The Garden Battle: A Comparative Study on the Tensile Properties between Corn-based and Cassava-based Bioplastics

Damirson A. Co, Lourd Albert T. Bañaga, Daniel Marco M. Dela Concha, Darcy C. Mariano, Charlton Lance S. Reyes
Department of Industrial Engineering, Faculty of Engineering
University of Santo Tomas
España Blvd, 1015, Manila Philippines
daco@ust.edu.ph, lourdalbert.banaga.eng@ust.edu.ph, danielmarco.delaconcha.eng@ust.edu.ph, darcy.mariano.eng@ust.edu.ph, charltonlance.reyes.eng@ust.edu.ph

Abstract

As technology advances, climate change comes along with it. The world advances towards an era where everything can be easily manufactured. So, it is essential to know which materials and resources to use and utilize. This study was conducted to know which organic material is stronger as the main component in the production of bioplastics. Such findings benefit the companies that produce or plan to produce eco-friendly bioplastics. The emerging need to use sustainable materials pushed them to divulge in this study. Moreover, this redounds to the benefit of humanity, considering that non-biodegradable materials continue to litter the planet. This paper aimed to promote sustainability and resourcefulness by identifying the better material for manufacturing bioplastics. The literature review presented a detailed discussion on plastics. From how it is caused, up to how it should be reduced and diminished. The researchers prepared samples of corn-based and cassava-based bioplastic, and prepared samples of petroleum-based plastic to serve as the standard in this comparative study. These samples were tested under a series of trials to determine the difference between their tensile strength. The researchers analyzed the results of these trials by using the Independent Samples T-test as a statistical tool to determine the statistical difference between these bioplastics in terms of their tensile properties, with the petroleum-based plastic packages as the standard. From there, the researchers concluded that corn-based bioplastics are up to par with petroleum-based plastics regarding tensile strength. However, it is recommended to try a more relevant test to have more in-depth knowledge of these plastics.

Keywords
Sustainability, Bioplastics, Independent Samples T-test, Tensile Properties

1. Introduction

Bioplastics can be created entirely or partially from renewable biomass sources like sugarcane and corn and microbes like yeast. Under the right circumstances, some bioplastics are biodegradable or even compostable. Bioplastics manufactured from renewable resources can be naturally recycled by biological processes, protecting the environment, and reducing fossil fuel consumption. With that said, bioplastics are indeed sustainable, biodegradable, and biocompatible. Bioplastics are plastics manufactured from natural materials like vegetable oils and starches (Ashter 2016). The researchers will compare two biodegradable plastics: corn-based and cassava-based bioplastics. Corn-based bioplastics are made from corn and its by-product, which are then fermented to produce Polylactic Acid (PLA), the primary material in the production of bioplastics. Meanwhile, cassava-based bioplastics are made from cassava and its by-product, fermented to produce PLA.

Annually, about 4 to 12 million tons of plastic waste go directly to the world's oceans. 20% of the waste is marine-based, originating from maritime activities and operations such as fishing and shipping. At the same time, 80% of the waste comes from land-based sources. Moreover, the Philippines is one of the 5 countries considered where 60% or most of the plastic waste leaks into the ocean; other countries are China, Indonesia, Thailand, and Vietnam (Akenji et al. 2020). Each year, the Philippines produces an astounding 2.7 million tons of plastic garbage, of which an estimated 20% ends up in the water. Since the country is made up of more than 7,500 islands, the Philippines' coastal communities and the fishing, shipping, and tourism industries are particularly exposed to the effects of marine debris. (World Bank Group 2021). The country also cannot recycle plastic waste efficiently. Only 28% of the plastics Collected For Recycling (CFR) are recycled, and 72% are discarded. Due to this, the Philippines realizes a significant opportunity cost of 890 million dollars per year due to dumping recyclable plastic products rather than recycling them into other valuable materials. (World Bank Group 2021).

With the solutions being invented by the people dedicated to helping to resolve this problem, the researchers want to contribute. According to Moshood et al. (2022), biodegradable plastics can easily be disintegrated by living organisms' activities, commonly known as microbes in the water. This type of plastic can be an alternative to plastics that are non-biodegradable to minimize the stress from the dwindling availability of landfill sites and plastic pollution. Moreover, the application of biodegradable plastics can reduce greenhouse gas emissions during usage. With that said, bioplastics is significant to the said problem. However, the type of materials to manufacture biodegradable plastics should be studied. When producing bioplastics, people should investigate the available resources and the most appropriate materials. Thus, maximizing the availability of resources and optimizing the solution.

1.1 Objectives

The general objective of this study is to determine the statistical difference between the bioplastics in terms of their tensile properties, with the petroleum-based plastic packages as the standard. Moreover, Analyzing the tensile strength of each plastics using Independent Samples T-test. The data analysis results help discerned a more effective main component between corn-based and cassava-based bioplastics in bioplastic film production. The results on which material is better between the said components will benefit biodegradable plastics manufacturers. These manufacturers can provide quality products and support the agricultural sector in the country. In line with this, the production of bioplastics will cultivate a more sustainable agricultural production.

2. Literature Review

Plastic is a synthetic organic polymer used in various industries, especially food and packaging. Plastics were first used in 1950 by a plastic made from synthetic materials called "Bakelite." Until then, plastics became a common material used globally in everyday lives. The use of this polymer is still expected to rise due to the global shift from reusable to single-use packaging and containers. Most of the monomers used in making plastics, such as ethylene and propylene, are petroleum-based (Geyer et al. 2017). Due to this, most plastics take a long time to degrade, and most of them accumulate in landfills and bodies of water, which causes plastic pollution (Windsor et al. 2019). Therefore, plastics are called a "poorly reversible pollutant" as their emission or usage rate is challenging to alleviate.

Biopolymers have been considered a potential substitute for petroleum-based products in the plastic industry. Poly(lactic) acid (PLA) is one of the promising polymers with its properties as a solution to plastic waste. PLA's production process goes through the fermentation of renewable resources like corn, cassava, and sugarcane. The process of degradation of the polymer is linked to the issue of plastic wastes. Further research regarding the bacteria, fungus, and enzymes that collectively play a vital role in PLA biodegradation has been experimented with within the study. The biochemical process under microorganisms and environmental conditions through a simulated system has been used to analyze the complete degradation of the polymer.

Different efforts have alleviated plastic pollution at the source and in the sinks. The said efforts include source reduction policies: bans, charges, deposits, fees, fines, incentives, penalties, refunds, and taxes (Andreas et al. 2021). In Taiwan, an environmental non-governmental organization held beach cleanups and created online and offline outreach educational programs. They also learned further scientific monitoring and survey methods to attract media attention, creating more public awareness and pressure to deal with the plastic pollution problem.

Conventional plastic packaging has been an essential part of the packaging industries' operations. The industry is open to a greener solution in replacing conventional plastic with biodegradable plastics, namely polyhydroxyalkanoates (PHA), polylactic acid (PLA), and bio polyethylene (BioPE). These bioplastics are potentially crucial to the packaging industry because of the nonrenewable life of conventional plastics. Currently, PLA is the most well-known bioplastic and has been frequently found in bags, food containers, and bottles (Ehman & Area 2021). Bioplastics contribute to a greener economy; however, bioplastics cannot measure up to the standards that conventional plastics have set. The scale in the production of bioplastics is complex and complicated operations. With that, the tensile properties of bioplastics are the focus of researching PLA. Accepting bioplastics is expected to contribute to a greener environment by improving waste management and pollution, the quality of citizens' health, and wildlife (Lawal & Valapa 2021).

In summary, bioplastics play a vital role in combating the pollution caused by single-use and petroleum-based plastic. The causes of such pollution are rooted in its number of uses, inexpensiveness, and the "sachet economy." The current solution provided by the government and non-government agencies relies on policy implementation and cleanup drives. It costs a lot to rehabilitate and recover the damage done by pollution. Moreover, it is emphasized in the literature review that investing in preventive measures will lessen the cost and minimize the threats that may arise. Even with its disadvantages, PLA is more obliging than it is damaging. With that said, it is crucial to know what material is the fittest as a bioplastic.

Most of the present literature focuses only on investigating the properties of different types of PLA and how they compare to one another or with the properties of traditional petroleum-based plastics. Generally, literature follows the same methodology, even in studies that focus solely on starch-based bioplastics. Typically, they only examined different plastics under different tests to know their mechanical properties and how fast they degrade. Then, after the experimentation, they would only compare each plastic's properties without necessarily saying that one plastic is better than the other.

2.1. Theoretical Framework

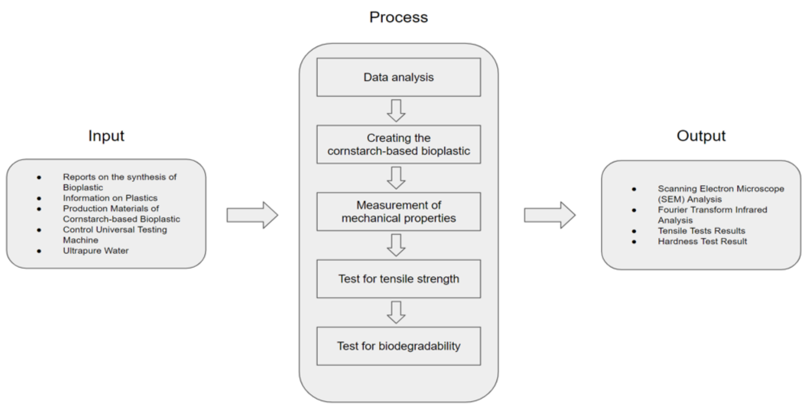

Figure 1. Theoretical framework
(Produced by Nandiyanto et al. 2020)

This theoretical framework is produced from an engineering study conducted in Indonesia (2020). The study's objective is to test the mechanical and biodegradation properties of bioplastic made from pure cornstarch. Doing so, it used a Digital microscope, Scanning Electron microscope, and Fourier Transform infrared as tools for the tests. The scope of this study is limited only to the data acquired from the tests and its definition of one bioplastic. It did not evaluate its variables to know the most significant factor of a standard bioplastic.

Based on the study, the data will be used to analyze and apply the production and experimentation of the corn-based bioplastic. For creating the corn-based bioplastic, the following materials: micron-sized cornstarch, acetic acid 25%, and glycerol 95% will go through mixing, heating, molding, and drying. The properties of the bioplastic will then be analyzed using the following tools and formula: Scanning Electron Microscope (physicochemical properties), Fourier Transform infrared (physicochemical properties), Control Universal Testing Machine (mechanical properties), and Young's Modulus (tensile strength). For its biodegradability test, multiple bioplastics with sizes of about 5 x 5 mm will be immersed in ultrapure water to measure the weight losses of each sample. Thus, obtaining the needed results.

3. Methods

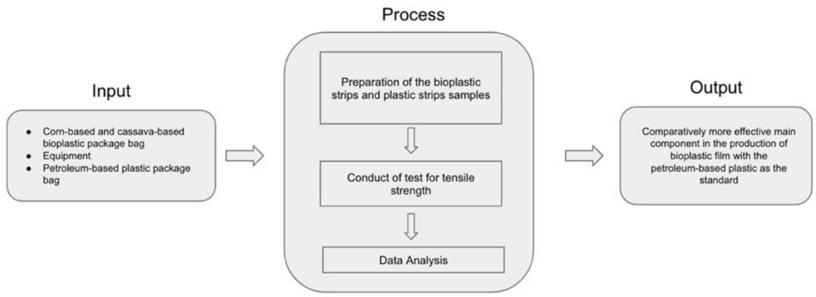

Figure 2. Research Paradigm

The researchers will gather corn-based and cassava-based bioplastics from suppliers while considering the availability of materials and expenses. Necessary equipment for this research will be prepared and get permission from the laboratories to lend the equipment. The standard for comparing corn-based and cassava-based plastic is a petroleum-based plastic available in the market.

This research will first start with the preparation of bioplastic strips and petroleum-based plastic samples. The researchers will conduct the test for tensile strength of the corn-based and cassava-based bioplastic film and petroleum-based plastic. The results from the test for tensile strength of both bioplastics will undergo data analysis through Analysis of Variance (ANOVA). With the data analysis results, the researchers will discern a more effective main component between corn-based and cassava-based bioplastics in bioplastic film production.

3.1. Research Design

In this study, the researchers will use a quantitative comparative research design. Quantitative comparative research seeks to analyze and compare two or more groups to know their differences and similarities. In nature, quantitative research is experimental research, which deals with manipulating an independent variable to understand its effect or influence on a dependent variable. Also, these groups might have vastly different social contexts (Richardson, 2018). The researchers chose this research design to compare if there is a statistically significant difference between the corn-based bioplastic, cassava-based bioplastic, and petroleum-based or traditional plastic. This study aims to know whether corn or cassava is the comparatively more effective main component in the production of bioplastic film based on its tensile strength, with petroleum-based plastic as the standard.

Table 1. Definition of variables

Variable	Definition of Variable and Description of Relationship	Reference
Corn-based Bioplastic	Corn-based bioplastic is defined by Nasir (2021) as plastic formed by the mixture of extracted cornstarch from corn, plasticizers, and some plastic additives.	Nasir (2021)
Cassava-based Bioplastic	A cassava-based bioplastic was developed in the study of Zoungranan et al. (2020) in which cassava biosources underwent the starch extraction process and were mixed with water, glycerol, and HCl.	Zoungranan et al. (2020)
Petroleum-based Plastics	Plastic is defined by Bharathi et al. (2019) as a single-use plastic that has generated a significant amount of waste in the environment.	Bharathi et al. (2019)
Tensile Strength	In the study of Nandiyanto et al. (2020), the definition of tensile strength is the maximum force that a specimen can withstand before breaking when stretched or pulled.	Nandiyanto et al. (2020)

3.2. Subject and Study Sites

The researchers will be conducting experiments in the Mechanical Engineering Laboratory of the University of Santo Tomas. As per the sampling plan, the researchers used a G*Power to compute the sample size. Following the recommendations of Cohen (1977,1988), they used 0.4 for the effect size, 0.05 for the alpha, and 0.80 for the statistical power. It resulted in a sample size of 22 per group. This implies that the researchers will be testing 22 strips per plastic.

3.3. Data Measures

The independent variables of this study are corn-starch bioplastic film, cassava-based bioplastic film, and petroleum-based plastic. The researchers will buy corn-based and cassava-based bioplastics in this study. Then, they will use a readily available petroleum-based plastic in the market to be used as samples. The dependent variable of this study is the tensile strength of plastics and bioplastics. The unit of measurement and instrumentation for these dependent variables are listed in the table below.

Table 2. Data Measurement and Instrumentation for Dependent Variables

Properties of Plastics	Unit of Measurement	Instrument Used for Measurement
Tensile Strength	Megapascal (MPa)	Spring Scale Steel Rule Digital Vernier Caliper Tensile Stress Formula

3.4. Data Gathering Procedure

The following is the step-by-step procedure for gathering the data required to complete this study. The researchers:

1. Prepare the plastic films by cutting the sample strips into 200 mm in length and 25 mm in width using a steel rule and a cutter. Then, measure the thickness, which is 0.04 in mm, using a Digital Vernier Caliper. Ready 22 sample strips of each material.
2. Perform the test on both corn-based and cassava-based bioplastic film including the petroleum-based using the different tools and formula: test for tensile strength (Stress Formula).
3. To measure the tensile strength, the 20 x 0.04 mm formed film sample of each bioplastic will be undergoing a tensile test. The tensile properties will be tested on a Spring Scale.
4. The test is performed by knotting the strip on the spring scale. Then, it will be pulled in a parallel direction, manually. The entire process is documented using a video camera to identify the load applied to the strip up until it reaches the strip’s breaking point. It will be repeated twenty-two times for each material.
5. After conducting the test on corn-based bioplastic, cassava-based bioplastics, and petroleum-based plastic, the results for each renewable material will be recorded.
6. Analyze and interpret the results of the data.

3.5. Mode of Data Analysis

The researchers utilized the Independent Samples T-test as the primary statistical tool in analyzing and interpreting the data gathered. The significance of using this tool will determine the output of this research paper on comparing either corn or cassava, as the comparatively more effective main component in the production of bioplastic film based on its tensile properties, with the petroleum-based plastic as the standard.

In this research, for the researchers to gather data, analyze, and interpret these data, the following statistical software are utilized:

IBM SPSS Statistics
The researchers will use IBM SPSS Statistics as the primary statistical software to analyze and interpret the data. SPSS Statistics is known for solving complex statistical data analysis and performing evidence tests for assumptions like normality, homogeneity of variance, etc.
G*Power Statistical Software
The researchers will use G*Power Statistical Software to compute the sample size needed for the statistical tool to be utilized. The sample size will then be used for the researchers to gather the data they need for the analysis.
Microsoft Excel Spreadsheet Software
The researchers used Microsoft Excel Spreadsheet Software as another statistical software to analyze and interpret the data. It was used to check the results and to further analyze the test.

4. Data Collection

4.1 Tensile Property

This property refers to the force needed to break material at a constant rate of load over an area, in which tensile strength is the ability of a material to withstand being pulled by an external force called tensile force. It is also the maximum tensile stress a material can sustain before it undergoes a permanent physical deformation, or in this study, the maximum stress the samples of plastics can take before they break or snap into two. Tensile stress is the force over a cross-sectional area, and it is measured in terms of Megapascal (MPa). In getting the tensile strength of each sample, the researchers multiplied the mass it takes before the samples break by gravity (9.8 m/s) to get the force (in Newton). Then, the researchers multiplied the length by each sample's thickness (Length x Thickness) to get the cross-sectional area (in mm2). Each plastic sample strip has a length of 200 mm and a thickness of 0.04 mm. This area was computed because the tensile force exerted on each sample during the experiment was perpendicular to this resulting cross-sectional area.

Furthermore, the researchers divided the force over the area after getting the force and area to get the tensile stress (in MPa). Tables 3, 4, and 5 show the test results for corn-based, cassava-based, and petroleum-based or traditional plastics, respectively.

Table 3. Corn-based bioplastics tensile strength

Corn-based bioplastics									
Sample	**Mass (Kg)**	**Force (Newton)**	**Area (mm^2)**	**Tensile Strength (MPa)**	**Sample**	**Mass (Kg)**	**Force (Newton)**	**Area (mm^2)**	**Tensile Strength (MPa)**
1	2.5	24.5	8	3.06	12	2.1	20.58	8	2.57
2	3	29.4	8	3.68	13	2.4	23.52	8	2.94
3	2.5	24.5	8	3.06	14	2.1	20.58	8	2.57
4	2.7	26.46	8	3.31	15	2.2	21.56	8	2.7
5	2.5	24.5	8	3.06	16	2.3	22.54	8	2.82
6	2.5	24.5	8	3.06	17	2.2	21.56	8	2.7
7	2.2	21.56	8	2.7	18	2.6	25.48	8	3.19
8	2.3	22.54	8	2.82	19	2.8	27.44	8	3.43
9	2.2	21.56	8	2.7	20	2	19.6	8	2.45
10	2.7	26.46	8	3.31	21	2.6	25.48	8	3.19
11	2.5	24.5	8	3.06	22	2.1	20.58	8	2.57

Table 4. Cassava-based bioplastics tensile strength

Cassava-based bioplastics									
Sample	**Mass (Kg)**	**Force (Newton)**	**Area (mm^2)**	**Tensile Strength (MPa)**	**Sample**	**Mass (Kg)**	**Force (Newton)**	**Area (mm^2)**	**Tensile Strength (MPa)**
1	1	9.8	8	1.23	12	1	9.8	8	1.23
2	1.2	11.76	8	1.47	13	1.2	9.8	8	1.23
3	1.5	14.7	8	1.84	14	0.9	8.82	8	1.1
4	1.4	13.72	8	1.72	15	1.4	13.72	8	1.72
5	1.5	14.7	8	1.84	16	1.1	10.78	8	1.35
6	1.4	13.72	8	1.72	17	0.9	8.82	8	1.1
7	1.1	10.78	8	1.35	18	1.2	11.76	8	1.47
8	1.2	11.76	8	1.47	19	1	9.8	8	1.23
9	1.4	13.72	8	1.72	20	1.4	13.72	8	1.72
10	1	9.8	8	1.23	21	1.2	11.76	8	1.47

11	1	9.8	8	1.23	22	1.3	12.74	8	1.59

Table 5. Traditional or petroleum-based plastics tensile strength

Traditional or Petroleum-based bioplastics									
Sample	**Mass (Kg)**	**Force (Newton)**	**Area (mm^2)**	**Tensile Strength (MPa)**	**Sample**	**Mass (Kg)**	**Force (Newton)**	**Area (mm^2)**	**Tensile Strength (MPa)**
1	2.4	23.52	8	2.9	12	2.7	26.46	8	3.3
2	2.5	24.5	8	3.1	13	2.8	27.44	8	3.4
3	2.4	23.52	8	2.9	14	3	29.4	8	3.7
4	2.8	27.44	8	3.4	15	3.3	32.34	8	4
5	3.2	31.36	8	3.9	16	2.9	28.42	8	3.6
6	2.8	27.44	8	3.4	17	2.7	26.46	8	3.3
7	2.9	28.42	8	3.6	18	3.2	31.36	8	3.9
8	2.8	27.44	8	3.4	19	2.9	28.42	8	3.6
9	3	29.4	8	3.7	20	2.9	28.42	8	3.6
10	3.1	30.38	8	3.8	21	2.8	27.44	8	3.4
11	3.5	34.3	8	4.3	22	2.7	26.46	8	3.3

4.4 Cost-Benefit Analysis

In this section, the researchers performed a cost-benefit analysis of the two different types of biodegradable plastic to encourage the optimal usage or manufacture of such. They compared two alternative materials which could potentially be used by companies who use or manufacture plastics. Each alternative is differentiated and rated based on the commercially used petroleum-based plastic, as well as on their estimated impact on market growth and the benefits to the targeted groups.

4.4.1 Possible Costs of the Proposal

Cost of Raw Materials

In assessing the cost-benefit analysis of the study, it is important to present the cost of the alternatives. As shown in the table below, all of the raw materials' prices were compared and aligned according to the inflation rates listed in the Philippine Statistics Authority (2022). Crude oil, corn, and cassava are converted and differentiated in PhP. Moreover, according to Wallin et al. and Stanford.edu, the amount needed of the said materials to produce a ton of plastic is listed in the third column of the Table 6.

Table 6. Cost of Raw Materials

Material	Price per Kilogram (PhP)	Kilograms needed per ton of plastic (kg)	Total Cost (PhP)	Data Sources
Crude Oil	31.91	2217	70744.47	https://www.statista.com/statistics/262860/uk-brent-crude-oil-price-changes-since-1976/
Corn	109	470	51230	https://www.selinawamucii.com/insights/prices/philippines/sweet-corn/
Cassava	66	470	31020	https://www.selinawamucii.com/insights/prices/philippines/cassava/

In Table 7, the cost of the different materials were compared to see the difference of each. As seen in the table below, both of the bioplastics will result in cost-savings. However, using cassava as a main component in producing plastic will have more savings than corn.

Table 7. Cost-Difference

Material	Cost -Difference (PhP)	Remarks
Crude Oil - Corn	19514.47	Savings
Crude Oil - Cassava	39724.47	Savings

Cost of Additional Production Processes.
The proponents included the cost of the additional production processes seen in Table 8 that may incur if the manufacturing companies were to shift from conventional to biodegradable plastic. According to Wellenreuthe et. al (2022), using the Monte Carlo technique, pre-treatment and fermentation processes have an estimated cost of $0.009 and $0.380 respectively. To be consistent, the proponents converted it to PHP. As shown in the table below, the cost of feedstock and polymerization processes were excluded since both are already in the production stage of conventional plastic. With that, the researchers only included those who are added to the process. Thus, adding an estimated cost of PHP 10,366 per ton of plastic if the companies were to transition from manufacturing traditional to biodegradable plastic packaging.

Table 8. Cost of Additional Processes

Production Stages of Bioplastics	Price per Kilogram (PhP)	Kilograms needed per ton of plastic (kg)	Cost per ton of Plastic (PhP)	Data Sources
Feedstock				https://www.hwwi.org/fileadmin/hwwi/Publikationen/Research/2021/HWWI_Research_Paper_197.pdf
Pre-treatment	0.5103	470	239.84	
Fermentation	21.546	470	10126.62	
Polymerization				
		Total Cost	**10366.461**	

4.4.2 Positive Effects to the Targeted Group

Increase in sales from being a Sustainable Enterprise.
According to Maryville Online (2021), there is a link between business leadership on sustainability and a company's profitability. It is said that there is an 18% higher return on investment than to those companies that aren't. Moreover, ethics and integrity were cited as the top reason for pursuing business sustainability by respondents to the 2018 BSR/Globescan poll of business leaders in charge of sustainability and corporate social responsibility (CSR). As plastic manufacturers, it is important to embrace the greener ways. After all, In the absence of government action, 63% of Americans want businesses to promote social and environmental change, according to a Cone Communications survey on corporate social responsibility.

Builds the company's reputation.
There are now many advocates of sustainability who will always defend the environment. It is important to provide a reputation in which one can be proud of, especially to those who are watching the plastic industry. According to Maryville Online (2021), establishing a positive image through message and action alignment is the goal of reputation management in business. Consumers consider sustainability to be positive, thus businesses with green principles are engaged to highlight them. Going green demonstrates to others that one cares about things other than just a bottom line. When promoting a company and creating a brand identity, leaning towards sustainability is the way. In fact, encouragement and practice of resource conservation not only raises brand awareness but also has a deeper impact on staff members, their families, and others. If the business doesn't practice what it teaches, the chance to improve brand image is lost (Environmental Leader 2022).

5. Results and Discussion

5.1 Statistical Assumptions for Independent Samples T-test

Assumption 1. The dependent variables should be continuous**.**
The dependent variable in the study is the tensile stress the samples can sustain. Tensile stress is a quantitative variable as it is numerical, measured along a continuum, and can take on an unlimited number of values. Consequently, the data complied with this assumption.
Assumption 2. The independent variable should consist of two or more categorical independent groups**.**
The independent variables in the study were the types of plastics used as samples in the experiment. The experiment used three types of plastics: corn-based, cassava-based, and petroleum-based. Thus, the data complied with this assumption.

Assumption 3. The observations should have independence**.**
Different manufacturers manufacture each type of plastic. Also, the independent variables were believed to have independence, and there is no relationship between each group or the groups themselves of either plastic. Moreover, each sample was made from individual plstics, which means if plastic is already used to create a sample, it is not viable to make another sample. Therefore, it was safe to assume that each observation or result was in no way influenced by or related to the development of other observations.

Assumption 4. There should be no significant outliers in any of the independent groups.
Figure 3 shows the box plot with no significant outliers or tensile stress for each type of plastic. In addition, no single data point within the data does not follow the pattern of other data or lies beyond the box plot for each sample. Consequently, the data complied with this assumption

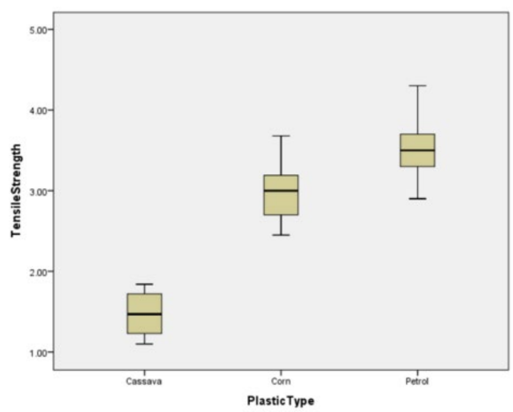

Figure 3. Tensile Strength Boxplot

Assumption 5. The dependent variables should be approximately normally distributed for each category of the independent variables.
Based on Table 9, the Shapiro-Wilk test has a statistically significant p-value of greater than 0.05 for each type of plastic (0.122, 0.414, 0.697 for cassava, corn, and petrol, respectively).

Table 9. Shapiro-Wilk test result

Shapiro-Wilk			
	Statistic	**df**	**Sig. value**
Cassava	0.930	22	0.122
Corn	0.956	22	0.414
Petrol	0.969	22	0.697

Assumption 6. There should be a homogeneity of variances.
For the test between corn-based bioplastic and traditional plastic, as shown in Table 10, Levene's test for the assumption of homogeneity, the result has an F-value of 0.001 and a significant value of greater than 0.05 (p = 0.981). This means that the assumption of homogeneity was not violated.

Table 10. Levene's test of homogeneity: corn-based and traditional

Levene's Test for Equality of Variances			
Tensile Strength		**F**	**Sig. value**
	Equal Variances Assumed	0.001	0.981
	Equal Variances Not Assumed		

For the test between cassava-based bioplastic and traditional plastic, as shown in Table 11, Levene's test for the assumption of homogeneity, the result has an F-value of 1.97, and a significant value greater than 0.05 (p = 0.167). This means that the assumption of homogeneity was not violated.

Table 11. Levene's test of homogeneity: cassava-based and traditional plastic

Levene's Test for Equality of Variances			
Tensile Strength		**F**	**Sig. value**
	Equal Variances Assumed	1.975	0.167
	Equal Variances Not Assumed		

5.2 Test Between Corn-based bioplastic and Traditional plastic
5.2.1 Group Statistics
Table 12 shows the group statistics result of the statistical test. Based on the development, corn-based plastic has a mean of 2.9523 and a standard deviation (SD) of 0.32110. Petroleum or traditional- based plastic has a mean of 3.5227 and an SD of 0.34217.

Table 12. Group statistics: corn and traditional

Plastic Type	N	Mean	Std. Dev	Std. Error Mean
Petrol	22	3.5227	0.34217	0.07295
Corn	22	2.9523	0.32110	0.06846

5.2.2 Hypothesis Testing
H0: µCorn-based ≤ µTraditional; The mean tensile strength of corn-based bioplastic is less than or equal to the mean tensile strength of traditional plastic.
H1: µCorn-based > µTraditional; The mean tensile strength of corn-based bioplastic is greater than the mean tensile strength of traditional plastic.
Alpha: 0.05
P-value: 0.0000005
Conclusion: Fail to reject H0. Based on table 7, since the p-value acquired was 0.0000005 and less than the α of 0.05, the null hypothesis can be rejected. Therefore, traditional plastics have statistically higher tensile strength than corn-based bioplastics.

Table 13. Independent samples test: corn and traditional

t	df	Sig. value (2- tailed)	Mean Difference
5.702	42	0.000001	0.57045
5.702	41.832	0.000	0.57045

5.3 Test Between Cassava-based bioplastic and Traditional plastic

5.3.1 Group Statistics

Table 14 shows the group statistics result of the statistical test. Based on the development, cassava-based plastic has a mean of 1.489 and an SD of 0.05007. Petroleum or traditional-based plastic has a mean of 3.5227 and an SD of 0.34217.

Table 14. Group statistics: cassava and traditional

Plastic Type	N	Mean	Std. Dev	Std. Error Mean
Petrol	22	3.5227	0.34217	0.07295
Cassava	22	1.4891	0.23484	0.05007

5.3.2 Hypothesis Testing

H0: μCassava-based ≤ μTraditional; The mean tensile strength of cassava-based bioplastic is less than or equal to the mean tensile strength of traditional plastic.
H1: μCassava-based > μTraditional; The mean tensile strength of cassava-based bioplastic is greater than the mean tensile strength of traditional plastic.
Alpha: 0.05
P-value: 1.0303x10-25
Conclusion: Fail to reject H0. Based on table 9, since the p-value acquired was 1.0303x10-25 and less than the α of 0.05, the null hypothesis can be rejected. Therefore, traditional plastics have statistically higher tensile strength than cassava-based bioplastics.

Table 15. Independent samples test: cassava and traditional

t	df	Sig. value (2- tailed)	Mean Difference
22.984	42	2.06E-25	2.03364

5.3 Proposed Improvements

Based on the results and conclusion, it was considered that both extracted polymers from each starch are a feasible option as replacement for plastics. The gathered data indicates that the mean tensile strength values for both components catch up with the industry benchmark mean value of the plastic industry. In addition, the proponents highly recommend that the respondents utilize biodegradable plastics rather than conventional plastics. Due to the cost-benefit analysis, the best recommendation/action plan for how the respondents can benefit from the study is to adapt and embrace the greener option. This would be beneficial for the environment of the nation or the planet and the plastic manufacturing industry.

The action plan could be implemented by investing in research and development pertaining to sustainability. It is important to fund research studies such as this, so that information on bioplastics will continuously improve. With that, innovative ideas and technological advancements will immensely grow. It is important to acknowledge papers on biodegradable plastic and take it a lot further. Adapting solutions in reducing waste will be world changing. There is still knowledge that could be tapped on which can be obliging to society. Most importantly, it may be profitable to companies without damaging the environment.

6. Conclusion and Recommendations

The possibilities for the optimum component in the manufacture of biodegradable plastic packaging were determined by statistical analysis of the dependent variable resulting from the independent variable. With the statistical analysis of the study, corn-based starch would be the ideal choice for the primary component, which would be greatly beneficial for the local farmers and corn harvesters, the plastics sector with regard to the manufacturers of plastics, and the corn industry. This would imply that the findings of the study, which compared the tensile qualities of the two components, could support manufacturers in evaluating which would be more advantageous to use as the primary component in the creation of bioplastics.

In the future, researchers interested in studying the potential of bioplastics to replace conventional plastics, as well as the target respondents mentioned, should introduce variables for testing the properties of these materials. It is recommended for future researchers to test the morphological and degradation properties of both raw materials in order to determine the overall potential of the polymers.

The experimental procedures of the mentioned variables are as follows: physicochemical test and degradation test. For the first procedure, it is a necessary method of testing because it defines the physical and chemical properties, composition, quality, purity, and stability of the polymer. On the other hand, the degradation test focuses on the rate of degradation of each polymer because it is a significant criterion for helping the global situation of the environment. The following are the equipment needed for the mentioned testing methods: Digital and Scanning Electron Microscope, Fourier Transform Infrared, and Weighing Scale. Furthermore, it is also recommended that future researchers make the samples so that the accurate quantitative measurements of raw materials used in making the plastics can be assessed and further expound on which materials affect each property by using correlation analysis. Consequently, it is also recommended to use regression analysis that does indeed significantly impact the overall quality of the plastic. Thus, knowing which plastics are statistically better than the other plastics.

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Biographies

Damirson A. Co, or Dason, graduated with a degree of Bachelor of Science in Industrial Engineering from the University of Santo Tomas in 2003. He earned his degree in Master of Science in Industrial Engineering Major in Production Systems from the University of the Philippines – Diliman in 2009. He is a Professional Industrial Engineer, and a member of the Philippine Institute of Industrial Engineers, and the Institute of Internal Auditors – Philippines. He has been a part-time faculty member of the UST Department of Industrial Engineering since 2007. He is also an adviser of an Undergraduate Research study in which several papers of his students were accepted for journal publication.

Lourd Albert T. Bañaga is currently a 4th-year undergraduate student pursuing his bachelor's degree in Industrial Engineering at the University of Santo Tomas.

Daniel Marco M. Dela Concha is currently a 4th-year undergraduate student pursuing his bachelor's degree in Industrial Engineering at the University of Santo Tomas.

Darcy C. Mariano is currently a 4th-year undergraduate student pursuing her bachelor's degree in Industrial Engineering at the University of Santo Tomas.

Charlton Lance S. Reyes is currently a 4th-year undergraduate student pursuing his bachelor's degree in Industrial Engineering at the University of Santo Tomas.