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A Comparative Study between Cassava, Potato, and Purple Yam as a Potential Bioplastic

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Abstract:- With the high demand for single-use plastics in the Philippines, which has a negative impact on the environment, the development of biodegradable plastics for both industrial and commercial applications is critical these days. The study was conducted to determine the best bioplastic out of three staple crops in the country that can be used in the long run in the community. Bioplastic samples are created from the extraction of cassava roots, potatoes, and purple yam and tested using ASTM-D638-77, a mechanical testing method for calculating the tensile strength of an object, and the Soil Burial Test, determining the biodegradability level of the bioplastics made. Based on the findings after the experimentation and observations, the made bioplastic out of potato starch was the best bioplastic that fell under the criteria of a bioplastic with its incredible strength as well as its degradability rate. With that, it is recommended that more leading crops and plants in the Philippines are to be tested for bioplastic manufacturing such as Gabi which can also have the potential as it is a thickening ingredient. It is also great if future researchers will experiment with the amount of glycerin added to the bioplastics to work out and establish a more durable bioplastic. Last, but not the least, it is recommended to have more bioplastics shaped with different silicone mold containers to figure out how to strengthen the bioplastics out of different shapes and appearances, and structures.

Keywords:- *Bioplastic, Cassava, Potato, Purple Yam.*

I. INTRODUCTION

Overpopulation, urbanization, and the use of disposable products are the main contributors to the quantity of waste generation, which is known as municipal solid waste [16]. Plastic wastes hold the most amount in solid wastes. Plastic wastes are produced chiefly from packaging materials and discarded items [16]. In addition, the [30] Plastic Health Coalition (2022) discussed the natural materials used in manufacturing, such as paper, glass, and cotton, have been replaced by plastic, which led to extreme plastic pollution in the environment. As specified by [29] Parker (2019), half of all manufactured plastics have been made in the last 15 years, and the 448 million tons of garbage last 2015 is expected to double in 2050. Plastics have additives in them, making them more robust, more flexible, and durable, which is estimated to prolong their lives, taking at least 400 years to break down.

It was also stated [30] that it is no longer an environmental issue, as pointed out by Professor Doctor Dick Vethaak "We are dealing with a human health issue as well." To be more specific, plastic products contain chemical additives, and some of them are associated with severe health problems such as hormone-related cancers, infertility, and neurodevelopmental disorders like attention deficit hyperactivity disorder (ADHD) and autism. Since plastics are everywhere, they attract microorganisms such as harmful bacteria when they end up in the environment. When they enter the body, they may increase the risk of infection [30]. Moreover, millions of animals are killed solely because of plastics, particularly microplastics. Microplastics have been found in more than 100 aquatic species, including fish, shrimp, and mussels, which are the source of nutrients and foods [29].

Given that knowledge, only 16% of plastics are recycled, and the rest are directed to the oceans and rivers, which is a threat to animals, plants, and climate change, as well as plastics gradually release greenhouse gases when breaking down [17] [43]. Ritchie and Roser (2018) presented that the countries with the highest plastic waste generation per day are Kuwait, Guyana, Germany, the Netherlands, Ireland, and the United States of America without considering plastic waste management. However, in the context of mismanaged waste, the countries that topped the list were India, China, the Philippines, Brazil, and Nigeria. Mismanaged wastes are poorly managed wastes that commonly go into oceans and rivers. In the same article, the Philippines is pointed out as a significant contributor to emitting plastic into the ocean [23] [34].

SEA Circular (2020) [39] also informed that the plastic market in the Philippines is above a hundred million United States dollars; data from 2016 and 2017 showed that 48% of plastics are used for packaging purposes, making them a major contributor to pollution. Furthermore, Porcalla (2018) [31] stated that the Philippines is a great generator of plastic waste, especially in the oceans, as most of the compatriots live alongside waterways. It was discovered as well that seven out of the top ten most plastic-polluted rivers could be found in the Philippines. Not only plastics can harm humanity but wildlife as well, knowing that this dirt is destroying marine animals' habitat, and they tend to ingest some of it from time to time. To exemplify, an endangered turtle (*Chelonia mydas*) that is nearing death was found in Davao, Philippines, by a fisherman. Professionals nursed it because it kept floating as they brought it back to the ocean,

but it died after 11 days, and the cause of death was a large amount of plastic waste in its stomach [38]. Additionally, in a local context, for the same reason, which is the increase in the use of packaging materials, Baguio City has a total of 168 tons a day of the volume of waste [2] [11].

For these reasons, the use of bioplastics could be a solution to the problem, aside from promoting the use of reusable containers. Bioplastics are biodegradable materials made from renewable resources such as cornstarch and cellulose [32]. This will be a pivotal help in realizing the benefits and essence of these kinds of materials for the environment and for the health of living organisms. In addition, bioplastics are biobased and biodegradable plastics, meaning they break down naturally, or bioplastics can be both. It can also be recycled, as opposed to what many people believe [6].

Because of the rise of the use of bioplastics these days, are now more widely used in the industry than often, wherein it is used for food packaging, agriculture, horticulture, composting bags, and hygiene. The limitations do not end there because bioplastics have found their use in biomedical, structural, electrical, and other consumer products, and much research is still in progress to find further realizations of the use of bioplastics [5]. Furthermore, bioplastics have the unique potential to reduce greenhouse gas (GHG) emissions or be carbon neutral. Plants do absorb atmospheric carbon dioxide as they grow. Using biomass to manufacture bioplastics temporarily remove GHG from the atmosphere. It also generalizes waste management efficiency [12] [13].

The determination of bioplastics relies on the following characteristics that they possess upon thorough observation, experimentation, and investigation: (a) high heat resistance, (b) great flexibility and tensile strength, and (c) biodegradability [7]. Its compostability is also highly measured especially since bioplastics help to remove marine plastic pollution, knowing that conventional plastics harm and float on the water at most times [7].

Considering that, tapioca starch is a renewable resource that can be made into a bioplastic. Tapioca is a starch extracted from the root of a plant whose scientific name is Manihot esculenta. It is mainly produced in the countries of Brazil, Nigeria, and Thailand. Additionally, it is mainly used as a thickening ingredient for soups [24]. Often, tapioca is mistaken for being the same as cassava. Although they are indeed related, they are not the same. Tapioca is a starch extracted from cassava root. Production of this varies, but the process always includes squeezing the starchy liquid out of the ground cassava root, then the water will evaporate, and after that, a fine tapioca powder is left behind. From there, pearls, flakes, and such are processed further and most milk teas have it in them [1] [8]. On the other hand, purple yam (*Dioscorea alata*), also known as Ube locally, is a staple crop that originated in the Philippines and can also be turned into a bioplastic in its powder form. Although the purple yam is widely known and used in the Philippines as an ingredient for desserts, it only began to be discovered in the West just recently [14]. While purple yam is being confused to be a sweet potato, they differ significantly. Yams are drier and starchier than sweet potatoes. Additionally, a yam's skin is more bark-like, and as opposed to the sweet potato, it does not come in a variety of colors but with a flesh of different hues and saturations. It is also known to be rich in antioxidants [42].

Moreover, one of the staple crops in the Philippines is potato (*Solanum tuberosumis*). Potato is a small plant that has large leaves and is rich in starch and other carbohydrates. In its starch form, it can be turned into a bioplastic. The plant has various uses in different industries such as the alcoholic beverage industry and food industry [22]. It belongs to the *Solanaceae* family of flowering plants. According to the [18] International Potato Center (2017), it is the third most important food crop in the whole world in terms of human consumption and more than a billion people eat it globally. Potato starch is produced from the extraction process of potatoes. It turns to a light, powdery, flour-like consistency once it has dried out. Just like tapioca starch, it is used as a thickening agent as it absorbs water effectively [36].

With all these contexts, this research will be beneficial to both living and non-living things as plastics are associated with both terms. As Bio-Fed (n.d.) [6] emphasizes, bioplastics will make it possible to develop innovative, alternative solutions compared to conventional plastics, which may lessen the burden on the existing waste systems and the environment as well.

- *Research Problem*

The researchers believe that this issue of plastic waste globally, in which the world has been experiencing numerous environmental problems with the prevalent example of climate change and one of the main factors is plastic pollution, which is a great contributor to the distraction of nature and the earth. Due to these occurrences in our nation, the researchers would like to identify the best bioplastic among the three root crops, namely: cassava, Purple yam, and potato. The key concern the researchers want to handle in this study is to determine the best-manufactured bioplastic among the three crops. The researchers considered each of these three crops to be a viable possibility for producing bioplastic because of their awareness that these are each primarily utilized as an ingredient in various dishes, which is another reason why these three crops were selected. This is also because these crops are not applied in industries other than the food business. The researchers seek to create the ideal bioplastic that will not only significantly reduce plastic pollution but also benefit plastic users and lessen health risks associated with plastic consumption.

➢ *Research Framework*

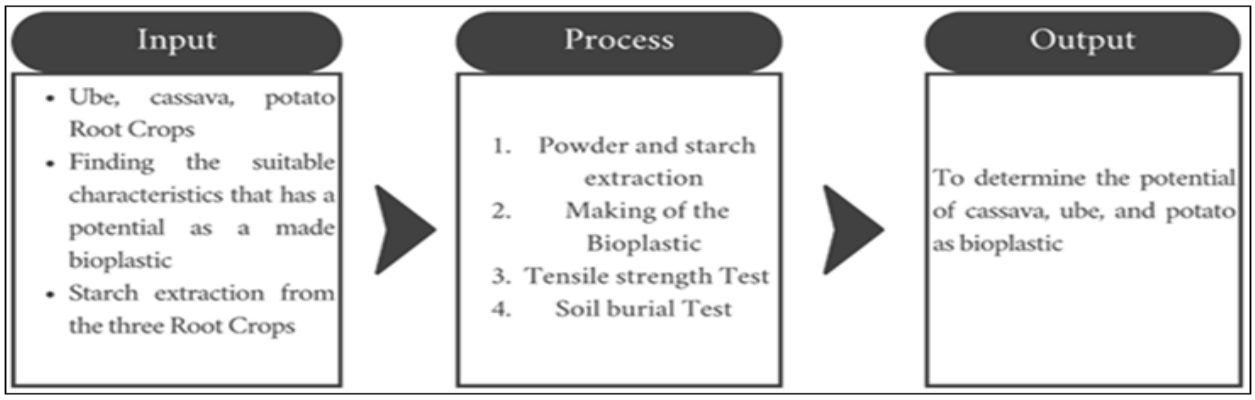

Fig 1 Research Framework

As shown in Figure 1, the study will determine the potential of the three root crops as made bioplastic, the researchers will first extract the root crops into starch and powder and then make them into Bioplastic. The researchers will analyze and collect data through two tests to get the suitable potential of the three root crops as made bioplastic. In Tensile Strength Test, the researchers will be the ones to manually stretch the bioplastic and will use ASTM-D638-77 to identify the tensile properties of the samples, and lastly, the Soil burial test will test the biodegradability of bioplastics to contrast and compare with plastic and that this study's target is to find its potential and to help the environment lessen the usage of single-use plastics.

➢ *Significance of the Study*

This research will show the significance of what the nature of ordinary plastic does to the environment. This study will show how bioplastics made from tapioca, potato starches, and Purple yam powder can affect specific community sectors and surroundings.

This study will help the community see the purpose and will further implicate the use of alternative plastics like tapioca and potato starches and Purple yam powder as bioplastics. With that in mind, the community will have an overview of the damage and an idea of what plastic is doing to the surroundings. This study will be beneficial to the following:

- The Youth - Youth nowadays has a better view of what is happening in their surroundings and how plastic is making a massive difference from the wrong point of view to our planet. This study would give an overview of the fact that there is an alternative (tapioca and potato starches and purple yam powder as bioplastic) rather than the usage of plastic. Furthermore, will be able to voice out the learnings from this research.
- Sellers/ Business operators - Given that they use plastic in most of their products, this segment of the community would benefit since they consume the most plastic.
- Common consumers - Since most individuals use plastics more frequently in their daily lives, this would be advantageous to regular people. With the help of this research, we can push for the use of more bioplastics.
- The environment – Since the world has been experiencing a lot of bad pollution which could cause harm to all living things. This comparative study could take advantage of lessening pollution, in particular plastic pollution.

II. METHODOLOGY

➢ *Research Design*

The study's experimental design was carried out using an experimental approach. This is because of the experiment being conducted to determine which of the three aforementioned crops will make the primary component of a plastic substitute. The researchers used a variety of measurements to determine the tensile strength of each created bioplastic as well as other formulas that would be correlated to the outcomes of the bioplastic, which is then characterized as a quantitative study using descriptive analysis. This technique has three important components: first, the researchers measure each variable; second, they interact with the three variables through direct contact. Finally, in order to compare the tensile strengths of potato starch, tapioca starch, and Purple yam powder, the researchers repeat the initial measurements and steps for each of the said variables [15] [40].

➢ *Research Instruments*

In this research experiment, the researchers used the following materials and instruments to properly conduct the experiment: 1 tablespoon of Tapioca Starch (Root of the cassava plant), 1 tablespoon of Purple Yam Powder, 1 tablespoon of Potato Starch, 1/3 tablespoon of Pure glycerin, 1/3 tablespoon of white vinegar, 4 tablespoons of Distilled Water, Digital Weighing Scale, Silicone mold (Square), 250 ml Beaker, Spoon, Stirring rod, Cheese Cloth, Blender, Thermometer, Basin, Oven dryer, Grater, Ruler or Vernier caliper, Compost soil, Incubator, Electric stove, Pot, Stove, Spatula, Strainer, Mixing bowl, and Parchment Paper

➢ *Data Collection Procedure*

- *Collection of Plant Material*

The cassava, purple yam, and potato that were used were purchased in the public market, in Baguio City. The samples were taken to Benguet State University for plant confirmation by their taxonomist, Mr. Jones Napaldet.

- *Preparation of the Tapioca Starch*

The extraction process of tapioca starch was adapted from a video of [27] Onyx Food Hill, a YouTube Channel, entitled "How to Make Tapioca Starch." This was also supported by [9] Brown (2020) from the website "Jotscroll" entitled "Tapioca flour (Tapioca Starch): How to Make Tapioca Flour at Home." For the tapioca starch-making process:

- ✓ The cassava roots were peeled, cut into pieces, and washed with clean water.
- ✓ Next, the cassava roots were grated, and for some cassava, further sliced into cubes and blended well.
- ✓ The grated and blended cassava roots were then mixed, and water was added, it was strained, and the mixture was separated.
- ✓ After that, the filtrate was set aside, and the substance was suspended overnight.
- ✓ After a while, the water was removed, and the suspended tapioca starch was kept.
- ✓ Lastly, the tapioca was crushed and fully dried under the heat of the sun.

- *Preparation of the Potato Starch*

The extraction process of Potato Starch was adapted from a website called 'Just a pinch recipe' entitled "DIY Essentials: Homemade Potato Starch.". This is also supported by the study of [3, 36] Rowden (2021) posted on the website Medical News Today. For the Potato starch making process:

- ✓ The potato was peeled and washed.
- ✓ After the first process, the potato was grated, placed in a large pot, and poured in some warm water just enough to cover the shredded potato.
- ✓ Once time had passed for a little while, the potato was swirled with water, then dumped through a strainer, with a cheesecloth into another bowl.
- ✓ After that, it was squeezed out of the cheesecloth to fully extract the starch of the potato, then the mixture was rested for 4-5 hours.
- ✓ After resting, the water was removed, and the potato starch was suspended.
- ✓ Lastly, the potato starch was fully dried and had the right powder texture.

- *Preparation of the Purple yam powder*

The extraction process of purple yam powder was adapted from a website called Alpha Foodie, entitled "How to make Purple yam powder / Purple sweet potato powder". This process is assisted by [37] Samira (2023) posted on the website, "Alphafoodie." For the Purple yam powder-making process:

- ✓ The purple yam was washed, peeled, and sliced into pieces.
- ✓ Next, the thin pieces of purple yams were baked for 2 hours until totally dried.
- ✓ Lastly the dehydrated yams were grounded until they had the right powder texture.

- *Preparation and Making of the Bioplastic*

After the starches and powder were already extracted, the primary ingredients in making the bioplastic, the main experiment began. The experiment procedure was patterned from the research of [34] Arikan and Bilgen (2019). To begin, the researchers:

- ✓ Weighed 1 tbsp of starch/powder and measured 4 tbsp of water, 1/3 tablespoon of vinegar, and 1/3 tbsp of glycerin that were added to the starch.
- ✓ After that, each of the mixtures was heated in a pan and mixed continuously until it reached 100 degrees Celsius and continued for 20 minutes (low heat).
- ✓ Lastly, the mixture was left to air dry for about 96 hours and waited for the firm texture of the bioplastic.

- *Tensile Test of the Bioplastic*

The researchers used ASTM-D638-77 as the standard method to determine the mechanical properties of the bioplastics made that were patterned to the study of [19] Kasmuri and Muhammad (2018). As for the illustration presented below (see Figure 2), it was also patterned to the study created by [19] Kasmuri and Muhammad (2018) as an alternative to the lack of tensile testing machines. ASTM-D638-77 is the most common testing method utilized to determine the tensile properties of reinforced and non-reinforced plastics [21].

- ✓ To start,
- ✓ Samples of bioplastics made with an 80 mm x 50 mm measurement were prepared for each type of bioplastic made.
- ✓ Next, the sample was hung using a thread to a clamp (clothespin) with an attached hook at the bottom part of the sample with a Ziploc to place the loads (coins) (see Figure 2).
- ✓ Then, the load (5-peso coins) was applied until the sample failed.
- ✓ The procedure was repeated for each sample and type of bioplastic made.
- ✓ The total loads (in grams) were recorded, and the total length of the failed sample was measured.
- ✓ Lastly, Young's Modulus (YM) was calculated.

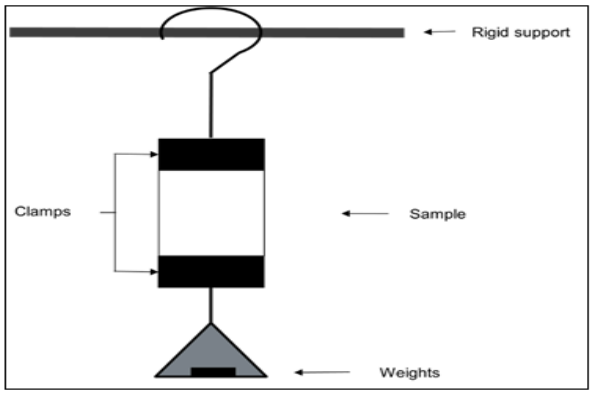

Fig 2 Illustration of Tensile Strength on Bioplastic [19]

- *Soil Burial Test*

This test was used to measure the degradability of the created bioplastics. This test is based on the research of [26] Nissa et al. (2019). Before starting, measure first the initial sample weight of the bioplastic. To begin,

- ✓ Firstly, measure the initial weight of the samples on the weighing scale.
- ✓ Three bioplastic samples measured 1 cm by 1 cm will be buried in compost soil at 7.5 cm depth.
- ✓ Each sample was incubated at room temperature (23 Degrees Celsius) for six days with a sampling time of every three days.
- ✓ After that, the buried samples were cleaned from the soil and weighed using the weighing scale.
- ✓ The weight loss of the bioplastics was measured and calculated.

➢ *Place and Time of Study*

The documentation and experiment were performed in Saint Louis School, Inc. High School Department at the Chemistry Laboratory, Physics Laboratory, and Home Economics Laboratory from February to March 2023.

➢ *Treatment of Data*

In testing the mechanical properties of the bioplastics made, the ASTM D638-77 was used. In this method, Young's Modulus was calculated in relation to the tensile strength test. According to [41] Washington (n.d.), Young's Modulus or Elastic Modulus is basically the stiffness of a material. Specifically, the physics and numerical values are interpreted in the following manner:

$$\text{Young's Modulus} = \frac{Stress}{Strain} \qquad (1)$$

Where:

$$Stress \frac{force}{cross\ sec sec\ tional\ area} \qquad (2)$$

$$Strain = \frac{change\ in\ length}{original\ length} \qquad (3)$$

In a more simplified manner, the formula that was used was

$$Young's\ Modulus\ (\frac{N}{mm^2}) = \frac{\frac{F}{A}}{\frac{L_1 - L_0}{L_0}} \qquad (4)$$

Where:

F is the total load applied (N),
A is the area of bioplastic (mm^2),
L_1 is the total length of the bioplastic after breaking (mm), and;
L_0 is the initial length of bioplastic (mm).

As for the Soil Burial test, it was done to identify the biodegradability of the bioplastics made. The weight loss of the bioplastic samples was measured wherein the higher the weight loss, the higher the degradation. Based on the study of [26] Nissa et al. (2019), the formula used was:

$$\%\ Weight\ loss = \frac{W_0 - W_f}{W_0}\ x\ 100 \qquad (5)$$

Where:

W_0 is the initial sample weight and;
W_f is the final weight after six days

Thus in this study, the researchers used Descriptive Statistics wherein the data sets are summarized and organized for the readers to understand them quickly. This analysis is basically used to give descriptions of information [25]. Additionally, it describes the relationships between the variables in the sample or population. In this, different types of variables are included (nominal, ordinal, interval, and ratio) as well as measures of frequency, central tendency, dispersion/variation, and position [28]. With that, as this research only have a small number of samples, it is better to use descriptive analysis, and there are only single samples that do not qualify for other test statistics as they need groups to look for means, standard deviation, and the like.

III. RESULTS AND DISCUSSIONS

Determining the best bioplastics out of the three crops (Purple yam, cassava, and potato) was achieved with all the experimentation and observation. The process of making the bioplastic was not an easy process as to how easy it looked like as there were failures encountered wherein the researchers needed to redo the whole process especially when measurements were not followed discreetly. However, the bioplastic made out of the purple yam was unsuccessful due to its runniness texture and the lack of drying even though it was dried for more than two weeks. The said bioplastic was weak and could not form into a bioplastic. As for the two other bioplastics, visually assessing, the bioplastic out of the potato was yellowish while the bioplastic out of the cassava was transparent and sticky when feeling it. In evaluating the bioplastics made, various factors were considered namely, the high resistance to pressure, great flexibility, high level of biodegradability, and visual appearance as they mostly complete the characteristics of bioplastics which were based on [12, 13] European Bioplastics (2016). The following are the observations about the two bioplastics made:

Table 1 Soil Burial Test Result (Weight Loss Percentage)

Bioplastic Type	Initial Weight (g)	Final Weight (g)	Weight Loss (%)
Potato	9	11	-22
Tapioca	8	5	37.5

After observing the bioplastics for six days in an incubator at 23 degrees Celsius, the bioplastic out of the potato starch did not lose weight, instead, it gained a total of two grams of weight. This is due to the fact that potatoes are naturally and highly sensitive to soil moisture [10] which is why they needed more days to degrade and more exposure to a higher temperature. On the other hand, the other bioplastic lost a total of three grams of weight. With that result, since it is a biodegradability test, tapioca bioplastic has an advantage. The bioplastics further showed their biodegradability after the researchers washed them, the two of them were easily crushed into pieces once in contact with water, making them equal in that part, even the potato bioplastic which did not lose any weight during the soil burial process.

Table 2 Tensile Strength Result (Young's Modulus)

Bioplastic Type	Initial Length (mm)	Final Length (mm)	Load Applied (N)	Young's Modulus ($\frac{N}{mm^2}$)
Potato	80	82	23.53596006873336	0.2353596
Tapioca	80	68	0.00078453	0.00078453

The table above shows the pressure of the two bioplastics. The loads were recorded in grams which were then converted into Newton. The unit N/mm^2 means Newton per Square millimeter which is a unit for pressure. In this context, the higher the N/mm^2 is, the higher its chance of reaching the characteristic of bioplastic which is strength. Upon experimentation, the bioplastic made from potato is the one that is most likely not to break when dealing with medium-weight loads. As for the other bioplastic, although it is flexible, it easily breaks when loads are put into it because of its low resistance to pressure and force. Clearly, the potato bioplastic is the one that is an advantage when it comes to strength. This is because the starch content of tapioca is estimated to be about 17% [33]. while the starch content of potatoes can be highly variable which is about 60-80% [35]. Starch contents in this case determine how robust the bioplastic would turn out. When it comes to the bioplastics made that were not starches, the Ginger tea bioplastic had the highest record as of the moment with 2.9 N/mm^2 and was able to withstand a 2.9kg total load as it was tested as a packaging material and not a bioplastic film [20].

Thus, combining the two results and other observations during the data collection procedure, the bioplastic created from potatoes is the one that had the most advantages out of the three bioplastics. Not only does it have high resistance against pressure, but it is also thick and biodegradable in nature, although it takes time unless submerged in water. For its visual presence, there are certain measures to be taken to make it transparent and reduce the aroma of the vinegar that is used.

IV. CONCLUSION

The three bioplastics that have been made showed different results, as the two bioplastics made, which were tapioca starch-based and potato starch-based, had the most potential out of the three. However, the Purple yam/purple yam bioplastic failed since it did not dry up and ended up exfoliating after being dried for 15 days. And as to test the comparative study between the two made bioplastics. The findings of the tensile strength showed that the potato lacks strength as a bioplastic, and the cassava had more potential for tensile strength. The results of the biodegradability of the two bioplastics showed that the cassava starch bioplastic had more promise to test than the potato. To conclude, the potato starch bioplastic has the most potential out of the three.

RECOMMENDATIONS

To have a deeper understanding and further knowledge about bioplastics, it is recommended that future research in relation to this should be able to explore more about the many aspects or circumstances that the researchers may have chosen to add to their study. As shown in the study, the researchers applied the same quantity of glycerin to all the root crops that were tested. In line with this, the researchers would like to recommend the following:

- It would have been a great factor (different measurements of glycerin) to compare the results of the various root crops. Future research will be able to see the contrasts between each response and each root crop. Cassava, potato, and Purple yam were the three root crops that the researchers decided to evaluate.
- It will be advantageous if a root crop of gabi, specifically taro, were included in the study. This is due to the reason that gabi is also known for having components that are useful as an ingredient for thickening, which is important for producing precise and suitable bioplastic.
- Future researchers should utilize various molds to create packaging products and different shapes of bioplastics, not only silicone square molds to really analyze and observe the mechanical properties of the bioplastics that are being produced.

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