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Bioplastic Made from *Manihot Esculenta* (Cassava) and *Ficus Benjamina* as an Ecological Alternative for Food Products

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The present research aimed to obtain a bioplastic made of *Manihot esculenta* (cassava) and *Ficus benjamina*. For this purpose, the residual lignocellulose of *Ficus benjamina* was mechanically conditioned until obtaining a particle size lower than 180 μm. There were elaborated samples of cassava starch bioplastic as blank test (BPY) and samples of cassava starch bioplastic with lignocellulose proportions of 12.59% (BPL5), 17.65% (BPL6) and 22.22% (BPL7). The average results of tensile strength evaluation of the BPY, BPL5, BPL6 and BPL7 samples were 9.9, 14.6, 14.8 and 15.7 Kpa, respectively. The BPY sample provided a higher elongation percentage with an average value of 13.59%. As for the biodegradation by gravimetric method for 5, 10 and 20 days, better results were evidenced for the BPL7 sample, with percentages of weight loss of 17.45, 27.08 and 48.69%, respectively. Finally, it is concluded that the bioplastic based on cassava and *Ficus benjamina* could be established as a favorable ecological alternative to be used in food products due to its good properties of resistance and favorable biodegradation.

1. Introduction

Currently, the large generation of plastic waste is causing various environmental problems, critically affecting both ecosystems and human health (Memon et al., 2019). From 1950 to 2015, an estimated total of 6.30 billion tons of plastic waste was generated, with only 9% recycled, leaving more than 80% to accumulate in landfills or in the natural environment (Brooks et al., 2018; Liang et al., 2021). In 2016, the world generated 242 Mt of plastic waste (Kaza et al., 2018). Already, by 2018, the world production of microplastics reached almost 360 million tons, being 2.01 million tons of bioplastics, which represents 0.56% of the world plastic production (Jogi and Bhat, 2020). Plastic waste has attracted great attention around the world and various management and evaluation methods have been used in the management of plastic waste (Aziz et al., 2020; Koch and Mihalyi, 2018; Liang et al., 2021). For this reason, biodegradable starch-based polymers are being investigated as substitutes for common plastics; However, these polymers have low mechanical properties (Alarcón and Arroyo, 2016; Encalada et al., 2018), and the improvement of these bioplastics is the object of study.

Cassava is considered a staple food present as a basic resource in millions of families after wheat, corn and rice (García et al., 2014; Pérez et al., 2019; Brenes, 2017; Chandrasekaran et al., 2017; Suárez and Mederos, 2011). Cassava starch is a raw material not only in food but also in the textile industry, the paper industry, processed foods and in the composition of bioplastic (Cortés et al., 2015). At the molecular level, starch is made up of amylopectin and amylose, the first considered main component is a branched molecule while amylose has a linear structure (Acevedo-Estupiñan et al., 2015; Cortés et al., 2015; Villarroel et al., 2018).

Ficus benjamina, considered an ornamental plant that belongs to the *Moreceae* family, has arboreal growth, fallen branches, and glossy greenish leaves (Shah et al., 2017). This tree can measure between 4 and 8 m in height, and is found in Southeast Asia, India, Malaysia, northern Australia, America and certain countries in Europe (Mukhtar et al., 2018; Mumtaz et al., 2018). Lignocellulose is the primary compound of biomass and approximately half of the matter generated by photosynthesis. The polymers that make up lignocellulose at the

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molecular level are cellulose, lignin and hemicellulose (Rodríguez et al., 2017). Bioplastics have this name because they are biodegradable and because they are made of a biological base (Bioplastics European, 2020). These differ from conventional plastics due to their chemical structure, which allows degradation by bacteria and fungi that transform these polymers into methane, biomass, carbon dioxide and water (Rodríguez, 2012). On the other hand, bioplastics allow the reduction of the volume of plastic compounds, minimize the cost in terms of handling these wastes and can increase soil fertility (Tokiwa et al., 2009). This research aims to obtain a bioplastic made of *Manihot esculenta* (cassava) and *Ficus benjamina* as an ecological alternative for food products.

2. Materials and methods

2.1 Raw material

Cassava starch, glycerol as plasticizer, acetic acid with a concentration of 3-5% and distilled water were used. The residual lignocellulose of *Ficus Benjamina* was obtained as a result of the maintenance activities of green areas in the city of Lima, Peru. To do this, all the material was cleaned, ground and dried at 35ºC for 9 hours, to then be crushed with a mortar and sieved until obtaining a particle size of less than 180 μm.

2.2 Manufacture of bioplastic

7 g of cassava starch was weighed and in a beaker it was mixed with 1 mL of acetic acid, 1mL of glycerol and 50 mL of distilled water. Subsequently, the doses of lignocellulose (1 g, 1.5 g and 2 g) were added for each sample and it was stirred until the compound was homogenized at a temperature of 70 °C. Next, the obtained product (bioplastic) was spread in a glass mold to be dried at room temperature (23 ºC) for 24 hours. After drying, the samples were removed from the mold for subsequent analysis of elongation, traction and biodegradability. It should be noted that a cassava bioplastic sample was made as a blank test to evaluate it with cassava starch bioplastics that contained lignocellulose (see Table 1).

Table 1: Components of bioplastic samples

Sample	Code	Residual lignocellulose of *Ficus benjamina* (g)	% mass	cassava starch (g)	% mass	Rate lignocellulose/starch
blank	BPY	0	0.00	7	100.00	0/7
1	BPL5	1	12.50	7	87.50	1/7
2	BPL6	1.5	17.65	7	82.35	1.5/7
3	BPL7	2	22.22	7	77.78	2/7

2.3. Elongation and tensile strength tests

Elongation and tensile strength tests were performed by the physical method using ASTM D882 as a reference, and were performed continuously to guarantee the method. For the evaluation of the elongation percentage, bioplastic specimens with dimensions of 13 cm in length and 2 cm in width were used, and force was applied by means of the equipment Ferton Professional MQP120 20TON and digital dynamometer until reaching the imminent point of traction. The calculation of the percentage of elongation was determined by Equation 1.

$$\text{Percent elongation (\%)} = \frac{(\text{Final length} - \text{initial length})}{\text{Initial length}} x100 \tag{1}$$

For the tensile strength test, a force was applied until the specimen broke (maximum tensile stress), and it was calculated using Equation 2.

$$\text{Tensile stress} = \frac{\text{Applied force}}{\text{Initial area}} \tag{2}$$

2.4. Evaluation of biodegradability

For the evaluation of biodegradation, the gravimetric method was used. For this, bioplastic specimens with dimensions of 2 cm wide by 2 cm long were used. These cassava starch bioplastic test tubes (blank tests) and cassava starch bioplastic test tubes with dosed lignocellulose. These test tubes were weighed and introduced into garden soil (pH = 6 and% H = 11.85%) at a depth of 10 cm for 20 days, since the highest activity by microorganisms occurs in the first centimeters of the soil (Paolini, 2018). Every 5 days, the samples were unearthed, cleaned and placed in a desiccator for 30 minutes for subsequent weighing. Biodegradation was evaluated following Equation 3.

$$\text{Weightloss} \ (\%) = \frac{\text{Initial dry weight} - \text{final dry weight}}{\text{Initial dry weight}} \qquad (3)$$

3. Results and discussion

3.1. Bioplastic samples

The BPL1 no form bioplastic and BPL2, BPL3 and BPL4 have weak consistency and break easily. The BPL5, BPL6 and BPL7 have high consistency and not break easily. For these reasons, only BPL5, BPL6 and BPL7 were considered in this research. The bioplastic samples were made according to the proportions indicated in Table 1. Figure 1 shows the bioplastic samples made from cassava starch and residual lignocellulose.

Figure 1: Bioplastic samples: a) BPY, b) BPL5, c) BPL6 y d) BPL7

3.2. Elongation and tensile strength tests

The results of percentage elongation (Figure 2a) showed a maximum value (13.59%) for the BPY sample that contained 7g of cassava starch. The other BPL5, BPL6 and BPL7 samples showed values of 4.36, 3.08 and 1.79%, respectively. This indicated that the percentage of elongation decreased as the content of lignocellulose increased in the sample. Alarcón and Arroyo (2016) reported increases from 13.97% to 33% in the percentages of elongation in biopolymers with additives from Chitosan and Xathan; however, the maximum tensile force was low with a value of 8.47 N for its best sample. While in the results of tensile strength (Figure 2b) the opposite was observed, indicating that the increase in the content of lignocellulose of *Ficus benjamina* increased the tensile strength of the bioplastic samples, obtaining a maximum value of 15.7 KPa for the sample BPL7 containing 22.22% residual lignocellulose.

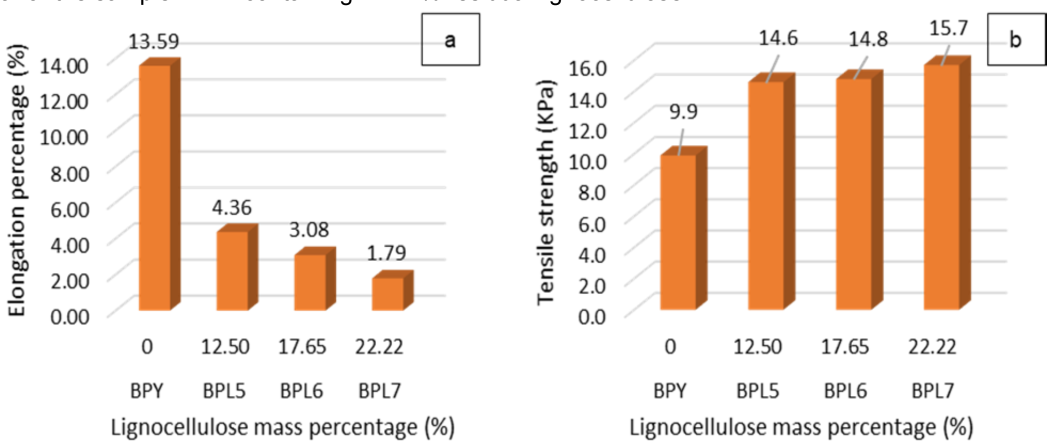

Figure 2: Relation between Lignocellulose mass percentage with elongation percentage and tensile strength. a) Average elongation percentage of bioplastic samples, and b) Average tensile strength of bioplastic samples.

According to the results obtained in Figure 2b, a mass percentage of 22.22% of lignocellulose in the bioplastic increases the tensile strength up to 58.59% with respect to the cassava starch bioplastic (BPY). A similar result was reported by Jaafar (2018) in the production of a tapioca bioplastic, increasing the tensile strength up to 42% with the addition of 30% pineapple leaf fiber. Prachayawarakorn and Hanchana (2017) and Gonzalez et al. (2018) also reported better tensile strength results when using 30% Neem sawdust and 15% wood sawdust in the composition of their biopolymer, respectively. On the other hand, Espina et al. (2016) indicated that the optimal concentration of agroindustrial fibers is 15% in starch-based polymers because at values greater than 30%, the tensile strength of the polymer decreases. Also, Luna et al. (2009) indicated based on their results that values greater than 15% of fique fiber in the cassava starch biopolymer decrease the resistance of the product.

3.3. Biodegradability of bioplastic samples

Table 2 shows the average biodegradation of the bioplastic samples that were introduced into the garden soil. It was observed that the percentage of biodegradation of the bioplastic sample increased when the percentage of lignocellulose of *Ficus benjamina* and the contact time in the soil was greater. The maximum biodegradation value (48.69%) was reached with the BPL7 sample in 20 days of contact in the soil. Other researchers such as Charro (2015) and Portillo (2017) reported mass losses of 93.13% (t = 20 days) and 8.67% (t = 16 days) in potato starch bioplastic and biodegradable films for Psidium guajava, respectively. These differences in weight losses are possibly due to the composition of the bioplastics and the contact medium that were submitted for their biodegradability evaluation because the biodegradability of the bioplastic depends on the physico-chemical structure of the polymer and environmental conditions such as the Average pH, temperature, humidity and oxygen content (Jogi and Bhat, 2020).

Table 2: Average percentage of biodegradation of bioplastic samples

Sample	Lignocellulose mass percentage (%)	Contact time in soil (days)	Average of biodegradation (%)
BPY	0	5	5.79
BPL5	12.50		8.72
BPL6	17.65		13.96
BPL7	22.22		17.45
BPY	0	10	10.74
BPL5	12.50		14.87
BPL6	17.65		21.89
BPL7	22.22		27.08
BPY	0	15	14.08
BPL5	12.50		22.93
BPL6	17.65		33.22
BPL7	22.22		36.95
BPY	0	20	22.64
BPL5	12.50		31.11
BPL6	17.65		41.49
BPL7	22.22		48.69

4. Conclusions

The residual lignocellulose of *Ficus benjamina* improves the quality of the cassava bioplastic by increasing its tensile strength and biodegradation. Furthermore, this bioplastic could be projected as a favorable ecological alternative to be used in food products. Among the most relevant results, it was witnessed that the bioplastic sample BPY (*Ficus benjamina* lignocellulose = 0%) had a higher percentage of elongation (13.59%), while BPL7 (*Ficus benjamina* lignocellulose = 22.22%) reached a resistance value to the traction of 15.7 KPa and an average percentage of biodegradability of 48.69% in a period of 20 days, indicating that the hygroscopic property of lignocellulose could intervene in the acceleration of this degradation process.

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References

Acevedo-Estupiñan M. V., Parra-Escudero C. O., Muvdi-Nova C. J., 2015, Study of clarification process of cassava starch hydrolysates using ceramic membranes, *Study of Clarification Process of Cassava Starch Hydrolysates Using Ceramic Membranes*, *22*(2), 121–129. https://doi.org/10.17533/udea.vitae.v22n2a06

Alarcón C., H. A., Arroyo B., E., 2016, Evaluation of chemical and mechanical properties of biopolymers by modified potato starch, *Revista de La Sociedad Química Del Perú*, *82*(3), 315–323. https://doi.org/10.37761/rsqp.v82i3.92

Aziz Z., Keshavarz, T., Kyazze G., 2020, Recycling and the environment: A comparative review between mineral-based plastics and bioplastics, *Chemical Engineering Transactions*, *79*, 355–360. https://doi.org/https://doi.org/10.3303/CET2079060

Bioplastics European, 2020, *Bioplastics - facts and figures*. European Bioplastics, https://docs.european-bioplastics.org/publications/EUBP_Facts_and_figures.pdf

Brenes Aguilar E., 2017, Manual Del Cultivo De Yuca, *Instituto Nacional de Innovación y Transferencia en Tecnología Agropecuaria*. http://www.mag.go.cr/bibliotecavirtual/F01-10918.pdf

Brooks A. L., Wang S., Jambeck J. R., 2018, The Chinese import ban and its impact on global plastic waste trade, *Science Advances*, *4*(6), 1–8. https://doi.org/10.1126/sciadv.aat0131

Chandrasekaran A. P., Sivamani S., Ranjithkumar V., 2017, Characterization of combined organic–inorganic acid-pretreated cassava stem, *International Journal of Environmental Science and Technology*, *14*(6), 1291–1296. https://doi.org/10.1007/s13762-016-1232-8

Charro Espinosa M. M., 2015, *Obtención de plástico biodegradable a partir de almidón de patata* [Universidad Central del Ecuador]. http://www.dspace.uce.edu.ec/handle/25000/3788

Cortés S., S., Chavarriaga P., Ceballos H., López C., 2015, Evaluación de la expresión de genes implicados en la biosíntesis de almidón en diferentes variedades de yuca, *Acta Biologica Colombiana*, *20*(2), 37–46. https://doi.org/10.15446/abc.v20n2.42875

Encalada K., Aldás M. B., Proaño E., Valle V., 2018, An overview of starch-based biopolymers and their biodegradability Una revisión sobre biopolímeros con base en almidón y su biodegradabilidad, *Ciencia e Ingeniería*, *39*(3), 245–258.

Espina M., Cruz-Tirado J. P., Siche R., 2016, Mechanical properties of trays based on starch of native plant species and fiber of agroindustrial wastes, *Scientia Agropecuaria*, *07*(02), 133–143. https://doi.org/10.17268/sci.agropecu.2016.02.06

García Y. B., Jiménez M. D. M., Arbelo O. C., Cabrera A. R., Pérez M. B., Pino A. S., Torres J. L., Vega V. R. M., Alfonso J. A. C., Díaz E. R., Pérez D. R., 2014, Morphological and agronomic characterization of cuban cassava cultivars (Manihot esculenta Crantz), *Cultivos Tropicales*, *35*(2), 43–50.

Gonzalez Y., Salamanca J., Vargas J., 2018, *The effect of potato starch modified as a coupling agent in polymer-wood fiber composites*. *16*(1), 107–113. https://doi.org/10.15665/rp.v16i1.1236

Jaafar J., Siregar J. P., Oumer A. N., Hazim M., Hamdan M., Tezara C., Sapuan M., 2018, Experimental Investigation on Performance of Short Pineapple Leaf Fiber Reinforced Tapioca Biopolymer Composites, *BioResources*, *13*(3), 6341–6355.

Jogi K., Bhat R., 2020, Valorization of food processing wastes and by-products for bioplastic production, *Sustainable Chemistry and Pharmacy*, *18*, 1–10. https://doi.org/10.1016/j.scp.2020.100326

Kaza S., Yao L., Bhada-Tata P., Van Woerden F., 2018, *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*, The World Bank. https://doi.org/10.1596/978-1-4648-1329-0

Koch D., Mihalyi B., 2018, Assessing the Change in Environmental Impact Categories when Replacing Conventional Plastic with Bioplastic in Chosen Application Fields, *Chemical Engineering Transactions*, *70*, 853–858. https://doi.org/10.3303/CET1870143

Liang Y., Tan Q., Song Q., Li J., 2021, An analysis of the plastic waste trade and management in Asia. *Waste Management*, *119*, 242–253. https://doi.org/10.1016/j.wasman.2020.09.049

Luna G., Villada H., Velasco R., 2009, Almidón termoplástico de yuca reforzado con fibra de fique: Preliminares, *Dyna (Colombia)*, *76*(159), 145–151.

Memon A. H., Peerzada M. H., Muhammad K., Memon S. A., Mangi S. A., Mujtaba G., 2019, Recent Eco-Friendly Developments in Personal Protective Clothing Materials for Reducing Plastic Pollution: A Review, *Engineering, Technology & Applied Science Research*, *9*(2), 4012–4018.

Mukhtar H. M., Singh A., Kaur H., 2018, Bioassay guided fractionation and in vitro anti-plasmodial activity of ficus deltoidea and *ficus benjamina*, *Pharmacognosy Journal*, *10*(2), 235–240. https://doi.org/10.5530/pj.2018.2.41

Mumtaz M. W., Al-Zuaidy M. H., Hamid A. A., Danish M., Akhtar M. T., Mukhtar H., 2018, Metabolite profiling and inhibitory properties of leaf extracts of *Ficus benjamina* towards α-glucosidase and α-amylase, *International Journal of Food Properties*, *21*(1), 1560–1574. https://doi.org/10.1080/10942912.2018.1499112

Paolini J. E., 2018, Actividad microbiológica y biomasa microbiana en suelos cafetaleros de los Andes venezolanos Microbial activity and microbial biomass in coffee soils of the Venezuelan Andes, *Tierra Latinoamericana*, *36*, 13–22. https://doi.org/https://doi.org/10.28940/terra.v36i1.257

Pérez D., Mora R., López-Carrascal C., 2019, Conservation of the cassava diversity in the traditional cultivation systems of the Amazon, *Acta Biologica Colombiana*, *24*(2), 202–212. https://doi.org/10.15446/abc.v24n2.75428

Portillo M. F. P., 2017, *Desarrollo de bioplástico para Guayaba (Psidium guajava variedad Pedro Sato)* [Universidad Zamorano]. http://hdl.handle.net/11036/6069

Prachayawarakorn J., Hanchana A., 2017, Effect of neem wood sawdust content on properties of biodegradable thermoplastic acetylated cassava starch/neem wood sawdust composites, *Starch/Staerke*, *69*(3–4), 1–9. https://doi.org/10.1002/star.201600113

Rodríguez A., 2012, Biodegradabilidad de materiales bioplásticos. *Ciencia y Tecnología de Alimentos*, *22*(3), 69–72. https://www.researchgate.net/publication/328676031_Biodegradabilidad_de_materiales_bioplasticos

Rodríguez M. D., Castrillo M. L., Velázquez J. E., Kramer G. R., Sedler C., Zapata P. D., Villalba L., 2017, Obtención de azúcares fermentables a partir de aserrín de pino pretratado secuencialmente con ácido-base. *Revista Internacional de Contaminacion Ambiental*, *33*(2), 317–324. https://doi.org/10.20937/RICA.2017.33.02.12

Shah K., Ul Amin N., Ahmad I., Shah S. & Hussain K., 2017, Dust Particles Induce Stress, Reduce Various Photosynthetic Pigments and their Derivatives in *Ficus benjamina*: A Landscape Plant, *International Journal of Agriculture & Biology*, *19*, 1469–1474. https://doi.org/10.17957/IJAB/15.0445

Suárez G., L. & Mederos V., V. R., 2011, Revisión bibliográfica: Apuntes sobre el cultivo de la yuca (Manihot esculenta Crantz). Tendencias actuales, *Cultivos Tropicales*, *32*(3), 27–35.

Tokiwa Y., Calabia B. P., Ugwu C. U., Aiba S., 2009, Biodegradability of plastics. *International Journal of Molecular Sciences*, *10*(9), 3722–3742. https://doi.org/10.3390/ijms10093722

Villarroel P., Gómez C., Vera C., Torres J., 2018, Almidón resistente: Características tecnológicas e intereses fisiológicos, *Revista Chilena de Nutrición*, *45*(3), 271–278. https://doi.org/10.4067/s0717-75182018000400271