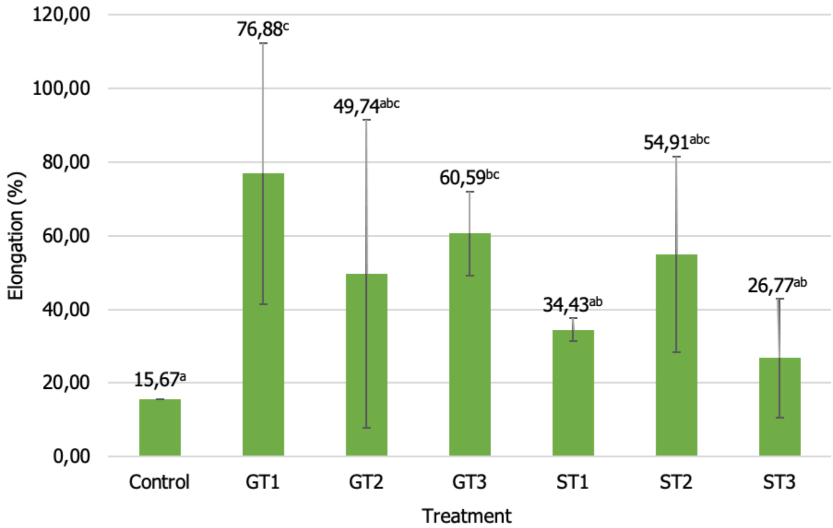

Figure 3. Results of Elongation Test

Explanation:

Control : Conventional *boba's* straws
GT_1 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 75°C.
GT_2 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 80°C.
GT_3 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 85°C.
ST_1 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 75°C.
ST_2 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 80°C.
ST_3 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 85°C.

The elongation test results that represented on Fig.3 showed the GT_1 sample has the highest elongation value (76.88%), while the control sample has the lowest elongation value (15.67%). Elongation has a value that inversely proportional against to tensile strength value (Muhammad et al., 2020). This is caused by the enhancement of stirring temperature will reduce the water content in the biodegradable film solution so that the molecular structure is more homogeneous and closer which results in a decrease in elongation value (Hartatik, 2014).

In terms of the type of plasticizer, biodegradable straws with glycerol as plasticizer were generally have a higher elongation value than biodegradable straws with sorbitol as plasticizer. Glycerol is known to have a higher molecular mobility and solubility compared to sorbitol so it can be distributed more evenly in the solution which causes a higher elongation value (Nuriyah et al., 2018; Sinaga et al., 2014). Besides that, starch which is heated at the gelatinization temperature causes the amylose bonds to come closer together so that their elongation will decrease (Ginting et al., 2014).

Theoretically, the elongation value should decrease as the stirring temperature increases, but the test results showed the opposite and tend to fluctuate value (Epriyanti et al., 2016). High deviation of elongation value result is thought to be caused by the stirring and rolling process. Manual stirring was also carried out using a stir rod because the viscosity of solution was quite high. This made it possible for some samples have an uneven in stirring process which caused in a less homogeneous of starch and plasticizers, and also an uneven distribution of chitosan that caused the elongation value is fluctuate (Nafiyanto, 2019; Tamiogy et al., 2019). Rolling process by manually also thought for this case because the density of sample sheet when it is rolled is not controlled.

The two-tailed test showed the enhancement of stirring temperature and different type of plasticizers did not affect the elongation value of biodegradable straws from ambon banana peel waste ($p > 0.05$). Conversely, the comparison test showed that the elongation value of biodegradable straws was significantly different against of conventional *boba's* straw ($p < 0.05$). Therefore, duncan test was conducted which showed that the GT_3 sample was significantly different to the control sample, while the GT1 sample was very significantly different to the control sample. The elongation values of the GT_2, ST_1, ST_2, and ST_3 samples can be said to be close to the control samples because they are in the same subset.

3.1.3. Biodegradation

The graphic below is the average of biodegradation level from 4 times of replication. The samples of all treatment were planted in humus soil at a depth of 2 cm for 7 days at the room conditions.

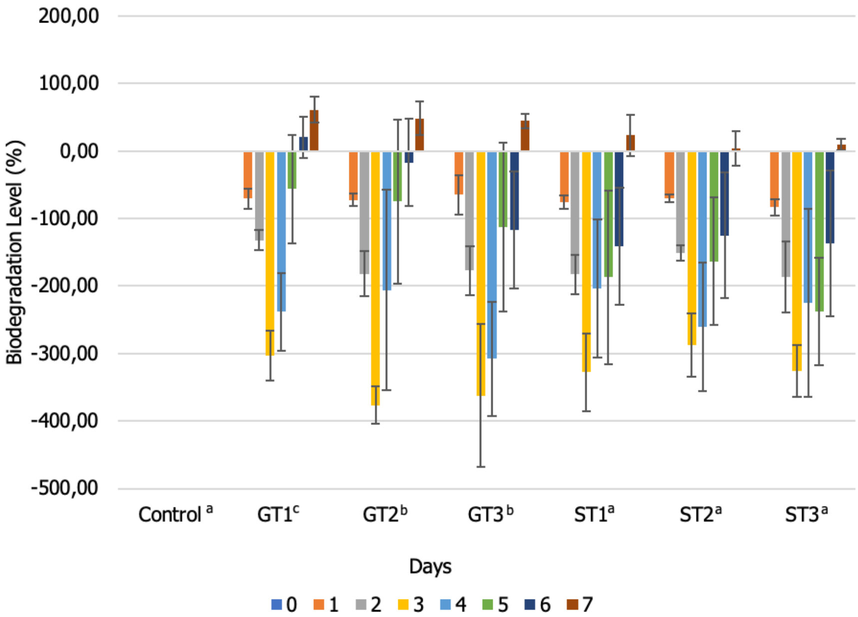

Figure 4. Results of Biodegradation Test

Explanation:

Control : Conventional *boba's* straws

GT_1 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 75°C.

GT_2 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 80°C.

GT_3 : Biodegradable straws with glycerol as plasticizer and stirring temperature at 85°C.

ST_1 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 75°C.

ST_2 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 80°C.

ST_3 : Biodegradable straws with sorbitol as plasticizer and stirring temperature at 85°C.

Based on Fig.4, it showed that the control samples did not show a degradation process, on the other hand, biodegradable straws have shown a degradation process. On the 7^{th} day, the GT_1 sample has the highest biodegradation level (66.33%), meanwhile the control sample has a lowest biodegradation level (-0.12%). As a disclaimer, in terms of mass measurement, there are refracting factor in which the soil is attached to the sample and the sample fragments are already fused with the soil. That affects the results of mass measurement and also biodegradation level.

On the 1^{st} to 3^{rd} day, the sample showed an increase in mass due to the water absorption process which is the initial stage before the biodegradation occurs which results in an increase in mass (swelling process) (Nur et al., 2020). After 7 days, the biodegradable straws with glycerol as plasticizer showed a higher biodegradation level than biodegradable straws with sorbitol as plasticizer. According to Lusiana et al (2019), glycerol has a higher ability than sorbitol to absorb water so that glycerol is more hydrophilic compared to sorbitol. It cause sample with glycrol as plasticizer have a better value in biodegradation level.

Glycerol is also known to be more hydrophilic than sorbitol plasticizer, so it can absorb more water which results in a faster of biodegradation level. Glycerol is known to have 3 hydroxyl groups, more than sorbitol which has 2 hydroxyl groups (Faust et al., 2021; Lee et al., 2018; Prasetyo et al., 2012). Beside that, enhancement of stirring temperature will reduce the water content in the biodegradable film solution which caused the molecular structure will be closer. Therefore, the water molecules will be difficult to penetrate into biodegradable straws (Hartatik, 2014). Furthermore, Pradipa & Mawarani (2012) stated that an increase of stirring temperature causes greater evaporation so the space of plasticizer is larger which results in reduce of water absorption. These condition can be cause a slowing of biodegradation level.

After data is processed using two-tailed test, it can be known that the enhancement of stirring temperature and different type of plasticizers did not affect the biodegradation level of biodegradable straws from ambon banana peel waste ($p > 0.05$). Related to the comparison test, the biodegradation level of biodegradable straws was significantly different against of conventional *boba's* straw ($p < 0.05$). Thus, duncan test was carried out which showed the GT_2 and GT_3 samples were significantly different to the control sample, while the GT_1 sample was very significantly different to the control sample. ST_1, ST_2, and ST_3 samples can be said to be close against of the control samples because they are in the same subset.

3.1.4. Water Uptake

Water uptake test was carried out to determine the percentage of water that can be absorbed by the sample for 30 minutes. The results that showed by graphic below is an average of water uptake percentage from 4 times of replication.

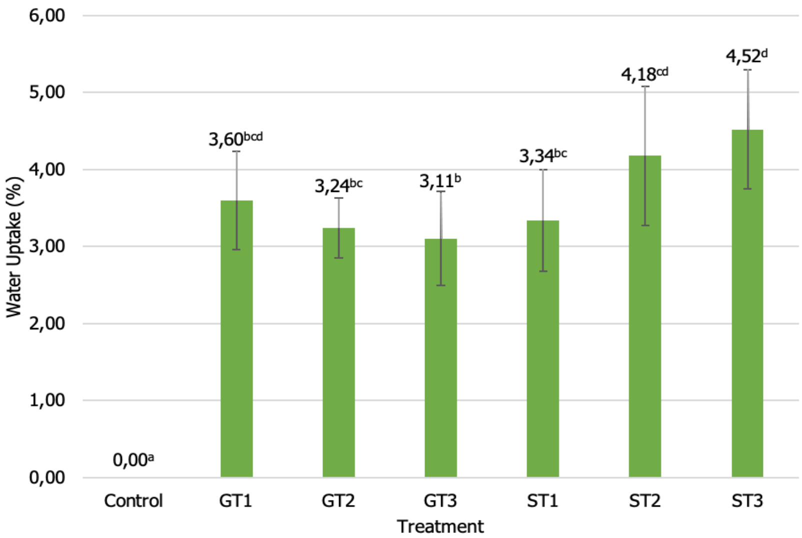

Figure 5. Results of Water Uptake Test

Explanation:

Control	: Conventional *boba's* straws
GT_1	: Biodegradable straws with glycerol as plasticizer and stirring temperature at 75°C.
GT_2	: Biodegradable straws with glycerol as plasticizer and stirring temperature at 80°C.
GT_3	: Biodegradable straws with glycerol as plasticizer and stirring temperature at 85°C.
ST_1	: Biodegradable straws with sorbitol as plasticizer and stirring temperature at 75°C.
ST_2	: Biodegradable straws with sorbitol as plasticizer and stirring temperature at 80°C.
ST_3	: Biodegradable straws with sorbitol as plasticizer and stirring temperature at 85°C.

Data that represented on Fig.5 showed the ST_3 sample has the highest water uptake value (4.52%), while the control sample has the lowest water uptake value (0.00%). The use of plasticizer causes water uptake in biodegradable straws to be high. Plasticizers have hydrophilic characteristic so the material will easily absorb the water (Putra et al., 2017). The enhancement of stirring temperature will also reduce the water content in the biodegradable film solution so that the molecular structure is more homogeneous and closer which results in a decrease in water uptake value (Hartatik, 2014). This is supported by Pradipa & Mawarani (2012) that stated an increase of stirring temperature causes greater evaporation so the space of plasticizer is larger which results in reduce of water absorption.

Theoretically, the water uptake of biodegradable straws with sorbitol as plasticizer should be lower than glycerol. This caused by sorbitol is known to have a larger molecular weight than glycerol which will strengthen intermolecular bonds so that water is more difficult to penetrate (Azizaturrohmah, 2019; Hartatik, 2014). Moreover, glycerol has a higher ability than sorbitol to absorb water so that glycerol is more hydrophilic compared to sorbitol (Lusiana et al (2019). However, the data from water uptake test showed the opposite. According to Nur et al., (2020), the water uptake value is also influenced by the thickness of biodegradable film. That is thought to causing the biodegradable straws with sorbitol as plasticizer to show an increasing trend of water absorption even though the stirring temperature has increased. When the samples were to be rolled, there were 2 samples of ST_2 and ST_3 respectively were too dry on one side. These sample must trim out which influenced the thickness of the samples and thought caused an increase in water uptake value even though the stirring temperature has increased.

The two-tailed test results showed that the enhancement of stirring temperature and different type of plasticizers did not affect the water uptake value of biodegradable straws from ambon banana peel waste ($p > 0.05$). On the other hand, the comparison test showed that the water uptake value of biodegradable straws was significantly different against of conventional *boba's* straw ($p < 0.05$). From the duncan test results, it can be shown that the GT_1, GT_2, GT_3, and ST_1 samples were significantly different from to control samples. Besides that, the ST_2 sample showed a very significant difference to the control sample and the ST_3 sample showed a highly significant difference to the control sample.

Compared with another study, Putri & Falah (2020) have developed biodegradable straw using combination of unused rice and rice bran. The study showed that biodegradable straw that made by unused rice and rice brand has a higher value in water uptake and biodegradation value, but lower in elongation value compared with biodegradable straw from ambon banana peel waste. Moreover, biodegradable straw from unused rice and rice brand has water update value of 100% and completely degraded in 4 days. This is presumably because the unused rice and rice brand have more hydrophilic properties than ambon banana peel waste. Nevertheless, the characteristic of both biodegradable straws statistically are not close to conventional straw which is used as a control variable in each study, but more environmentally friendly because it can be degraded in a matter of days.

The availability of ambon bananas in Indonesia is quite abundant. Ambon banana are often used as a consumption fruit or processed into chips, juice, and "*salé pisang*". So, it can be said that there are good prospects related to the sustainable development of biodegradable straw from ambon banana peel waste, especially in Indonesia. The procurement of ambon banana peel waste can be carried out with a cooperation scheme with industry/small and medium enterprise so as to facilitate the procurement of raw materials while preventing the wasting of ambon banana peel waste into the environment which can cause contamination. In addition, biodegradable straw products, especially those intended for *boba* drinks, have not yet been widely developed. Therefore, there are good prospects for conducting further research and development related to the functional aspects of biodegradable straw from ambon banana peel waste that expected to be mass produced in the future as an environmentally friendly *boba's* straw.

4. CONCLUSIONS

The development of biodegradabl *boba's* straw from ambon banana peel waste is an innovation to produce *boba's* straws that are more environmentally friendly and has the potential to replace the use of plastic straw in the future. Biodegradable *boba's* straw that have been developed has a colour of black, being rigid, with a length of 13 cm and an external diameter of 1.2 cm. The colour and external diameter of biodegradable *boba's* straw looks similar with conventional *boba's* straw but shorter in length. Based on sample testing, the enhancement of stirring temperature and different type of plasticizer did not significantly affect the characteristics of biodegradable straw from ambon banana peel waste ($p > 0.05$).

ACKNOWLEDGEMENT

We acknowledge all support received from the Agroindustrial Product Development Study Program, Vocational College, Universitas Gadjah Mada, and Department of Agroindustrial Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada. We also want to thank all the parties who support this research, from the procurement of raw materials, manufacture and sample testing, to the preparation of this manuscript.

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