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DEVELOPMENT AND EVALUATION OF A BIOPOLYMER FROM *BETINA* REJECTED POTATO *(SOLANUM TUBEROSUM L., BETINA VARIETY)* STARCH

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Abstract: This study focused on the development, extraction, and evaluation of a biopolymer derived from potato starch (*Solanum tuberosum L.*, variety *Betina*), specifically using "rejected potatoes"—tubers excluded from commercial markets due to factors such as size irregularities, price fluctuations, disease, or climatic variability. The starch was then characterized for its physicochemical properties, yielding a moisture content of 29,2%, ash content of 0,22%, and pH of 7,6. A biopolymer film was then formulated using glycerol as a plasticizer and tested for mechanical and biodegradability properties. Tensile strength analysis was conducted using a TA.XT Plus Texture Analyzer and NEXYGEN Plus software. Young's modulus was found to lie between the typical values of low- and high--density polystyrene (1,04 and 10 MPa, respectively). The elongation at break was measured at 22,547%, and the density was 1,4 g/cm^3. Biodegradability tests were performed under two conditions: composting at 55 °C using commercial compost (Anasac)and natural exposure to ambient air following ISO 14855-1. After 42 days in composting conditions, the samples exhibited complete degradation. Under open-air exposure, the films showed initial fracturing by day 14 and total disintegration by day 33.

INTRODUCTION

Each year, approximately 100 million tonnes of plastic are produced globally, with about 30% used for single-use packaging materials, which are quickly discarded and often end up in landfills or natural ecosystems, where they can persist for more than a century [1]. If current production and waste management trends continue, it is estimated that by 2050, up to 12 billion tonnes of plastic waste will have accumulated [2]. The situation in Colombia is equally concerning, where annual plastic consumption reaches 1.25 million tonnes, and 74% of packaging materials are disposed of in landfills [3].

Plastic recycling is limited by the complex composition of waste, which may include adhesives, resins, and unknown materials that hinder separation and reuse. Some plastics, such as PVC, emit toxic particles and are unsuitable for reuse or incineration, making recycling processes expensive, inefficient, and environmentally harmful [4]. Consequently, nearly 90% of the world's plastic has never undergone any recycling process [5].

Polymers can be broadly classified into synthetic (petroleum-based) and natural types, the latter including cellulose and starches from cereals, tubers, and other sources. Among the alternatives for producing biodegradable polymers, potato starch stands out due to its high starch content, large-scale production, and favorable structural characteristics, especially its amylose-to-amylopectin ratio, which is a key parameter for biodegradability [6].

Despite Colombia's vast agricultural potential, the country faces alarming levels of food loss and waste. In the case of roots and tubers alone, about 4.9 million tonnes are produced annually, with 2.4 million tonnes (49%) being lost or wasted [7]. Potatoes are one of the most affected crops. In 2020, the departments of Nariño and Boyacá cultivated 24,200 and 34,175 hectares of potatoes, respectively [8]. A significant portion of the harvest is considered reject-grade due to failing to meet quality standards for commercialization. While not systematically quantified, these rejected potatoes represent a considerable potential source of starch for biopolymer production [9-11]. Although there is no official record of rejected potato losses, data collected from local farmers estimate that from one hectare, an average of 500 commercial potato sacks (each ~50 kg) are harvested, totaling approximately 25 metric tons [12]. On the same scale, around 100 sacks (~5 metric tons) correspond to

non-commercial rejected potatoes [13].

The valorization of agro-industrial waste as raw material for biopolymer development not only reduces environmental impact but also creates economic and social value. This is particularly relevant in the context of rising public awareness and urgency around sustainable development goals [14]. For instance, Weerasooriya et al. developed a biodegradable plastic film from oil palm fruit bunch waste, extracting hemicellulose using alkaline ethanol to produce carboxymethylcellulose-based films [15].

Similarly, researchers from the Institute of Biotechnology at the Universidad Autónoma de México genetically modified *Escherichia coli* to produce D- and L-lactic acid isomers, which serve as monomers for polylactic acid (PLA), a biodegradable and renewable alternative to conventional plastics [16]. Other studies have explored the use of banana peel and green banana starch to develop biodegradable membranes with satisfactory physical and chemical characteristics [17]. In Spain, AIMPLAS has developed PLA-based biopolymers using enzymatic fermentation of bakery waste, producing food-safe and biodegradable packaging materials [18].

In Colombia, local research on potato starch modification and bioplastic production has shown promising results. Holguín describes a two-stage process involving the modification of native potato starch to improve mechanical properties, followed by bioplastic formulation enhanced by specific additives [19]. At Universidad de Boyacá, ongoing work since 2019 has focused on producing biopolymers from native *Solanum phureja* (criolla potato) starch, combining scientific research with regional agricultural support [20]. Morales suggests that Colombia's abundant crops—corn, cassava, sugarcane, and potatoes—could support a bio-based plastics industry, contributing to innovation and environmental management [21].

These findings establish a strong foundation for advancing national biopolymer research, highlighting the potential for innovation, sustainability, and circular economy practices based on underutilized agricultural resources such as rejected potatoes [22].

MATERIALS AND METHODS

This project was carried out at the pilot food plant of the Universidad de La Salle, located in La Candelaria neighborhood (Bogotá D.C., Colombia). The research was conducted in three stages: The first stage involved the extraction and characterization of starch from rejected *Betina* variety potatoes *(Solanum tuberosum L., Betina Variety)*. The potatoes, totaling 2 kilograms, were sourced from the municipality of Boyacá and showed signs of damage due to storage, cuts, and bruises—typical characteristics of rejected produce. The second stage consisted of the formulation and production of the biopolymer films, and the third stage focused on biodegradation in composting material for a period of over 40 days, incubated at 55 °C, along with mechanical testing of the biopolymer.

STARCH EXTRACTION

Potatoes (*Solanum tuberosum*) are a rich source of starch, containing approximately 13% of this polysaccharide in their composition. The yield of starch extraction through physical methods ranges between 60% and 80%, depending on factors such as potato variety, ripeness, and processing conditions. Based on this information and following methodologies reported by the Potato Starch Processing Plant in Andahuaylas (MINAG) and the procedure proposed by Melian (2010) [23]. Figure 1 outlines the experimental protocol for extracting the biopolymer using rejected Betina variety potatoes. A total of 2 kg of this raw material was employed to obtain the biopolymer.

First, post-harvest rejected potatoes were

selected—those that do not meet commercial quality standards but still retain physicochemical properties suitable for starch extraction [18]. Potatoes were washed with potable water containing 100 ppm of available chlorine for 2–3 minutes to effectively remove soil residues and organic matter. They were then manually peeled and grated. [19].

The grated mass was mixed with distilled water in a 1:2 (weight/volume) ratio and stirred continuously for 10 minutes [20]. The mixture was then filtered through a fine mesh to separate the pulp, and the resulting liquid was allowed to settle for 12 hours to enable starch sedimentation [21]. After settling, the supernatant was carefully removed, and the wet starch was dried in an oven at 40 °C until it reached a moisture content below 12% [22].

The dried starch was sieved to homogenize its particle size and stored in airtight bags until its later use in the biopolymer formulation. Figure 1 shows the extraction process.

STARCH CHARACTERIZATION

pH, moisture content, and ash content were analyzed using AOAC official methods. For pH determination, the method described in AOAC 920.43, 2005 [23] was used. This technique involves quantifying acidic species via acid-base titration, using a strong base (NaOH) as the titrant, followed by back-titration of the excess NaOH with a strong acid (HCl). The pH was measured using a Metrohm pH meter, model 827 pH Lab, which features a resolution of ±0.001 pH units and an accuracy of ±0.002 pH units at 25 °C. This high-precision instrument ensured reliable monitoring of pH changes during the titration process

Ash content was determined using the AOAC 923.03, 1990 [24] method, which involves complete incineration of the sample's organic matter in a muffle furnace at 525 °C, leaving only the inorganic residue. A Thermo Scientific Thermolyne™ FB1310M-33 muffle furnace was used for this analysis. This furnace features a temperature range up to 1100 °C, a digital controller for precise temperature regulation, and a resolution of ±1 °C, ensuring consistent and accurate ash determination.

Moisture content was determined following the AOAC 23.003:2003 method [25]. This technique is based on drying the food sample in an oven at 105 °C until a constant weight is achieved. Measurements were taken every two hours, and after each drying interval, samples were placed in a desiccator for 15 minutes before weighing. Depending on the initial moisture level, the drying process required between 4 and 10 hours. A Memmert UN110 drying oven was used, featuring a temperature range from ambient +5 °C to 250 °C, a resolution of 0.1 °C, and a temperature uniformity of ±1.0 °C, ensuring precise and consistent drying conditions

BIOPOLYMER FORMULATION

Starch was blended with water and glycerol, molded into films, and dried at room temperature [26]. Figure 2 show this process

BIOPOLYMER EVALUATION

The functional performance of a biopolymer is determined by its mechanical strength, physical properties, and environmental behavior. Evaluating these parameters is essential to understand its suitability for various applications, particularly in sustainable packaging and biodegradable materials. In this study, the biopolymer obtained from rejected *Betina* variety potatoes was subjected to a series of tests to determine its mechanical properties, density, and biodegradability [24]. These evaluations provide insights into the material's structural integrity and its potential as an eco-friendly alternative to conventional plastics.

Mechanical properties, including tensile strength and elongation at break, were measured using a TA.XT Plus texture analyzer (Sta-

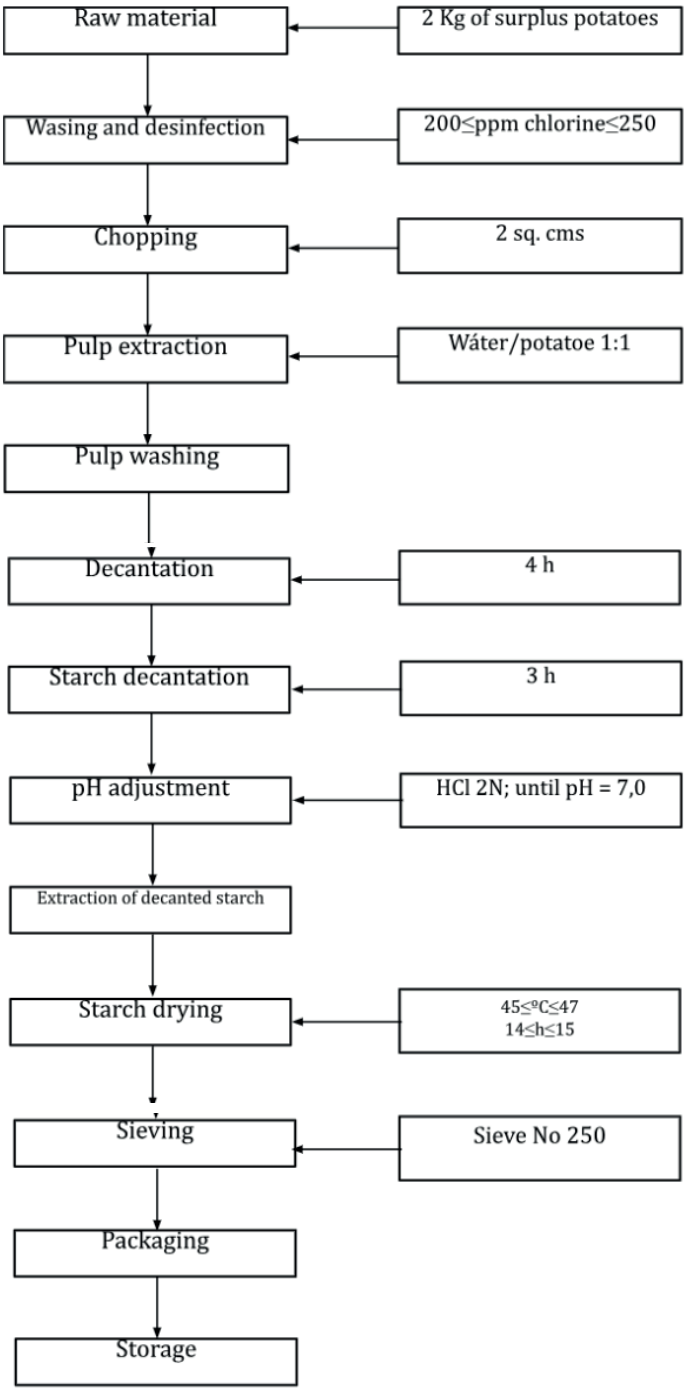


Figure 1. Extraction process of potatoe starch

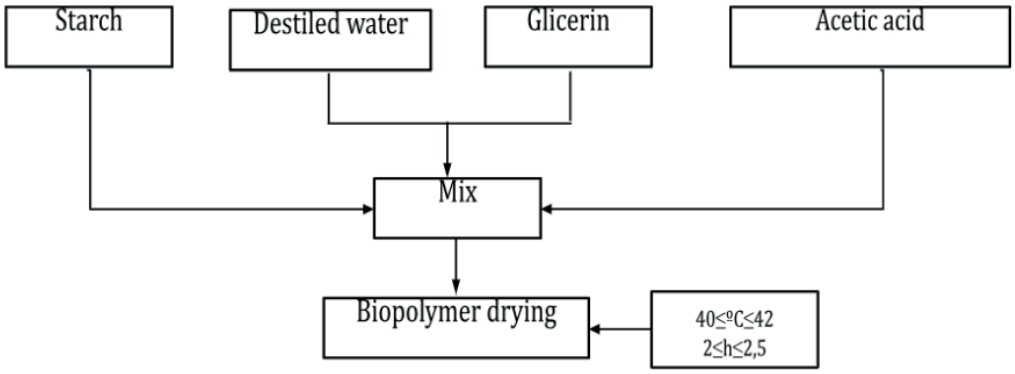


Figure 2. Biopolymer extraction process

ble Micro Systems Ltd.), following the ASTM D638 standard [27]. This method specifies the procedure for determining tensile properties of plastic materials under controlled conditions, ensuring accurate and reproducible results.

To get the density of the biopolymer, the method described in Iresiduo, 2017 [28] was followed; a sample of the plastic biopolymer was first weighed using an Ohaus analytical balance with a resolution of 0,01 mg, yielding a mass of 5,6 g. Subsequently, 50 mL of distilled water was placed in a 100 mL graduated cylinder. The biopolymer sample was then carefully submerged in the water until it was fully covered. The increase in the water level was recorded, corresponding to the volume of the plastic in cubic centimeters (cm^3).

The biodegradation test was carried out according to the parameters suggested by NTC ISO 14001 [29]. Compost was used as the inoculum, which was characterized prior to use to ensure it met the parameters established by the standard. The compost was then sieved using a 0,60 mm particle-size sieve to remove stones and plant material, achieving a uniform particle size. Afterwards, the compost was adjusted to 53,81% total solids using distilled water, mixed thoroughly, and a 240 g dry-weight sample was prepared. Polymer samples were cut into portions of 40 g. each, maintaining a 6:1 compost-to-polymer ratio.

Each polymer sample was mixed homogeneously and separately with compost in plastic containers. These mixtures were then placed in incubators and incubated at a constant temperature of 58 °C ±2 °C using a Memmert IF110 forced-air incubator, which provides precise temperature control and uniform heat distribution [29]. The incubator features a temperature range from +10 °C above ambient to 80 °C, with a temperature stability of ±0.1 °C and uniformity of ±0.5 °C at 58 °C. It includes a digital PID controller, adjustable air circulation, and stainless-steel interior with corrosion-resistant construction, ensuring consistent incubation conditions for long-term testing. The percentage of biodegradation was determined based on the weight loss of the samples [30].

For the samples subjected to biodegradation under environmental (outdoor) conditions, the same procedure was followed, with the exception that incubation was not carried out in an incubator but instead outdoors, allowing full exposure to ambient environmental conditions.

RESULTS

In the initial stage of the research, the extracted starch was characterized to evaluate its physicochemical properties, which are essential for understanding its behavior and suitability in biopolymer production [31]. Key parameters analyzed included pH, moisture (humidity) content, and ash content. The

pH provides insight into the acidity or alkalinity of the starch, which can affect its reactivity and stability. Moisture content influences the starch's shelf life and processing characteristics, while ash content indicates the level of inorganic residue or impurities present [32]. Table 1 presents the measured values for these parameters from three independent samples, demonstrating consistent quality across the batch.

Table 2 shows the results for tensile properties of the biopolymer obtained from *Betina* rejected potatoe.The tensile test makes it possible to understand the characteristics of a material when subjected to tensile stress. The objective is to determine the breaking strength and the main mechanical properties of the material.

Table 3 evidence results of biodegradation process under controlled conditions [39]. For this test, pure organic soil, a natural product obtained through the decomposition of organic materials was used; additionally, naturally disinfected soil with low compactibility and high organic matter content in the form of compost, featuring high drainage capacity and aeration were applied.

Table 4 evidence the biodegradation test of the *Betina* starch biopolymer; it was decided to carry out a biodegradation test under natural conditions, that is, outdoors. Several biopolymer samples weighing approximately 2 g were taken and placed in a pot containing the same compost material used in the previous incubation test. This sample was subjected to greater monitoring and control compared to the other sample.

DISCUSSION

The low starch yield compared to literature (17–25%) is attributed to losses during decantation and drying [37]. The high moisture content indicates the need for optimized drying to improve starch stability. Although the tensile strength of the resulting biopolymer was lower than synthetic plastics, its flexibility and biodegradability suggest potential for short-term packaging applications [38]. Its rapid degradation demonstrates the feasibility of replacing petroleum-based plastics with biodegradable alternatives in specific contexts.

The biopolymer developed exhibited a tensile strength lower than that of low-density polyethylene (LDPE), which typically ranges from 5 to 25 MPa [33]. Regarding Young's modulus, the material showed an intermediate value between those reported for high-density and low-density polyethylene, approximately 10 MPa and 1,04 MPa, respectively [34]. The elongation at break was 22,547%, a value comparable to that of LDPE, which has been reported at 25,468% by Allende and Arriagada, 2013 [35]. Overall, the results presented in Table 2 and Figures 1–4 (Annex 1) demonstrate an elastic behavior prior to failure, indicating that the biopolymer possesses enhanced flexibility and ease of handling when compared to LDPE, the most comparable conventional material.

The density test of the biopolymer indicates a value of 1.4 g/cm^3, which is close to that of polyhydroxybutyrate (PHB), a biodegradable thermoplastic biopolymer produced through biotechnology, with a density of 1.25 g/cm^3 [36]. Although PHB is quite stable under normal conditions, its structure breaks down in landfills or during composting processes.

CONCLUSIONS

Starch derived from rejected *Betina* potatoes is a viable feedstock for biodegradable biopolymers. Despite mechanical limitations and extraction inefficiencies, the material's biodegradability supports its application in eco-friendly packaging. This study contributes to food waste valorization and the development of sustainable materials in Colombia. The degradation time for the samples obtained from rejected potato starch was 33 days for the samples exposed outdoors and 41 days for the samples incubated at 55 °C, with a biodegradation percentage of 94,33%. This successfully met the overall objective and complied with regulations that ensure biopolymers degrade within an approximate period of 40 days.

Sample	pH	Humidity (%)	Ashes (%)
1	7,6	29.55	0.164
2	7,5	29.07	0.228
3	7,6	29.30	0.289

Note: Distilled water is added, and the pH is adjusted with 2 N HCl until a pH of 7,0 is reached.

Table 1. Physicochemical Properties of Starch Extracted from *Betina* Variety Potatoes

Authors

Parameter	Sample 1	Sample 2	Sample 3	Sample 4
Young Modulus (MPa)	6,189	6,149	6,163	6,171
Maximum Load (N)	9,882	9,872	9,878	9,877
Resistance to tensile (MPa)	0,613	0,617	0,615	0,616
Maximum Work (J)	0,092	0,107	0,107	0,107
Strain to break (%)	22548	22547	22548	22546
Work to break (J)	0,092	0,109	0,111	0,110
Max. work to elasticity (J)	0,084	0,107	0,103	0,104
Max. Load of elasticity (N)	3,740	3,742	3,741	3,741
Max. extension of elasticity (mm)	3,654	3,654	4,363	4,363
Stress to deformation (MPa)	0,230	0,233	0,231	0,230

Table 2. Results of tensile properties of biopolymer

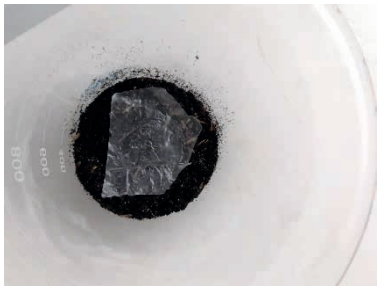
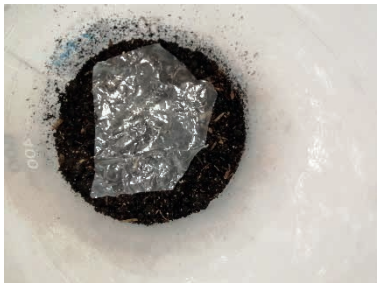
Sample		Results of biodegradation
Sample 1		Three samples, each weighing approximately 3 g., were placed in an incubator for 41 days at a temperature of 55 °C. This degradation process occurs in conjunction with oxidative degradation when the material is exposed to oxygen. Continuous monitoring during the test was not possible, as the laboratory underwent equipment calibration and maintenance, limiting student access. As a result, the samples were only observed after 30 days of incubation.
Sample 2		
Sample 3		
Day 30		By day 30, the samples had decreased in size and became brittle and fragile.
Day 41		By day 41, the samples had undergone almost complete degradation, leaving only small traces of material fragments. This allowed for the determination of the final weight of the material in order to calculate the biodegradability percentage at that time. The percentage of biodegradation was calculated using the Equation 1: **% Biodegradation = $[(W_0 - Wt) / W_0] \times 100$** (1) where W_0 is the initial dry weight and Wt is the dry weight after incubation. The final biodegradation percentage obtained on day 41 was 94.33%, indicating that the material can be considered biodegradable. (3g-0,17g)3g*100=94,33%

Table 3. Biodegradation under compost conditionsTable 4. Outdoor biodegradation test

Day	Sample	Biodegradation Results
1		The samples were exposed directly to rain and sunlight, simulating the typical conditions of natural ecosystems or sanitary landfills. In this case, aerobic biodegradation (in the presence of oxygen) was carried out under controlled conditions.
5		On day 5, the samples became moistened but did not yet show any visible cracks or noticeable changes to the naked eye.
15		By day 14, cracks in the material became evident in the samples. Degradability under humid conditions caused the starch granules to increase the biopolymer's capacity to absorb water, which facilitated the fragmentation of both the internal and external surfaces of the samples.
20		By day 20, the samples had become thinner, with an increased number of cracks in the material, and their size had been considerably reduced.

25		By day 24, the combined action of ultraviolet radiation, known as photodegradation—which affected the plasticizing additives present in the formulations, in this case glycerol—along with heat and atmospheric oxygen, broke down the chemical bonds of the biopolymer. These are slow processes. The polymer eventually fragments into smaller chains, resulting in residues or new biomass that are non-toxic to the environment.
33		Finally, by day 33, the samples had completely degraded, thus fulfilling the established objectives that demonstrate the biopolymer's degradability characteristics. Biopolymers retain their physicochemical properties throughout the product's life cycle but, once disposed of under composting conditions, biodegrade similarly to organic waste.

Table 4. Outdoor biodegradation test

REFERENCES

1. Acevedo, E., Garcia, E., Evangelista-Lozano, S., Rosales, O., & Bello, L. (2012). Características del almidón de maíz y relación con las enzimas de su biosíntesis. Obtenido de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-31952013000100001#:~:text=El%20almid%C3%B3n%20es%20el%20principal,de%20glucosa%3A%20amilosa%20y%20amilopectina

2. FEDEPAPA. (2020). Boletin Regional Boyaca. Obtenido de https://fedepapa.com/wp-content/uploads/2020/05/BOLET%c3%8dN-REGIONAL-BOYAC%c3%81-2020.pdf

3. Alonso, J. (2014). Consumo y mercado de la papa en Colombia. Obtenido de https://consumoymercadodepapa.wordpress.com/2014/11/28/consumo-y-mercadeo-de-la-papa-en-colombia/

4. Cercos, S. (2012). Que es el compost-VeoVerde. Nueva Mujer. Obtenido de https://www.nuevamujer.com/lifestyle/2012/11/04/que-es-el-compost.html

5. Gomez Rodriguez, L. (2015). Informe: Así es el mundo de la papa colombiana | Contexto ganadero | Noticias principales sobre ganadería y agricultura en Colombia. . Obtenido de https://www.contextoganadero.com/agricultura/informe-asi-es-el-mundo-de-la-papa-colombiana

6. CNN, E. (2019). ¿Qué países latinoamericanos han tomado medidas para reducir el plástico? Obtenido de https://cnnespanol.cnn.com/2019/07/19/que-paises-latinoamericanos-han-tomado-medidas-para-reducir-el-plastico/

7. Gonzalez, X. (2020). El país cuenta con 510.475 hectáreas aptas para la siembra de papa industrial. Obtenido de https://www.agronegocios.co/agricultura/el-pais-cuenta-con-510475-hectareas-aptas-para-la-siembra-de-papa-industrial-3014528

8. Marin. (2016). Quimica del almidon. Obtenido de https://www.academia.edu/21607198/Qu%C3%ADmica_del_almid%C3%B3n

9. Greenpeace. (2011). Di basta a los plásticos. Obtenido de https://www.greenpeace.org/colombia/involucrate/colombia-mejor-sin-plasticos/#:~:text=Se%20consumen%201.250.000%20toneladas,contaminan%20mares%2C%20r%C3%A-Dos%20y%20manglares.

10. Greenpeace. (2019). No todo el plástico se recicla. Obtenido de https://www.greenpeace.org/mexico/blog/2490/no-todo-el-plastico-se-recicla-sabes-por-que/

11. Greenpeace. (2021). Di basta a los plásticos. Obtenido de https://www.greenpeace.org/colombia/involucrate/colombia-mejor-sin-plasticos/#:~:text=Se%20consumen%201.250.000%20toneladas,contaminan%20mares%2C%20r%C3%A-Dos%20y%20manglares.

12. Weerasooriya, P., Nadhilah, R., Owolabi, F., Hashim, R., Abdul, H., Syahariza, Z., Haafiz, M. (2020). Exploración de las propiedades de la película de carboximetilcelulosa a base de hemicelulosa como posible envase ecológico. Obtenido de https://www.sciencedirect.com/science/article/pii/S2666086520300047

13. Argenpapa. (2019). Portal de la papa Argentnina. Colombia: Una hectarea de papa pastusa en Colombia cuesta $15.6 millones. Obtenido de https://www.argenpapa.com.ar/noticia/7692-colombia-cultivar-una-hectarea-de-papa-pastusa-en-colombia-cuesta-15-6-millones

14. Presidencia de la Republica. (2020). Colombia cuenta con más de 510.000 hectáreas aptas para la siembra de papa para uso industrial. Obtenido de https://id.presidencia.gov.co/Paginas/prensa/2020/Colombia-cuenta-con-mas-de-510000-hectareas-aptas-para-la-siembra-de-papa-para-uso-industrial-200603.aspx

15. Castillo, J. D. (2019). En Boyacá crean empaque biodegradable a partir de la papa criolla para remplazar el plástico. Obtenido de https://boyacaradio.com/noticia.php?id=24397

16. FAO. (2008). La papa. Obtenido de https://fao.org/potato-2008/es/lapapa/index.html

17. Gomez, J. (2020). La producción de bioplásticos creció un 3% en 2019. MundoPlast. Obtenido de https://mundoplast.com/produccion-bioplasticos-nova/

18. Morales. (208). Análisis de riesgos y oportunidades para potencializar la producción de biopolímeros basados en residuos orgánicos relacionados con la producción de papa en Colombia. Obtenido de https://repository.javeriana.edu.co/bitstream/handle/10554/38157/An%C3%A1lisis%20Riesgos%20y%20Oportunidades%20Biopol%C3%ADmeros%2020181016.pdf?sequence=1&isAllowed=y

19. Alonso, J. (2014). Consumo y mercado de la papa en Colombia. Obtenido de https://consumoymercadodepapa.wordpress.com/2014/11/28/consumo-y-mercadeo-de-la-papa-en-colombia/

20. Melian, D. (2010). Ensayo Comparativo de Dos Metodologías de Extracción de Almidón de Papa usando Muestras de Diez Variedades Nativas de Chiloé y dos Variedades Comerciales. Obtenido de http://cybertesis.uach.cl/tesis/uach/2010/fam522e/doc/fam522e.pdf

21. Duffó, G. (2010). Una mirada a la degradación de los materiales. Obtenido de https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.cab.cnea.gov.ar/ieds/images/extras/hojitas_conocimiento/materiales/pag_25_26_duffo_degrad_mater.pdf&ved=2ahUKEwjUifGinoHvAhWpp1kKHfj9DNQQFjAQegQIDBAC&usg=AOvVaw2FUfNxgZIQlhH5pvmW0-kw

22. AOAC International. Official Method 920.43. Acidity (Titratable) of Fruit Products. In: *Official Methods of Analysis of AOAC International*. 18th ed. Gaithersburg (MD): AOAC International; 2005.

23. AOAC International. Official Method 923.03. Ash of Flour (Direct Method). In: *Official Methods of Analysis of AOAC International*. 15th ed. Arlington (VA): Association of Official Analytical Chemists; 1990.

24. AOAC International. Official Method 23.003. Moisture Content. In: *Official Methods of Analysis of AOAC International*. 17th ed. Gaithersburg (MD): AOAC International; 2003.

25. Betancourt, M. (2015). POLÍTICA DE SEGURIDAD ALIMENTARIA NUTRICIONAL (SAN) Y DESARROLLO TERRITORIAL EN COLOMBIA. Obtenido de https://www.esap.edu.co/portal/index.php/Descargas/787/publicaciones-2018/34164/seguridad-alimentaria-nutricional-san-y-desarrollo-territorial-en-colombia.pdf

26. AgroRural (Dirección). (2010). Primera Planta procesadora de almidón de Papa en Andahuaylas - MINAG - AGRORURAL [Película]. Obtenido de https://www.youtube.com/watch?v=Z496gBscdq8&feature=youtu.be

27. ASTM International. Standard Test Method for Tensile Properties of Plastics. ASTM D638-14. West Conshohocken (PA): ASTM International; 2014.

28. Iresiduo. (2017). En busca de nuevos bioplásticos a partir de residuos agroindustriales. Obtenido de https://iresiduo.com/noticias/mexico/conacyt/17/10/19/busca-nuevos-bioplasticos-partir-residuos-agroindustriales

29. NTC-ISO14001. (s.f.). SISTEMAS DE GESTIÓN AMBIENTAL. REQUISITOS CON ORIENTACIÓN PARA SU USO. . Obtenido de https://informacion.unad.edu.co/images/control_interno/NTC_ISO_14001_2015.pdf

30. Povea Garcerant I. *La función del envase en la conservación de alimentos*. Bogotá (CO): Ecoe Ediciones; 2015. 160 p.

31. Avila. (2015). Descripción botánica de la planta de papa. PROGRAMA DE APOYO AGRÍCOLA Y AGROINDUSTRIAL VICEPRESIDENCIA DE FORTALECIMIENTO EMPRESARIAL CÁMARA DE COMERCIO DE BOGOTÁ).

32. Labeaga. (2018). Polímeros biodegradables. Importancia y potenciales aplicaciones. Obtenido de http://e-spacio.uned.es/fez/eserv/bibliuned:master-Ciencias-CyTQ-Alabeaga/Labeaga_Viteri_Aitziber_TFM.pdf

33. CNA. (2014). Presentación Área cosechada y producción. Obtenido de https://www.dane.gov.co/files/CensoAgropecuario/entrega-definitiva/Boletin-10-produccion/10-presentacion.pdf

34. Resolucion 1397 de 2018. (s.f.). Uso racional de bolsas plásticas. Obtenido de http://www.minambiente.gov.co/images/normativa/app/resoluciones/ff-RES%201397%20DE%202018.pdf

35. Allende, S., & Arriagada, P. (2013). POLIETILENO DE ALTA Y BAJA DENSIDAD. Obtenido de Universidad de chile: https://www.u-cursos.cl/usuario/c1f33623c53cd7f58fd77ef459693d6c/mi_blog/r/Polietileno.pdf

36. Acosta, J., Gomajoa, H., Benavides, Y., Charfuelan, A., & Valenzuela, F. (2018). Evaluación del almidón de papa (Solanum tuberosum) en la obtención de. Bionatura Conference Series. Obtenido de https://www.revistabionatura.com/files/CS--2018.01.01.2---Revista-bionatura.pdf

37. Villalobos, M., Lopez, M., Rodriguez, P., & Prado, M. (2014). Universidad Tecnológica de Jalisco. Obtenido de Obtención de almidón a partir de los residuos de papa del mercado Abastos: https://www.ecorfan.org/handbooks/Ciencias%20de%20la%20Ingenieria%20y%20Tecnologia%20T-V/Articulo_25.pdf

38. Campuzano, J., López, I., & Alvarez, C. (2018). Normativas y regulaciones para polímeros biodegradables y compostables. Obtenido de http://www.plastico.com/temas/Normativas-y-regulaciones-para-polimeros-biodegradables-y-compostables+126663

39. ISO. (2012). Determination of the final aerobic biodegradability of plastic materials under controlled composting conditions. Method by analysis of carbon dioxide released. Part 1: General method (ISO 14855-1:2012)

ANNEX

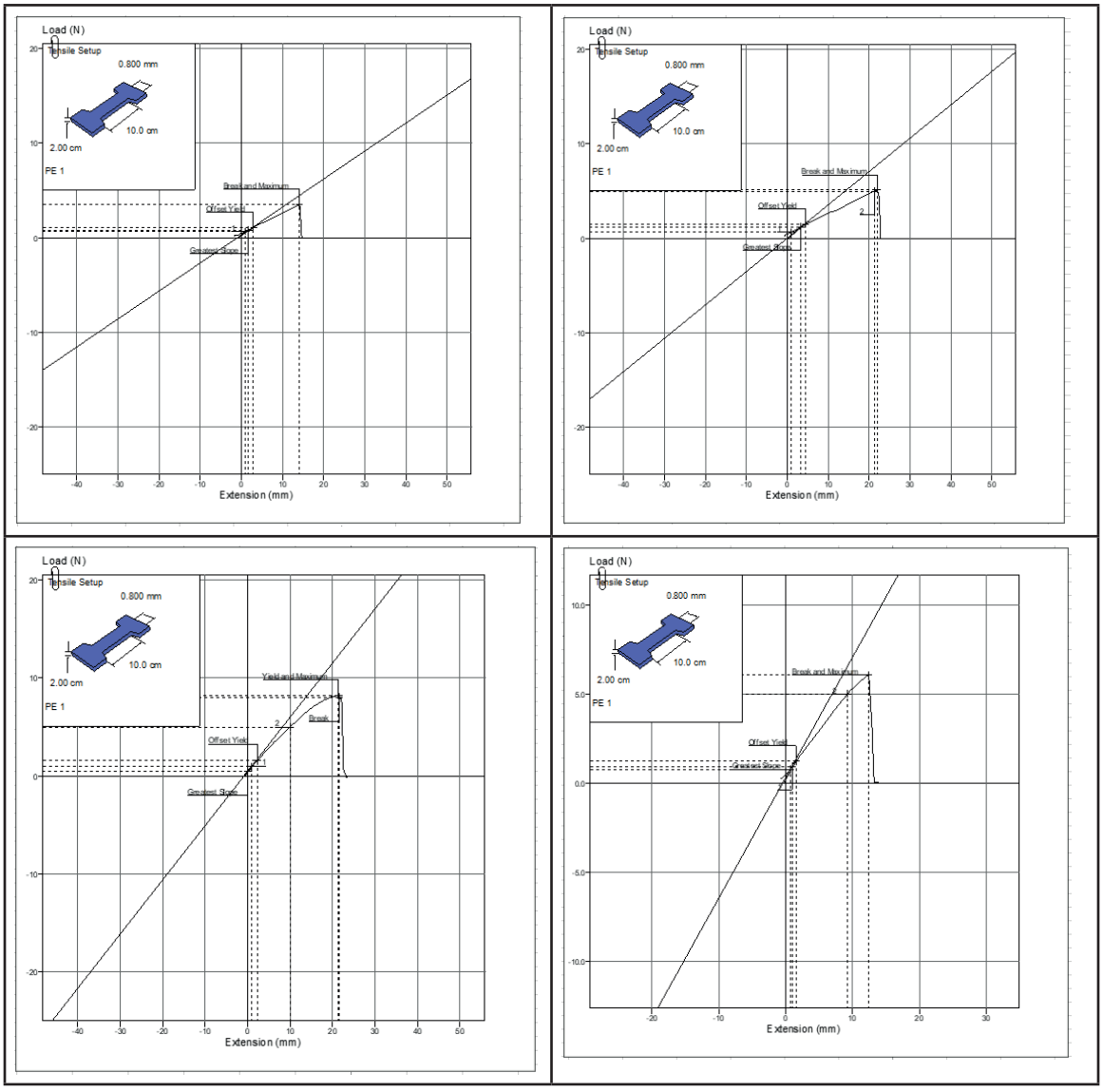


Figure 1. Tensile Results of Biopolymers for four samples