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Development of biodegradable casings from modified cassava starch

Elaboracion de fundas biodegradables a partir del almidón de yuca modificado

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Abstract

The present work was carried out with the objective of obtaining biodegradable casings from modified cassava starch, using celocell, glycerin, ethanol, Xanthan gum as plasticizers and mineral oil as lubricants. Three mixtures were made; experience 1 has a composition of 20 g of modified cassava starch with a percentage of 15% of the mixture; experience 2 has a composition of 30 g of modified cassava starch with a percentage of 20% of the mixture and experience 3 has a composition of 40 g of modified cassava starch with a percentage of 25% of the mixture, which were analyzed in their physicochemical properties at laboratory level, determining the following results: experience 1 has an elasticity of 39.2% with a biodegradability of 66.57%; experience 2 with a percentage of 6.89% of elasticity and a biodegradability of 50.53%; experience 3 with a percentage of 8.04% of elasticity and a biodegradability of 43.87%. In conclusion, experience 1 was determined to have better resistance to tearing, biodegradability, thickness and performance, the biodegradable casings can be used in food industries up to small accessories, such as related objects in the home.

Key words: Composting, Glycosides, birefringence, Colloidal water soluble, Insipid.

Resumen

El presente trabajo fue realizado con el objetivo de obtener fundas biodegradables a partir del almidón de yuca modificado, utilizando como plastificantes celocell, glicerina, etanol, goma Xanthan y como lubricantes aceite mineral. Se efectuaron 3 mezclas; la experiencia 1 tiene una composición de 20 g de almidón de yuca modificado con un porcentaje del 15% de la mezcla; la experiencia 2 tiene una composición de 30 g de almidón de yuca modificado con un porcentaje del 20% de la mezcla y la experiencia 3 tiene una composición de 40 g de almidón de yuca modificado con un porcentaje del 25% de la mezcla, las cuales fueron analizadas en sus propiedades fisicoquímicas a nivel de laboratorio,

determinando los siguientes resultados: la experiencia 1 tiene una elasticidad del 39,2% con una biodegradabilidad del 66,57%; la experiencia 2 con un porcentaje del 6,89% de elasticidad y con una biodegradabilidad del 50,53%; la experiencia 3 con un porcentaje del 8,04% de elasticidad y con una biodegradabilidad del 43,87%. En conclusión, de determino la experiencia 1 resultado con mejor resistencia al desgarro, biodegradabilidad, espesor y rendimiento, las fundas biodegradables, puede ser utilizado en industrias alimenticias hasta accesorios pequeños, como objetos relacionados en el hogar.

Palabras clave: Compostaje, Glucosídicos, birrefringencia, Coloidal hidrosoluble, Insípida.

Introduction

Currently there is a lot of interest in the development of biodegradable plastics that are developed by renewable sources, with similar characteristics to common plastic and capable of replacing it without any problems. Starch is one of the raw materials that has caused curiosity for having a good development in its characteristics due to its ease of gelling and molding biofilms, and for having a high availability in the country taking into consideration its economic viability.

The concern that today is manifested with the pollution of the environment has generated a considerable increase in studies, research and development of new technologies, viable and sustainable, following the respective standards with biodegradable plastics and strict restrictions. As a result, research, technology and development have been employed in industrial activities, so that there is a great contribution to the environment and to begin to take care of our planet.

Cassava (*Manihot esculenta* Crantz) is considered a species of starchy roots that is cultivated in the tropics and subtropics of the country, there are varieties of cassava types in the country with the only difference in their physicochemical properties in relation to amylose, amylopectin and its molecular structure. The modification of starches is carried out in order to improve some of their characteristics such as resistance, degradation, solubility, decrease retrogradation, among others.

According to the problem statement, plastics are very resistant to various uses or environmental aggressions, they are lightweight compared to other materials that determine the same use and are low cost, due to their high production on an industrial scale. The problem that plastics have generated today is their increasing production, in which lies a low biodegradability causing a great threat in every corner of the planet. Plastics seriously damage the aquatic ecosystem and the other species that surround it. (Reitz et al., 2003, p. 234)

In Ecuador it is estimated that 1.5 million plastic bags are consumed each year and worldwide 500,000 million plastic bags end up in water currents and cause the death of 100,000 marine species.

There is a national scope where the inadequate use of solid waste is currently a problem, among them the basic urban sanitation services in the country, in terms of coverage, efficiency and quality, have not been able to serve the majority of the population in a correct or satisfactory manner. The formulation of the problem can be posed as a simple question but full of importance in the development of the present investigation: Can biodegradable laminates be elaborated using cassava starch? The purpose of this project is to contribute to the ecology with the reduction of plastics, currently plastic has generated pollution and danger to the species that inhabit the sea and land. Among its most common materials are polyethylene (PET), polyvinyl chloride (PVC) and high and low density polyethylene, these have a long decomposition time between 100 to 1000 years, which is why it has generated an increase in pollution in this way producing an extreme accumulation of waste, to be more specific, a PVC material could go through 10 generations to achieve its decomposition. Braga et al., (2018) The purpose of this topic is to suggest an alternative to improve the problem of waste produced by plastics such as plastic bags and many more everyday plastic products, considering the biodegradability time of the product in which we are going to perform.

This project aims to improve or combat existing pollution due to plastic waste caused by humans, increasingly producing the extinction of marine and terrestrial species among others and the wearing out of the atmosphere with toxic gases thrown by plastics, This is why we are looking for an alternative that contributes to improvements in the economic and environmental field and this is how we will innovate an ecological product that will replace plastics by biodegradable covers, common plastics is known by few that is one of the main pollutants today.

As a general objective of the present research we set out: To obtain a plastic biofilm from modified cassava starch, based on glycerin, celocell and other reagents with the respective percentages of the mixtures, establishing temperature ranges determined in the procedure.

In order to be able to fulfill the proposed objective and the development of the research that will lead us to satisfactory results, the following specific objectives are proposed:

- To obtain biodegradable plastic, varying the proportions of starch and plasticizers (15%; 85% - 20%; 80% - 25%; 75%), respectively.
- Determine the time of starch gelatinization for biofilm formation with respect to the temperature variation established in the procedure ranging from seventy to eighty degrees Celsius.
- To analyze qualitatively by observation, the characteristics of color and uniform compactness of the different plastic biofilms formed by varying the process conditions.
- Characterize the physical properties of plastic biofilms in terms of elasticity, physical resistance, biodegradability.
- To obtain biodegradable plastic casings by hot sealing or using thermal equipment.

The first plastic had its beginnings in the United States in 1860, when a prize was offered to whoever could replace or substitute ivory to manufacture billiard bags. One of the winners was John Hyatt, who was the inventor of celluloid, which in turn gave rise to the film industry.

By 1970, Leo Baekeland was the inventor of Bakelite, which was considered the first thermosetting plastic; it was an insulating plastic, resistant to moderate heat, acids and water. He was quickly recognized with this invention, and by 1930 scientists were creating the modern polymers that currently dominate the industry. The plastic has a series of substances of similar molecular structure and physical-chemical characteristics, these characteristics are determined with the elasticity and flexibility during a temperature range and this is how it allows its molding and adaptation to various forms. Plasticity is its eminent name, in which it is considered effective in acquiring various forms, when subjected to heat directly, these give off gases rich in dioxin, furans, carcinogenic hydrocarbons and compounds capable of suffocating living beings. (Farias da Silva & Soares, 2021, p. 32)

Bioplastics refers to plastics made from plants or other materials in which they are not derived from petroleum, as well as plastics derived from starch, cellulose and certain bacteria. According to "European Bioplastics" these bioplastics are designated as "polymers based on renewable resources".

Bioplastic is characterized by a naturally occurring plastic produced by a living organism and biodegradable in nature, synthesized from renewable sources, so it hardly causes any further pollution.

Déniz Mayor & Verona Martel, (2015) Bioplastics made from biodegradable material such as corn starch, potato and cassava, are no problem for humans as it has a high energy content, these bioplastic products marketed have 30 to 100% renewable materials. The use of renewable biomass helps to combat climate change, unlike petroleum-derived plastic, which generates massive greenhouse gases.

Bioplastics have disposable products that degrade in a period of one year, where the final residue of the process is carbon dioxide, water and biomass generation, contrary to disposable products made of common plastics that take 1,200 years to degrade, causing a cumulative contamination of the ecosystem.

Cassava (*Manihot esculenta* Grantz) is a plant originated in South America is considered a root rich in complex carbohydrates, mainly used for both human and animal consumption, ideal in a balanced diet, is a healthy food in terms of its high content of vitamins C and B6 and minerals such as potassium and magnesium, it is also used to obtain starch and other industrial uses.

In Ecuador, it is grown in the tropics and is located in all provinces of the country, including the Galapagos. It is cultivated by small producers of low economic income, since it is produced in poor soils or marginal lands. It requires little fertilizer, pesticides and water. It is a

subsistence crop because of its high calorie production per unit area, the amount of labor required for cultivation, the stability of its yields and the long potential harvest period (8 to 24 months after planting). As a cheap source of calories, it is well received by rural and urban consumers and is considered a priority product for food security.

The use of this plant is characterized by the consumption of its root, in which a large amount of components are accumulated, among them starch is found naturally, and this happens when the plant stores energy by assimilation of atmospheric carbon through the chlorophyll present in the leaves. (Ortega-García et al., 2021 p. 32)

The chemical composition of cassava is basically amylose and amylopectin, 2 carbohydrates of very different structure, these are the functional properties of starch.

The chemical composition of cassava root varies greatly in its composition and consists of 64-72% starch and 4% sugars. It is understood that it has 71% sucrose, 13% glucose, 9% fructose and 3% maltose, contains (1-2%) of proteins, lipids 0.5% and does not contain vitamins.

Gomez-Gamez et al., (2020) Cassava lacks proteins and fats, but it is very rich in complex carbohydrates and a very good source of vitamin B and C. A nutritional table of cassava is described below.

Materials and methods

In accordance with the research method, the present work is of a descriptive-experimental type used for the elaboration process of biodegradable casings from modified cassava starch, which will be used to establish the different percentage compositions with the purpose of determining the correct and indicated mixture for the elaboration of the casings.

For the elaboration of biodegradable casings from modified cassava starch, the following steps will be followed, which consist of selecting the raw material, weighing, drying, sieving, mixing with plasticizers and other reagents and finally drying to obtain the biofilm, then laboratory tests will be carried out for physicochemical and mechanical tests.

The raw material (cassava starch) came from the province of Manabí, the reagents and materials were obtained from commercial houses in the city of Guayaquil and the physical and chemical analyses were carried out in the laboratory in the city of Guayaquil.

Table 1. Materials and Equipment

MATERIALS AND EQUIPMENT	
SUBSTANCES	EQUIPMENT
Cassava starch	Beaker
Distilled water	Stirrer
Acetic acid 5%.	Oven
Boric acid	Heating plate with stirring
Sodium chloride	Stove
Celocell	Spruce
Glycerin	Thermometer
Ethanol	pH strips
Sodium hydroxide 0.1 N	Weighs
Mineral oil	
Xanthan gum	

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For the production of biodegradable casings from modified cassava starch, preliminary tests were carried out to determine the best percentage of starch to use in the production of biodegradable casings. For the preliminary tests, cassava starch was used with the following concentrations (15%; 20%; 25% starch). The 3 mixtures plus plasticizers with different percentages were tested.

Table 2. Percentages of Mixtures

Water: 80ml		
Samples	% Cassava starch	Plasticizers
1		

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Regarding the techniques and instruments used for the development of the research, the experimental procedure is established in steps and sequences at laboratory level and as instruments the number of experimental tests with their respective results, as detailed:

Cassava starch washing

The native cassava starch is washed with distilled water and mixed with a glass stirrer until a homogeneous solution is achieved, then the aqueous mixture is passed through the centrifuge equipment to accelerate its sedimentation with operating conditions of 2600 rpm for 15

minutes, this process must be repeated three times to ensure that the starch is free of contaminants.

Then it is filtered with a vacuum pump to ensure the separation of the 2 phases and thus extract as much water as possible, finally, it enters a tray oven at a temperature of 35 C for 12 hours and the starch must be expanded uniformly, and finally the particle size is reduced by passing the starch through some sieves, i.e. meshes, thus bringing it to a uniform particle size of 0.297mm.

Modification of cassava starch

The chemical modification of starch allows it to change its structure modifying its properties, in this process it is required to keep controlled variables such as: temperature, pH, amount of reagent, reaction time, this method is related to the substitution of the hydrogens present in the hydroxyl groups of the amylose molecule, with these modifications achieves a product with better characteristics increasing its resistance, permeability, compatibility with some hydrophobic products, this method consists of performing it prior to start the process of obtaining the biofilm, the modification is made through to the starch molecule through acylation. (Neto et al., 2021) acetylation has been developed from the esterification of starch with acetic acid, the type of acetylation is according to the one required i.e. (GS) the low, it is used in the food industry for its properties of durability, consistency, texture and (GH) is the high degree of substitution, and is used for the replacement of thermoplastics.

For the modification process, distilled water is added to hydrate the starch, then 5% acetic acid (modifying agent) is added drop by drop to react with the starch, the pH of the mixture should be maintained at 8-8.5 to achieve the indicated pH, the catalyst (NaOH) is added and then the starch should be washed with water to remove excess modifying agent, centrifuged to remove excess moisture for 10 minutes and placed in an oven at 40°C for 8 hours. °C for 8 hours.

Modified cassava starch drying

The acetylation process is taken to a centrifuge to remove excess moisture for 15 minutes, at a temperature of 15°C and at a speed of 2600 rpm, then it is placed in a tray oven at 35°C for a period of 8 hours, extending the syrup to a temperature of 35°C. °C for a time of 8 hours spreading the starch in the tray so that the drying is uniformly (Wichmann et al., 2022)

The gelatinization temperature of the cassava starch is 62-73 °C and with the modified starch it was 70-90°C i.e. the water retention capacity and the deformation of the material increases.

Biofilm processing

For the development of the biofilm, four premixes are prepared in order to speed up the method of obtaining the material; the importance of these premixes is to avoid clusters during the homogenization process.

First premix

The first premix is the modified starch together with distilled water, which is agitated in a heating plate at 25°C at a speed of 150 rpm for 30 min.

Second premix

The second premix is the celocell together with the distilled water with agitation of 250 rpm, to 40°C for 5 minutes under these conditions the whole process is maintained.

Third premix

This third premix consists of NaCl and Boric Acid, these are proceeded to weigh before and to have it reserved until the moment to add it, its agitation is during 5 minutes at a temperature of 38°C, and then it is added to the mixture.°C.

Fourth premix

Then the glycerin is added to the distilled water for 5 minutes at a temperature of 40°C, then the ethanol is added to dissolve the granules.°C After this, ethanol is added to dissolve the granules, after 2 minutes a lubricant is added, which in this case is a mineral oil or it can be stearic acid.

Fifth premix

At the moment that the polymerization reaction takes place, the fifth premix is made, which is ethanol together with distilled water.

Sixth premix

The Xanthan gum and distilled water are added, which must be agitated for 5 minutes at a temperature of 40°C, then 2 minutes after adding the fourth mixture the lubricating oil is added.°C After 2 minutes of adding the fourth mixture, the lubricating oil is added, after having all the premixes in optimal conditions to develop a united of all the mixtures.

Lubricant is added to the mixture as it serves as a lubricant for the biofilm, the drying of the material should be in an oven at a maximum temperature of 110°C for 6 to 18 hours.°C A release agent is used to avoid deformation of the biofilm at the time of drying. ASTM standards indicate that the thickness of the biofilm should be less than 1-0 mm (0.04 inches) in order to be able to perform mechanical tests.

Formulas were used as instruments for the evaluation of physical-mechanical properties such as: sensory analysis, as well as the most important organoleptic aspects such as: texture, flexibility, resistance.

Others such as thickness determination, moisture content determination, bioplastic yield, pH, product temperature, tensile strength test, biodegradability determination, biofilm weight loss, solubility.

Result

Table 3. *Sensory analysis for the biofilm*

Organoleptic aspects					
	Appearance	Texture	Flexibility	Resistance	Points
Sample 1	Translucent	Lisa	Flexible	Fort	5
Sample 2	Translucent	Lisa	Flexible	Fort	5
Sample 3	Translucent	Lisa	Unflexible	Fort	

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Table 4: *Thickness of the biofilm*

Bioplastic	Replicas	Thickness (mm)
Sample 1	1	0,365
		0,290
		0,330
		0,415
	Average	
Sample 2	1	0,815
		0,915
		0,995
		1,045
Average		0,94

Sample 3	1	1,760
		1,832
		1,780
		1,795
Average		1,792

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Table 5: *Moisture content*

Bioplastic	Weights	Value (g)	Average Moisture % Average Humidity % Average Humidity % Average Humidity
Sample 1	1	16,852	11,11
		16,951	
		16,940	
Sample 2	1	16,852	13,86
		16,953	
		16,939	
Sample 3	1	16,858	15,00
		16,958	
		16,943	

Table 6: *Bioplastic preparation yields*

	Sample 1 (g)	Sample 2 (g)	Sample 3 (g)
Starch	20,0		
Sodium chloride	1,5	1,5	1,5
Celocell	2,0	2,0	2,0
Boric Acid	0,3	0,3	0,3

Xanthan gum	0,3	0,3	0,3
Ethanol	15,0	15,0	
Glycerin	6,0	6,0	6,0
Mineral oil	3,0	3,0	3,0
Water			
Initial mass	138,1	148,1	158,1
Final mass	124,08	132,06	133,78
Performance	89,85	89,17	84,62

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Table 7: Tensile strength

Bioplastic	Test tubes	Maximum elongation cm	Max. elongation	Minimum Effort cm	Minimum Effort (%)
Sample 1	1		12,567		9,033
		12,7		9,1	
Sample 2	1	16,4	16,533	15,4	15,467
		16,6		15,5	
		16,6		15,5	
Sample 3	1	18,2	18,367	16,9	17,00
		18,4			
		18,5		17,1	

Table 8: Biodegradability

Bioplastic	Day	Weight loss	% Average weight loss
Sample 1	0	0,1815	66,57
	5	0,3136	
		0,6321	
		0,7028	
		0,8724	
		0,9723	
		0,985	
Sample 2	0	0,1334	50,53
	5	0,2286	
		0,3251	
		0,4272	
		0,5632	
		0,7981	
		1,0618	
Sample 3	0	0,1436	43,87
	5	0,1652	

	0,2181
	0,3382
	0,5943
	0,7482
	0,86312

Table 9: *Bioplastic Solubility*

Solubility (%)			
	Cold distilled water	Hot distilled water	Hot drinking water
Sample 1	0,96	4,02	92,836
Sample 2	0,022	3,418	92,341
Sample 3	0,073	3,223	89,612

As a contribution to the research for the elaboration of bioplastics from modified cassava starch, new techniques can be tested such as:

Modifying the process for obtaining the chemically modified cassava starch, by any other process different from the acylation process, or modifying the concentrations of the substances involved in the acylation method.

With 4% acetic acid within the acylation method in the process of chemically modified cassava starch will better % yields be obtained?

We can establish the variation modification of the different samples involved in the formulation for obtaining bioplastics, with respect to the % of cassava starch and % of plasticizers, with a different result from those of the present research in samples 1,2,3.

With the mixture of 60% plasticizer and 15% cassava starch, will better results than the present research be obtained in the elaboration of the bioplastic?

In order to obtain the biofilm, it is proposed to modify the control parameters such as temperature, number of RPM in the agitation, as well as the concentrations of the reagents involved in the different premixes.

With the modification in the concentrations of NaCl and boric acid, as well as in the time and temperature different from the present investigation, better results will be obtained in the elaboration of the biofilm.

Conclusions

The formulations for the elaboration of biodegradable casings of which the sensory analysis determined the best results with sample 1, whose value with the addition of plasticizers was 75%, this statement was confirmed by the analysis carried out through the surface of responses to the maximum stress values with a percentage of 39.12%. Sample 1 also presented the best conditions for development due to its properties of degradation, elasticity, flexibility, with a smooth texture and strong resistance. We can determine that the gelatinization temperature is found in a range of 67-73°C. The pH is a very important factor at the moment of gelatinization, it influences in the elaboration of strong acid media, producing masses that are not very stable, weak and damaging their structures, therefore it is necessary to modify it until it reaches a pH of a strong base medium for the correct elaboration of the casings.

The yield of sample 1 is 89.85% due to the viscous mass that is formed, where it adheres to the walls of the beaker producing losses in the development of the bioplastic, however, it is an acceptable value. 0,001746MPa. The moisture content is 11.11%, the solubility of the sample in hot drinking water is 92.836% and in terms of biodegradation there was a loss of weight of 66.57%. With all the analyses obtained for the application of the product elaborated with cassava starch, it should be used with a product that does not require a very high strength resistance as indicated in the results and that should not be exposed to very high temperature humidity, especially if it exceeds 60 minutes. The thickness obtained from sample 1 is not within the range indicated in the standards, but this confirms that the less grams of starch used, the better the characteristics will be.

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