Development of Biodegradable Straw using Combination of Unused Rice and Rice Bran

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Abstract

Plastics waste has been recently recognized as one of the most critical environmental issues. The most plastic is not recycleable and it takes 300-500 years to degraded perfectly. Plastics straw also contribute these negative impacts, so develop the biodegradable straw can be one of the solution. Natural ingredients that contain carbohydrates can be used as biodegradable straw materials are unused rice and rice bran, with glycerin from used cooking oil. This study aims to find out the effects of composition of unused rice flour and rice bran flour respectively on parameters. The parameters are the tensile strength, elongation, water uptake, and the biodegradation, then compare to the control. Statistical test were used to check, analysis, and compare between the data. The results show that combination variations in raw material flour had a significantly effect ($p<0.05$) on tensile strength, elongation, and biodegradation, but had not significantly effect ($p \geq 0.05$) on water uptake. Results obtained from the study of biodegradable straws for tensile strength ranges from 0.21-6.19 MPa, elongation range from 0.43-1.71%, water uptake 100%, and degraded 100%. Sample with a combination of 3 g unused rice flour : 0.5 g rice bran flour, has the highest tensile strength and elongation value and degraded within 4 days. However, the sample can not be used as an alternative to plastic straw because it does not have similar characteristics.

Keywords: *biodegradable straw, glycerin, rice bran, unused rice, used cooking oil*

1. INTRODUCTION

Plastics are made from petroleum raw materials that are limited in nature and are difficult to renew. This type of plastic includes plastics that are difficult to decompose or degrade in the soil because they are difficult to break down by microorganisms in the soil. Astuti et al. (2019) said that it takes about 300 to 500 years for plastics to decompose or decompose perfectly. This can certainly destabilize the environmental ecosystem if used without certain restrictions.

Putri (2022) said that plastics waste is still a global issue that needs a serious solution in its handling. The high use of plastics led to various environmental campaigns that appealed to minimize the use of plastics. One of the contents of the campaign echoed by environmental groups is reducing the use of plastic straws by drinking without straws or can also use environmentally friendly straws.

Fatia & Sugandi (2019) said that based on data from Divers Clean Action, a non-governmental organization focused on the problem of marine waste, at least 93 million plastic straws per day are produced by people in Indonesia. Plastic straws are usually made of poly propylene material, so it is difficult to degrade by soil. A good type of straws are straws made from renewable materials so that they are widely available in nature and easy to obtain. In addition, the use of such materials is expected to produce environmentally friendly straws to be more easily degraded in the soil, but have characteristics that are not much different from the type of plastic straws. There is one natural ingredient that can be used so that straws are easily degraded is all ingredients that contain carbohydrates. According to Nur (2017), this is because carbohydrates include compounds that can be decomposed by microorganisms. There are chains of glucose monomers in carbohydrates that are easily removed when given interference.

In previous research Selpiana et al. (2015) stated that biofilm can be made using organic monomer that can be found in starch, cellulose, and protein which formed become polymer. Natural ingredients that contain carbohydrates that can be used for the material of making biodegradable

ISSN 225-6137 (print), ISSN 2302-3848 (online), doi: 10.22146/aij.v8i2.76725.

straws are unused rice and rice bran. Based on the Directorate General of Trash, Waste, and Hazardous and Toxic Waste Management Ministry of Environment and Forestry (2020), the composition of food waste by 2020 reached 40.4% of the total waste heap or a total of 1.3 million tons. This means that in the amount of this waste is suspected any waste of leftover rice that can be converted into unused rice. On the other hand, based on Central Agency on Statistics, Directorate of Statistics of Food Crops, Horticulture (2021), the amount of rice plants production in Indonesia in 2020 reached 54.65 million tons. Nelfiyanti et al. (2020) said that the amount of rice bran obtained amounted to 10% (b/b) of the overall rice weight. This means that there are approximately 5.465 million tons of rice bran per year.

Unused rice and rice bran have a high carbohydrate content. Bahari & Cahyonugroho (2018) said that unused rice still has a high enough starch (carbohydrate) content. Sasria et al. (2020) revealed that the starch content of carbohydrate extraction in rice aking amounted to approximately 83.19%. Likewise, Hadipernata et al. (2012) said that rice bran still has a carbohydrate content of 22.04%. Astawan & Febrinda (2010) stated that the carbohydrate content in the form of starch in rice bran is 5-15%. Unused rice and rice bran are considered waste and are mostly only used as animal feed. Based on the carbohydrate content in both ingredients, it can be used into something that can increase value by being used as a basic material in the manufacture of biodegradable straws.

Another material that is also used in the manufacture of biodegradable straws, namely used cooking oil that can be converted into glycerin. According to Winarno & Octaria (2020), the benefits of glycerol/glycerin as a plasticizer is effective in lowering internal hydrogen bonds in the intermolecular bond to make the film structure increase, the mobility of the biopolymer chain increases, and the mechanical properties of the film become better. Additions in the manufacture of biodegradable straws can also increase the flexibility and permeability of the film against dissolved gases, water, vapors, and gases. Glycerin from the raw material of used cooking oil is obtained from the results of the stages of the reaction process using alcohol. Used cooking oil is a waste from the use of cooking oil in several uses. Used cooking oil comes from various cooking oils made of natural ingredients. One of them, namely oil made from palm fruit. Thus, this type of oil can be used as one of the ingredients in the manufacture of biodegradable straws.

This research is aimed to make biodegradable straws made from waste materials that are abundant in nature because of their availability as renewable materials, namely unused rice and rice bran. Then, mixed with glycerin from used cooking oil which is useful as a plasticizer for both main ingredients used. The type of straws produced is expected to be more environmentally friendly, but has characteristics that are not much different from plastic straws.

2. MATERIAL AND METHODS

2.1 Tools and Materials

The tools used for manufacturing biodegradable straws are oven (Memmert, Germany), blender (Philips, Indonesia), baking sheet, sieve, acrylic mold, analytical balance, hot plate, magnetic stirrer, stirring rod, pipette, and 25 ml measuring cylinder (Pyrex, Indonesia). The tools used for biodegradable straws and plastic straws testing are Universal Testing Machine (UTM i-Strentek 1510), analytical balance, trays, scoopula, and stationery. The materials used for manufacturing biodegradable straws are unused rice made from the C4 varieties of leftover rice obtained from hotels/restaurants/cafes, but in the implementation of this research conducted using raw material procurement methods, rice bran comes from local rice varieties in Kulon Progo, Yogyakarta, used cooking oil (palm oil) obtained from cooking oil that used by fried goods sellers in Kotagede, Yogyakarta, aquadest, alcohol 70%, acetic acid 1%, and chitosan. The materials used for biodegradable straws and plastic straws testing are latex gloves, tissues, aquadest, and humus soil.

2.2 Type of Research

This experimental study varies the combination amount of unused rice flour : rice bran flour (2.5 : 0.5 (A1), 3.0 : 0.5 (A2), 3.5 : 0.5 (A3), 0.5 : 2.5 (B1), 0.5 : 3.0 (B2), 0.5 : 3.5 g (B3). The sample testing of the experimental data for biodegradable straw that comparison with plastics straw as a control was shown in Table 1.

Table 1. Sample Testing for Comparison of Unused Rice Flour and Rice Bran Flour of Biodegradable Straw with Plastic Straw.

Sample Code	Unused Rice Flour	Rice Bran Flour
K	Plastic Straw	
A1	2.5 g	0.5 g
A2	3.0 g	0.5 g
A3	3.5 g	0.5 g
B1	0.5 g	2.5 g
B2	0.5 g	3.0 g
B3	0.5 g	3.5 g

Data were showed in four times repetition with standard deviation.

2.3 Manufacture of Glycerin from Used Cooking Oil

The stage of making glycerin from used cooking oil refers to (Nur, 2017). Used cooking oil that has been obtained is filtered and ensured the filter results are only the used cooking oil only. Then, used cooking oil and alcohol 70% are mixed with a ratio of 1:3. Then, both mixtures of solutions are heated at a temperature of 70 °C with stirring until two phases are formed in the mixture. Then, the mixture is transferred into a beaker glass and cooled at room temperature. Both mixtures will produce two phases (glycerin positioned at the bottom of the mixture) which are then separated manually using a pipette. Glycerin obtained is still placed on a beaker glass.

2.4 Manufacture of Unused Rice Flour

The stage of making unused rice flour refers to (Martina, et al., 2016). The unused rice with C4 varieties are prepared, then, drying the unused rice using an oven with temperature of 80 °C for 3 hours so that the water content is reduced to ±39%. After that, the dried unused rice will be mashed with a blender. Then, the resulting flour will be sieved using a 100 mesh sieve, so that the resulting particles are uniform.

2.5 Manufacture of Rice Bran Flour

The stage of making rice bran flour refers to (Nur, 2017). Rice bran that has been prepared, sieved using 100 mesh sieve to get a really smooth and uniform bran.

2.6 Biodegradable Straws Manufacturing

The stages of making biodegradable straws refer to (Selpiana, et al., 2015), (Nur, 2017), and (Rohmah, et al., 2020). The starch solution is made with the amount varies of unused rice flour : rice bran flour at 20 ml of aquadest at a heating temperature of 70 °C for 5 minutes, so that the starch gelatinizes to produce homogeneous results. Then, make a chitosan solution made with a composition of 3 g of chitosan (hydrophobic) at 100 mL acetic acid 1% (chitosan solvent) at a heating temperature of 70 °C for 20 minutes to produce homogeneous results. The starch solution is mixed into a chitosan solution at a heating temperature of 70 °C for 15 minutes and stirred until it gets a homogeneous result. Then, add 1.5 mL of glycerin (plasticizer) to a mixture solution that is 70 °C while stirring for a homogeneous mixture. Then, print the dough on an acrylic mold and put it in a 70 °C oven for 2.5 hours. After that, continued with the drying at room temperature 25 °C until the biofilm can be peeled from the mold and cut with a length x width ± 12x12 cm. Then, the biofilm is rolled up to obtain the form of a biodegradable straw resembling a type of straight straw. Then, biofilms that have been rolled up into biodegradable straws are re-ovened for 1 hour at 70 °C to dry biodegradable straws.

2.7 Sample Testing

Data obtained from this research are the results of tensile strength, elongation, water uptake, and biodegradation of the sample testing that is presented in Table 1 mentioned above. Then the analysis was conducted using Statistical Product and Service Solutions (SPSS) version 25.0 with the One-Way-ANOVA method with a significance level of 5%. The ANOVA test is used to determine whether or not the effect of variations in the composition of unused rice flour and rice bran flour on the characteristics of biodegradable straws. If there is a real or very real difference then duncan will be tested further. In addition, the test results of all treatment group samples were compared with the data of the test results of the control group samples (plastic straws). This comparison aims to analyze the extent of the suitability of the characteristics of biodegradable straws of unused rice and rice bran with plastic straws.

3. RESULTS AND DISCUSSION

3.1 Product Description

The appearance of biodegradable straw samples from unused rice and rice bran using glycerin from used cooking oil can be found in Fig.1. In appearance, the entire sample of biodegradable straw resembles the shape of a control plastic straw, a straight cylinder. There are 2 types of biodegradable straw treatment groups, namely A and B. Group A is a variation of unused rice flour with the same amount of rice bran flour and group B is a variation of rice bran flour with the same amount of unused rice flour. In both treatment groups, glycerin from used cooking oil and chitosan were added in each treatment group. Biodegradable straws from unused rice and rice bran using glycerin plasticizer from used cooking oil are printed on acrylic molds and dried. Then, the resulting biofilm is rolled up and dried back to resemble the shape of a control plastic straw (straight straw).

A1

B1

A2

B2

A3

B3

Figure 1. Product Biodegradable Straws from Combinations of Unused Rice Flour and Rice Bran Flour (2.5 : 0.5, A1), (3.0 : 0.5, A2), (3.5 : 0.5, A3), (0.5 : 2.5, B1), (0.5 : 3.0, B2), (0.5 : 3.5, B3), respectively.

Based on the manual visual appearance of the color of the entire sample, it is seen that the biodegradable straw with the treatment group A has a brighter color compared to the biodegradable straw with the treatment group B. The more the amount of unused rice flour in the biodegradable straw of the treatment group A, the brighter the sample color, while the more amount of rice bran flour added to the biodegradable straw of the treatment group B, the color of the resulting sample is getting darker. Based on the physical appearance of the surface of biodegradable straws, the treatment group A has a rougher surface compared to the biodegradable straw treatment group B.

3.2 Tensile Strength

According to Aritonang et al. (2020), tensile strength is the maximum voltage that can be held by biodegradable straws when pulled. The tensile strength value of the straws is found in Fig.2. The tensile strength value of biodegradable straws ranges from 0.21 MPa to 6.19 MPa. Based on the statistical analysis of the ANOVA test, the variation of two flours amount combination has a real effect ($p<0.05$) on the tensile strength value of biodegradable straws.

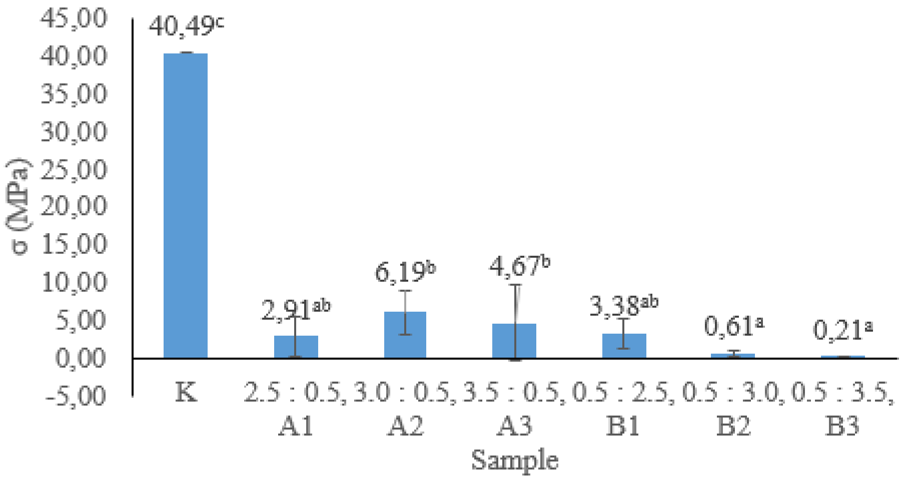

Figure 2. Tensile Strength of Straw Samples from Combinations of Unused Rice Flour and Rice Bran Flour respectively.

Fig.2 shows the tensile strength value of biodegradable straws with combination variations that have more amount of unused rice flour than rice bran flour is worth higher than biodegradable straws with combination variations that have more amount of rice bran flour than unused rice flour. This is also supported by duncan's follow-up test results that appeared in Fig.2. The tensile strength of A2 and A3 samples differ significantly from B2 and B3 samples. However, the A1 sample is not significantly different from other biodegradable straw samples.

Based on Fig.2 showed that the highest tensile strength value is 6.19 Mpa from the biodegradable straw A2 with a combination variation of unused rice flour 3.0 g : rice bran flour 0.5 g. The lowest tensile strength value is 0.21 Mpa from biodegradable straw B3 with a combination variation of unused rice flour 0.5 g : rice bran flour 3.5 g. The tensile strength value of biodegradable straw A2 is higher than biodegradable straw B3, it is suspected that the more dominant combination of unused rice flour contains more amylose. Purnavita et al. (2020) stated that the higher the content of amylose as a biofilm constituent material causes the film to be stronger so that the greater the force required per unit surface area of the film.

The process of gelatinization of starch from the combination of unused rice flour and rice bran flour also affects the tensile strength value of biodegradable straws. Biodegradable straws with a combination of the more dominant amount of rice bran flour are thought to have not been engaged during the process of making a starch solution. This results in the resulting biodegradable straw is having a strong tensile value lower than the biodegradable straw with a combination variation of the more dominant amount of rice flour. This is because biodegradable straws with variations in the combination of rice bran flour are more dominantly suspected to have different amylose and amylopectin content that require different gelatinization temperature and different gelatinization process times. Coniwanti et al. (2014) said that the gelatinization temperatures in each type of starch varies is different because the amount of amylose and amylopectin content in each type of starch also varies. In line with what Nisah (2018) said that the comparison of amylose and amylopectin levels can affect the solubility and degree of gelatinization of starch.

Based on Duncan's further tests found in Fig.2, the highest tensile strength of biodegradable straw in this study differs significantly from control plastic straw. This means that the tensile strength value of the A2 biodegradable straw has not come close to the control plastic straw.

3.3 Elongation

Sari et al. (2019) said that elongation is the maximum strain experienced by the film when subjected to force or can be referred as a percent increase in film length. The elongation value of the straws can be found in Fig.3. The elogation value of biodegradable straws ranges from 0.43% to 1.71%. Based on the statistical analysis of the ANOVA, the variation of two flours amount combination has a real effect ($p<0.05$) on the elongation value of biodegradable straws.

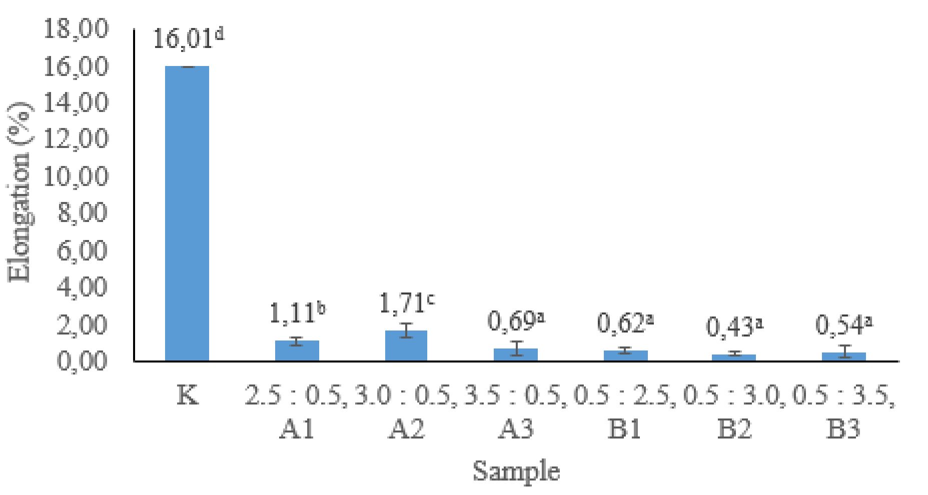

Figure 3. Elongation of Straw Samples from Combinations of Unused Rice Flour and Rice Bran Flour respectively.

Fig.3 shows the elongation of biodegradable straws with combination variations that have more amount of unused rice flour than rice bran flour is worth greater than biodegradable straws with combination variations that have more amount of rice bran flour than unused rice flour. This is also supported by duncan's follow-up test results contained in Fig.3. A1 and A2 samples differ significantly from those of B1, B2 and B3. However, A3 sample has no different from biodegradable straw samples B1, B2, and B3.

Based on Fig.3 indicated that the highest elongation value is 1.71% from the biodegradable straw A2 with a combination variation of unused rice flour 3.0 g : rice bran flour 0.5 g. The lowest elongation value is 0.43% of biodegradable straw B2 with a combination variation of unused rice flour 0.5 g : rice bran flour 3.0 g. According to Syura (2020), the highest value of percent elongation indicates that the biodegradable plastic that has been produced will not be easily broken because it can to withstand the load and attractiveness given. This means that biodegradable A2 straws are at least easily disconnected compared to other biodegradable straws.

The elongation's value has value that is inversely proportional to the tensile strength value (Coniwanti, et al., 2014). Therefore, theoretically biodegradable straws with a more amount of unused rice flour combination should have a lower elongation value. However, the test results showed that biodegradable straws with a more amount of unused rice flour combination were resulting in higher elongation value with fluctuating trends. If referring to the analysis contained in poin 3.2, the bias of the elongation value that is not theoretically suitable as a result of the solution of starch on biodegradable straws with variations of the combination of rice bran flour is more dominant has not been eroded.

In addition, the stirring process carried out also affects the elongation value so that it has a fluctuating trend. The process of stirring a combination starch solution and a chitosan solution at the time of the mixing process using a magnetic stirrer. However, the mixing process is also done by stirring manually using a stirring rod because the solution that becomes viscous inhibits the magnetic stirrer to function stirring normally. The process of manually stirring is done by not paying attention to the intensity or speed of stirring. This allows in some samples biodegradable straw replication to produce samples with a less even solution that causes starch and plasticizer to be less homogeneous, and the distribution of chitosan becomes less evenly and results in elongation values that show fluctuating trends (Nafiayanto, 2019).

Based on Duncan's further tests found in Fig.3, the highest biodegradable straw elongation in this study differs significantly from control plastic straw. This means that the elongation value of the A2 biodegradable straw has not come close to the control plastic straw.

3.4 Water Uptake

According to Putra & Saputra (2020), a water uptake test is conducted to determine the presence of bonds in polymers that occur as well as the regularity or level of bonding in polymers that can be caused through the percentage of polymer weight gain after the occurrence of swelling. The water uptake percentage value of straws can be found in Fig.4. The water uptake value for 30 minutes of soaking the entire sample of the biodegradable straws is worth 100%. Based on the statistical analysis of the ANOVA test, the variation of two flours amount combination has no real effect ($p \geq 0.05$) on the water uptake of biodegradable straw samples.

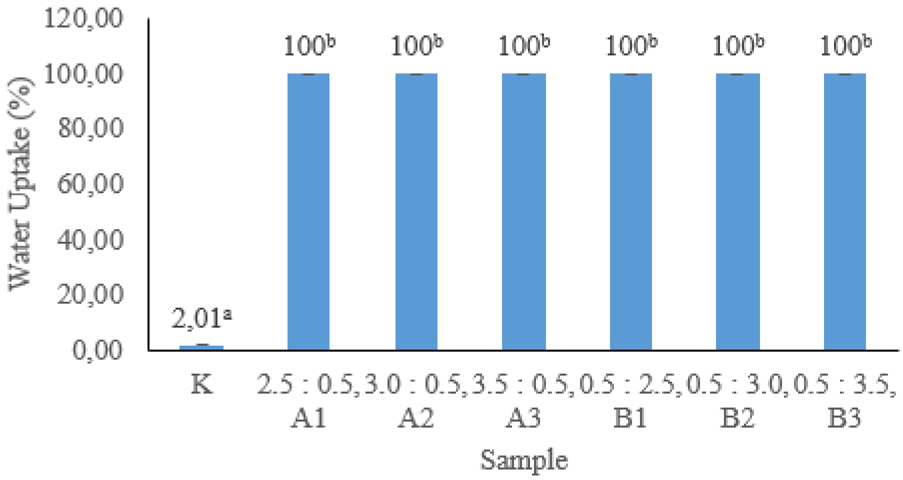

Figure 4. Water Uptake of Straw Samples from Combinations of Unused Rice Flour and Rice Bran Flour respectively.

Fig.4 shows a 100% water uptake value because after testing the biodegradable straw samples, it can not be measured the mass after the soaking of 30 minutes, so it is considered to be worth 100%. Biodegradable straw samples are not only have maximum water uptake, but also dissolve 100% in the testing media in the form of aquadest. Fig.4 shows the water uptake value of biodegradable straw with combination variations that have more amount of unused rice flour than rice bran flour is worth as much as the biodegradable straws with combination variations that have more amount of rice bran flour than unused rice flour. This is also supported by duncan's follow-up test results contained in Fig.4 that the water uptake of the entire biodegradable straw samples is not differ significantly. The entire samples have a high water uptake value allegedly because the combination of aking rice flour and rice bran increased the amount of starch content. This is in line with Budiman et al. (2018) statement that starch is hydrophilic, so it causes high water uptake in biodegradable straws. The higher the number of starches used, the higher the percentage value of water uptake in biodegradable straws. This is also a result of the still large content of the OH- hydroxyl group derived from starch (Tamiogy, et al., 2019).

In addition, the composition of the amount of chitosan used is also less so that the hydrophobic properties of chitosan can not decrease the water uptake value of biodegradable straws. If the composition of the amount of chitosan used is increased then biodegradable straws will experience a decrease in the percentage value of water uptake because chitosan is hydrophobic (Nafiayanto, 2019). Due to the water uptake of biodegradable straws is maximum, it may be possible to be given other additives that can improve the hydrophobic properties of biodegradable straws.

Based on Duncan's further tests found in Fig.4, the water uptake of all biodegradable straws in this study is significantly different from control plastic straw. This means that the water uptake of the entire biodegradable straw samples has not come close to the control plastic straw.

3.5 Biodegradation

Rozikhin et al. (2020) said that biodegradation is how long time need for plastic that is made can be degraded by microorganisms, so that they can be referred to as plastic that is environmentally friendly. Biodegradable straws biodegradation is viewed based on the percent of weight loss per day and the total length of time the sample is perfectly degraded. The biodegradation value of the straws is found in Fig.5. The length of biodegradation testing lasts for 7 days. Based on the statistical analysis of the ANOVA test, the variation of two flours amount combination has a real effect ($p<0.05$) on the biodegradation value of biodegradable straws.

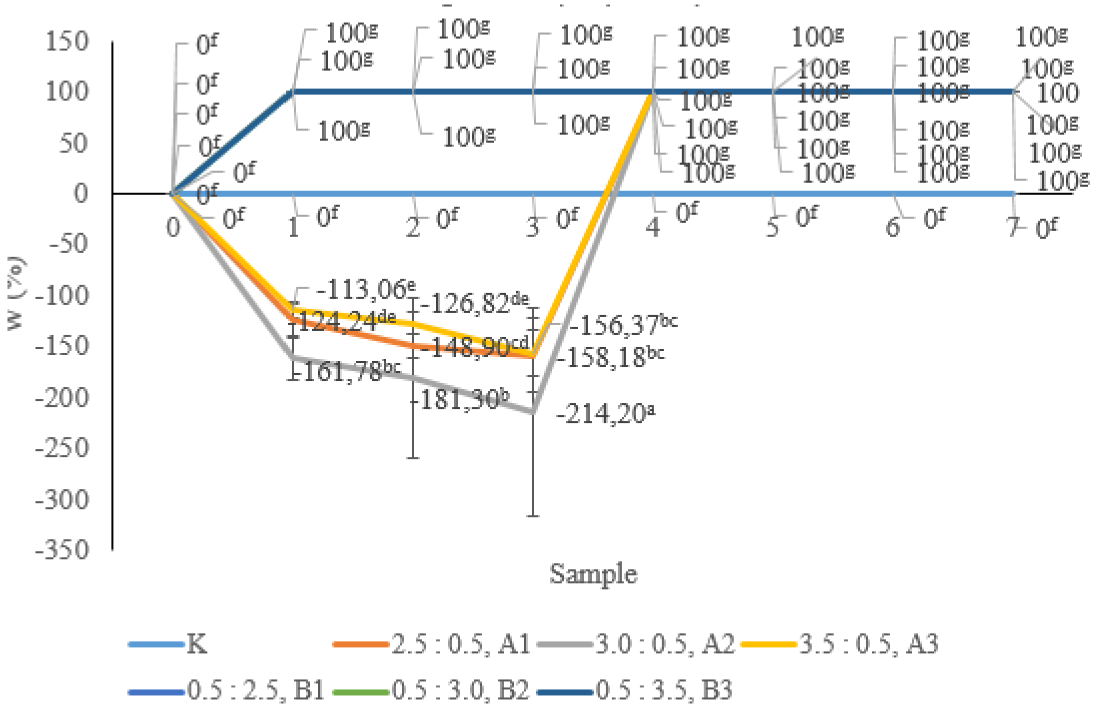

Figure 5. Biodegradation of Straw Samples from Combinations of Unused Rice Flour and Rice Bran Flour respectively.

Fig.5 shows negative biodegradation values due to cylinder-shaped biodegradable straw samples, so that during the biodegradation process takes place a lot of humus soil that is still attached to the sample and can not be cleaned as a whole resulting in the addition of sample mass. Biodegradable straws biodegradation with combination variations that have more amount of unused rice flour than rice bran flour have a longer time to degraded perfectly than biodegradable straws with combination variations that have more amount of rice bran flour than unused rice flour. Biodegradable straw samples A1, A2, and A3 degraded within 4 days, while biodegradable straw samples B1, B2, and B3 degraded within 1 day. Control plastic straw sample was not degraded for a period of 7 days. The length of degraded time of biodegradable straws is thought to be caused by hydrophilic starch. This is in line with the statement of (Pratami, et al., 2021), that one of the factors that influence the length of biodegradation time is the hydrophilic properties of biodegradable starch-based. The hydrophilic properties cause absorbed water molecules to cause microorganisms in the environment to enter the biodegradable straw matrix, so that biodegradable straws are easily decomposed.

Based on the length of time the sample was degraded, the entire biodegradable straw sample in this study was very different from the control plastic straw. This means that the biodegradation value of the entire biodegradable straw sample exceeds that of control plastic straw.

4. CONCLUSIONS

Based on the comparison of characteristics of biodegradable straw samples with a combination of unused rice flour : rice bran flour, 3.0 g : 0.5 g, has the highest tensile strength and elongation value compared to other biodegradable straw samples and can be degraded within 4 days. However, the sample has maximum water uptake value. All biodegradable straw samples do not yet has any characteristic similarities approaching to control plastic straw, even though they can be degraded perfectly. So, they can not be used as an alternative to control plastic straw.

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