Bio-Business of Polymer Derived from Cassava Waste for the Industrial Plastic Sector

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Abstract

This work deals with the design of a bio-business for the production of polymer-based cassava waste, located in the city of Guayaquil, for which several aspects were reviewed: theoretical, regulatory, labor, administrative, technical and financial. This business opportunity is propitious to take advantage of the solid organic waste produced in the markets. The target demand was the entrepreneurs of the plastics industry in the city of Guayaquil. Descriptive, analytical, and cross-sectional method was used, and data collection was done through interviews and surveys to analyze the supply of raw materials and the need for the purchase of the sector. The B2B model was proposed to commercialize the biopolymer. The technical processes were analyzed with semi-mechanize manufacturing to cover the demand and the economic and financial evaluation of the project generated positive indicators for the financial feasibility and sustainability of the project.

Keywords

Bio-business, Polymer, Cassava Waste, B2B Model, Industrial sector.

1. Introduction

A large amount of the plastic industry worldwide is produced based on chemical components derived from petroleum known as synthetic polymers, which have different uses for various economic sectors: for the home, construction, industrial inputs, textile industry, white goods, electrical and electronic equipment, computer equipment, automotive, etc. being a very desirable material for its resistance to decomposition by microorganisms and durability. According to Cahuana [1], plastic bags take between 100 to 400 years to degrade, making the generation of waste on a global scale a serious problem.

To mitigate the negative impact caused by the excessive use of plastic, some alternatives arise such as the production of biodegradable polymer, and the most relevant quality is that it can be obtained from organic waste residues that are present in nature.

Bio-businesses emerge as a response to the global need to reduce food waste and the use of polymers that can be made from organic waste in the industry. The problem lies in the fact that the solid organic waste generated in homes, restaurants, food markets, etc., when not managed

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properly, causes a series of problems such as unpleasant smells that affect the sense of smell, an increase in flies, rodents and other insects that get close to the waste, a bad appearance to the eye, and not least the increase in ambient temperature as a result of the decomposition of the waste, the inconvenience caused in the open air rubbish dumps in the markets in the various cities of the planet.

According to the Sustainable Development Goals Roadmap [2], Ecuador is no exception because "375,000 tons of solid urban waste are generated each year, but only 4% of this waste is recycled", i.e. 96% of the waste is buried, according to El Universo, ecología [3].

To counteract this problem, multiple actions have been established at a global level, such as the circular economy, which is linked to the production of biodegradable products. Facing this reality is what leads to the search for solutions to replace synthetic polymers with more environmentally friendly polymers since the vast majority of industries are based on petroleum-based chemicals such as synthetic polymers [4].

The idea of the bio-business is focused on the design of a company dedicated to the production of polymer that uses as raw material, organic material called starch, which is obtained from cassava waste. The biopolymer obtained from the process is intended to be marketed as a substitute raw material for industries that use synthetic polymer based on petroleum, this bio-business proposal represents an environmentally friendly solution [5].

2. Development

Since ancient times, the Egyptians 2000 BC used natural resins to preserve the deceased, thus it is stated that [1] "rubber, an isoprene polymer obtained from the latex of the Hevea brasiliensis tree, was used by the American Indians, such as the Aztecs or the Mayans, to make balls or shoes", in the 20th century Charles Goodyear by accident discovered that when rubber was exposed to heat it became resistant and elastic, which is known as thermosetting elastomer, in 1869 John Wesley Hyatt created cellulose, in 1909 the chemist Leo Baekelan discovered the first synthetic polymer known as Bakelite, named in his honor, which consists of a phenol resin plus formaldehyde in the presence of a catalyst, in 1912 cellophane was created.

After the Second World War and with industrial development, polyvinyl chloride (PVC, 1936), polyurethane (PU, 1937), and unsaturated polyester (PET, 1942), the raw materials used to manufacture plastic bottles, emerged. With the oil crisis of the 1970s, new research was carried out into the development of bioplastics, also known as biopolymers [1]. The most common polymers on the planet are: "polyethylene (PE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), and polyamide (PA), due to their mechanical properties and low production costs" (p.5). Polyhydroxybutyrate (PHB) is a natural polymer synthesized by a variety of microorganisms. This polymer is biocompatible, biodegradable, and widely studied for medical applications" [2].

Biopolymers come from resources that are extracted from nature, such as cellulosic polymer, obtained from wood, polylactic acid (PLA) obtained from corn, PHA which is produced by enzyme complexes that are present in bacteria, and Thermoplastic Search (TPS) [3]. These biopolymers have the quality of being biodegradable and do not release toxic elements in their degradation process. Biopolymers are emerging as an alternative to conventional petroleum-based polymers to reduce environmental pollution.

A "polymer is a large molecule composed of many smaller repeating units called monomers bonded together" [3]. Among the best-known polymers are elastomers, known as rubber, which is a natural or artificial material that has great elasticity, plastics are synthetic materials that are moldable and whose chemical composition includes cellulose, proteins, and resins. The main sources of biopolymers are those of animal origin (collagen or gelatin), marine origin (chitin or chitosan), agricultural origin (lipids and fats and hydrocolloids: proteins and polysaccharides), and microbial origins such as polylactic acid (PLA) and polyhydroxyalkanoates (PHA) [4].

Biopolymers have various applications, they can be used as raw material to manufacture containers for packaging products with short shelf life such as fresh fruits and vegetables, in products with long shelf life such as crisps and pasta, according to the raw material used they can be prepared for the following applications [5]:

a) Cellulose: packaging, household disposal, and electronic devices.
b) Starch: food packaging, agricultural foils, textiles, and construction.
c) PLA: films, food packaging
d) For PHA: food packaging.
e) PHB: medical applications.

Several studies have demonstrated the production of flexible biodegradable films based on the starch of cassava Manihot esculenta of the Euphorbiaceae family, Crantz (1766), native to central South America for more than 5000 years, as demonstrated in their research by the authors Almario [6] and Riera-Palma [7] "In Ecuador, yucca is grown in all geographical regions, from sea level to 1,620 m above sea level" [8]. It is grown by small and medium-sized farmers alongside other crops in the Amazon region, in the coastal zone as a monoculture, and in the low valleys of the Ecuadorian highlands as shown in Figure 1.

"The most cultivated varieties, especially on the Ecuadorian coast, are the following: INIAP Portoviejo-650, INIAP Portoviejo-951 and Three Months for the tropics "Escancela", "Patucha",

Figure 1: Types of sweet cassava produced in Ecuador

"Valencia", "Morada", INIAP-Portoviejo 650, INIAP Portoviejo 651 and the P-652 "La Rendidora" [8, 9].

The plastics industry in Ecuador is a dynamic sector that contributes 1.2% of the national GDP, generates around 20 thousand direct jobs and 120 thousand indirect jobs, producing about 500 thousand tons annually, figures provided by the Ecuadorian Association of Plastics, this association is composed of about 600 companies nationwide, of which 120 belong to the association, of these, most are located in Guayaquil, For the study, 27 plastic industries were considered, which seek to reduce the amount of material derived from synthetic polymer, so they are "working to incorporate recycled materials in their production processes, especially in those related to the transport of goods, covers and primary packaging for food preservation" [4].

According to the Ministerio de Producción, Comercio Exterior [10]. The demand for plastic in Ecuador is 20 kilos per capita per year, equivalent to 531,461 tons per year. The average of this figure corresponds to the consumption of soft plastic packaging-use packaging, such as sleeves or expanded polystyrene, which are difficult to recycle. This is 11.43% of the total waste generated in the country.

One of the actions by strategic line inserted in the White Paper on the Circular Economy of Ecuador, in paragraph three, states "Invest in research and development of new alternative materials and materials produced with a fraction of recycled plastic, reducing the use of additives that prevent its subsequent recyclability" [10]. Based on this strategic action in the line of plastic, the bio-business proposal is based, to offer alternatives that contribute to reducing pollution from plastic waste.

In terms of trade, the White Paper for the Circular Economy of Ecuador indicates that "new business models (servitization) must be implemented" [10]. For this purpose, the commercialization model for the study is focused on B2B, a business-to-business service, considering the benefits of the model as a distribution strategy.

The B2B e-commerce strategy consists of commercial operations carried out directly from company to company (business to business) through the use of technology and the internet, to achieve efficiency, boost sales, improve customer-supplier relations and enter various markets [11], E-commerce allows companies to innovate and be at the forefront, companies that do not align themselves with this way of doing business are relegated or tend to be invisible in the market, however, it is important to improve information services, networks, control mechanisms, payment systems, among others.

Currently, there is limited progress on new business models, despite being an important pillar for the growth and sustainability of companies, as it mentions that [12] "The ability to move quickly and successfully towards new business models is an important source of sustainable competitive advantage and a key lever for improving the sustainability performance of organizations".

The bio-business proposal is to consider the cassava waste generated in the municipal markets, which is a good opportunity to take advantage of this source of raw material that, in most cases, ends up in open-air rubbish dumps, damaging the environment due to the toxic waste that is spread into nature, as there is no good management of organic solid waste.

3. Materials and methods

For the development of this research, the mixed quantitative-qualitative approach was used as a scientific method, because it fits the object of study and a pragmatic stance is taken for a specific analysis as it refers to the specific situation in which the research was carried out [13]. The scope is descriptive because the situations related to the object of study were reviewed to place them in the context, as it indicates "detailing how they are and how they manifest themselves", as well as particularizing the properties of the plastic manufacturing industries and the characteristics they possess to classify them and devise a sample to obtain the data for a cross-sectional study.

According to Hernández-Sampieri et al. [14], the mixed method represents a set of systematic, empirical, and critical research processes and involves the collection and analysis of quantitative data, as well as their integration and joint discussion, to make inferences from all the information collected (meta-inferences) and to achieve a better understanding of the phenomenon under study [14, 15].

The research design is non-experimental because the data were collected and analyzed in their natural state, without manipulating the independent variable because they are phenomena that have already occurred and the researcher only collects, processes, and displays the results.

According to the Superintendence of Companies, Securities and Insurance of Ecuador [16], there are around 80 manufacturing companies in the plastics industry that use synthetic and organic polymers, 41 industries in the coastal region, and 39 industries in the highlands. For the study, the 37 industries located in the province of Guayas were considered as the population, corresponding to 46% of the total plastics industries that use polymers in Ecuador.

The 27 active plastic industries located in the city of Guayaquil, which correspond to the total number of industries, were taken as an intentional non-probabilistic non-experimental sample, so the calculation of the sample for a finite population with the statistical formula was not carried out, because it was decided to consider all industries that wanted to participate by answering the structured questionnaire with thirteen closed questions under the Likert scale, online, for the survey that was previously prepared and validated, then it was taken to a format on the google forms platform.

The instrument for the collection of quantitative data was the survey, application of the questionnaire was selected for the directors or purchasing managers of the plastic industries that use polymers, through the use of the technological means of e-mail. On the other hand, interviews were conducted under the person-to-person strategy, using an interview guide with 10 open questions, which were validated by experts and applied to three purchasing managers of plastic industries that use biodegradable polymers, for the processing of data from the interviews was performed in the Excel tool, to organize, tabulate and schematize the results.

Once the survey data had been collected, they were processed by constructing frequency tables with the Excel tool, using descriptive statistics for each of the variables, which resulted in frequency tables and figures, arranged in the different categories. The results were then analyzed to determine the interests, characteristics, and purchasing trends of raw materials in the plastic manufacturing industries in Guayaquil. With the results obtained from both the survey and the interview, key data were obtained to build the structure of the bio-business under the B2B model proposed in the study.

4. Discussion

After reviewing the literature concerning the bio-business of polymers with cassava waste for the plastics industry, which uses biodegradable polymers that arise from nature in their production process, it was possible to outline a structure of a bio-business plan using the B2B (business-to-business) business to the business model, as referred to by Pedraza [17], which should contain the following stages as a basis: (a) business description, (b) product portfolio, (c) market, (d) competition, (e) operating procedures, (f) organization, (g) economic and financial aspects, and (h) supporting documents, as shown in Figure 2.

Each stage describes the activities that were carried out to prepare the bio-business, after the theoretical and conceptual review of each of the components allowed to know, organize and incorporate in each stage of the bio-business plan, as well as identifying the technological elements, machinery, and equipment that are necessary for the implementation of a business, in addition to carrying out the organizational, administrative, legal and documentary analysis necessary to establish the business plan.

The results of the interviews and surveys can be summarized as follows:

The segment of the industry interested in acquiring organic polymers was the food sector at 44%, the industrial sector at 37%, and the agricultural sector at 18%, this information is very valuable because it gives the guideline of the sector with which the negotiations of organic polymers based on cassava waste will be established. Another element is that the industries involved in the production of plastic know a lot about organic biopolymers and seek to replace the synthetic polymer with another raw material by the regulations in favor of the environment

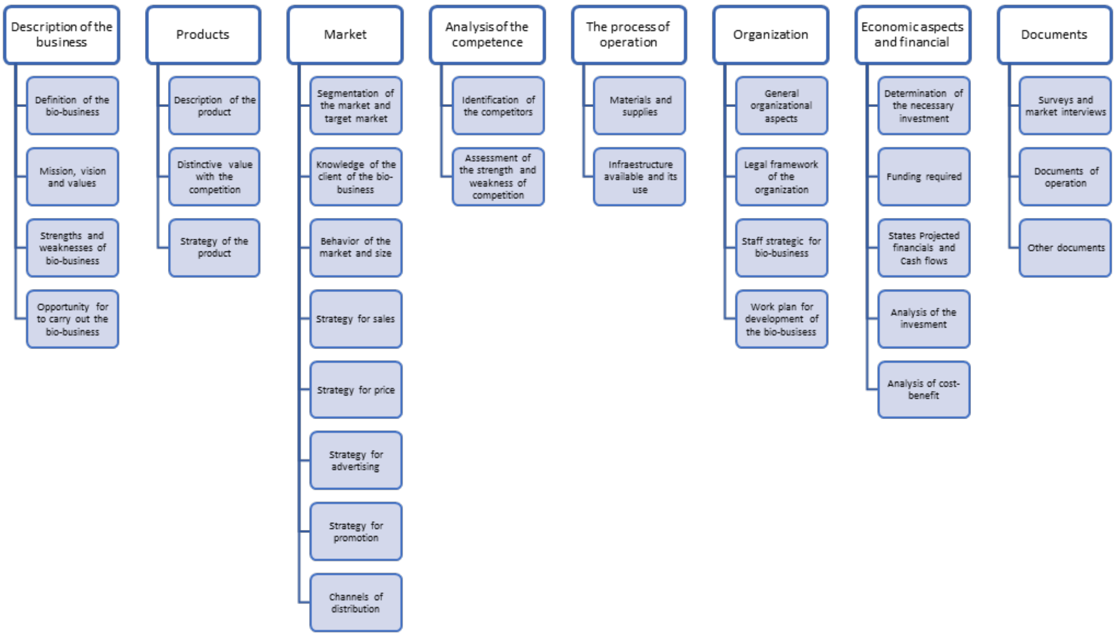

Figure 2: Structure of a bio-business plan for a cassava-based polymer for the plastics industry. Adapted from Modelo de Plan de Negocio para la Micro y Pequeña Empresa [17]

that are circumscribed in the White Paper on Circular Economy of Ecuador, constituting a good business opportunity to promote our product. It was also found that 55% of the industries have incorporated between 5% and 40% of the organic polymer as raw material in their production processes, justified by the limited supply of organic polymers in the market, which shows a great opportunity for investors wishing to venture into this type of bio-business.

The characteristics of the suppliers of organic biopolymers sought by the plastics industries are competitive prices at 48%, punctuality at 4%, product quality at 19%, responsiveness at 15%, and supply capacity at 14%, so it can be inferred that we are facing an elastic demand because they are looking for price rather than quality. The quantity demanded of organic biopolymers is between 1 to 40 metric tons per month, this data gives an idea of how much should be produced in the month according to the demand, who would be willing to pay between US $1,200 to US $1,600 US dollars per ton of organic polymer, so this data is key to determine the selling price that should be in this range.

The frequency of purchase 37% of the industries acquire the raw material weekly and fortnightly, this purchase behavior is because for the biopolymer to maintain its quality it must be supplied in the shortest possible time, i.e. it should not be stored for a longer period [16]. The biopolymer manufacturing process was worked out on a semi-mechanized scale, for which a flow chart was drawn up with the yarn model in which each of the process stages was specified.

To establish the economic and financial aspects of the bio-business, a five-year horizon was estimated for the project, macroeconomic variables such as GDP, inflation rate, system risks, microeconomic variables such as labor rules and regulations, interest rates, credit, and business amounts and terms, taxes, among others, were considered to incorporate them into the calculation of product costs and sales, and the amounts of the initial investment and the corresponding financing were established as shown in Table 1.

To calculate the electricity costs for the production of one ton of organic polymer, two and a half tons of cassava waste are needed, which, when processed in the respective machines, should be considered as US$3,196 per kilowatt-hour as shown in Table 2.

Table 1
An initial investment in the bio-business.

Items	US$	Period
Wages	8.736,46	(2 months)
Advertising Expenditure	600	(4 months)
Administrative Expenses	12.780,00	
Constitution Expenses	400	
Property, Plant, and Equipment	49.444,65	
Cost of sales	33.835,91	(2 months)
Total Investment	105.797,02	
Working Capital	31.199,17	
Working Capital	74.597,85	
Total Funding	105.797,02	
Own Investment	32.000,00	
Financed Investment	73.797,02	

Table 2
Costs per kilowatt-hour per ton of organic polymer

Machinery	Feature	A ton of processed cassava	Cost per Kilowatt hour	Cost per Daily production
Cassava cleaning machine (sieving machine)	Capacity(T/H) 2-4/Power (kW)3	2,5	0,799	1,598
Cassava crushing machine	Capacity(KG/H) 3000/Power (kW) 5.5	2,5	0,799	1,598
Energy cost used in the production of 1 ton of organic polymers				3,196

The raw material for processing the cassava waste does not have a cost as such, but the cost of mobilizing the raw material from the recycling facility to the processing plant, i.e. the cost of freight, is included. To produce 380 tons of biopolymer in a year, the average cost is approximately US$846.00 per metric ton, which represents a total cost of US$321,480.00, while the unit price for the sale of each ton of biopolymer is US$1,184.00, which represents US$450,018 for a sale of 380 tons in a year.

Table 3 shows the calculations of break-even quantities and prices for the production and marketing of biopolymer derived from cassava waste, in metric tons projected for five years, this information is key to knowing how much the minimum amount that must be produced and sold in order not to lose.

On the other hand, Table 4 shows the calculation of the projected Cash Flow for five years. With this information, the calculations of the financial indicators that will provide the guideline to know the profitability, viability, and sustainability of the bio-business will be carried out as shown in Table 5.

With the projected cash flow data we proceeded to calculate the Weighted Average Cost of Capital [18] (WACC), taking into account the values of the financing of the investment, both the internal financing provided by investors for equity and working capital, In this case, a

Table 3
The break-Even point for the production and marketing of cassava-base biopolymer

Description	Year 1	Year 2	Year 3	Year 4	Year 5
Fixed Cost	$92.036	$81.457	$81.457	$83.576	$89.004
Sales price excluding VAT per ton	$1.184	$1.234	$1.234	$1.451	$1.611
Cost of production per ton	$845	$881	$881	$1.036	$1.151
Breakeven point per unit	272	231	231	202	193
Breakeven point in dollars	$322.126	$285.099	$285.099	$292.517	$311.516

Table 4
Projected annual cash flow

Description	Year 1	Year 2	Year 3	Year 4	Year 5
Net cash flow	26.390	31.150	40.249	88.764	119.953
Cumulative flow	-79.407	-48.258	-8.008	80.755	200.708
Initial Investment	-105.797				

Table 5
NPV, IRR, MIRR, PAYBACK indicators

Periods	Value	Balance Recovery Period
0	(105.797,02)	
1	26.389,70	(79.407,31)
2	31.149,75	(48.257,56)
3	40.249,19	(8.008,38)
4	88.763,55	80.755,18
5	119.952,79	200.707,97
n	5 years	
i	10,21%	
WATCH	12,90%	
VAN	105.448,27	
IRR	35,27%	
TIRM	27,69%	
PAYBACK	28 Months	

three-year bank loan was considered with an annual interest rate of 10.21% per year in one of the entities of the national financial system, with this information an estimate of the CPPC of 12.90%, a value at which the NPV of the project is calculated, resulting in a positive value of US$105,448.27, which shows that the project is viable. The IRR is also calculated for the five-year flows, resulting in an IRR of 35.27%, which means that the project can return the initial investment, plus the financing costs and there is also a favorable return on investment, On the other hand, the IRRM was calculated in which the project is required to reinvest the flows at a WACC rate of 10.21%, it is convenient or not to reinvest, as a result, it was obtained that the project gives an IRRM of 27.69%, which can be concluded that the project is sustainable over time since it returns the investment in 28 months by calculating the payback.

The business idea proposed aims to design a bio-business based on the cassava waste produced in municipal markets, which, when not reused, ends up in open-air dumps, causing pollution and damage to the environment, so that at the end of the study and after an exhaustive review of literature on the study variables, applying a methodology with a mixed approach, descriptive in nature, Therefore, at the end of the study and after an exhaustive literature review of the study variables, applying a descriptive and explanatory mixed approach methodology, it was determined that the price elasticity of demand is elastic, that the plastics industry is willing to purchase the biopolymer produced with cassava waste, so this bio-business proposal could be of interest to investors who are committed to environmental protection and bet on a new profitable, viable and sustainable business opportunity, as shown by the economic valuation indicators of the project, which were favorable and which return the investment in the medium term. On the other hand, it generates sources of employment and contributes to the care of nature, avoiding the contamination of the soil, air, water, and living beings that live around the open-air dumps. New lines of research are opened to generate new businesses from solid and liquid organic waste.

5. Conclusions

The proposed business idea aims to design a bio-business based on the cassava waste produced in municipal markets, which when not reused ends up in open dumps, causing pollution and damage to the environment, so that at the end of the study and after a thorough review of literature on the study variables, applying a descriptive, explanatory methodology, it was determined that the price elasticity of demand is elastic, The plastic industry is willing to purchase the biopolymer produced from cassava waste, so this bio-business proposal could be of interest to investors who are committed to caring for the environment and are betting on a new profitable, viable and sustainable business opportunity, as shown by the economic valuation indicators of the project, which were favorable and which return the investment in the medium term. On the other hand, it generates sources of employment and contributes to the care of nature, avoiding the contamination of the soil, air, water, and living beings that live around the open-air dumps. New lines of research are opened to generate new businesses from solid and liquid organic waste.

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