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Organic packaging proposal of biopolymer base starch-exudate tree *Capparis scabrida* for blueberry's conservation

Propuesta de embalaje ecológico de biopolímero base almidón-exudado de árbol *Capparis scabrida* para la conservación de blueberries

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Abstract

The current need to reduce environmental degradation and seek environmentally friendly packaging alternatives has encouraged research into new products based on biological resources such as biopolymers (polysaccharides), such as the starch in potatoes. The objective of this research was to identify the properties of potato peel joined with a natural plasticizer obtained from tree exudate *Capparis scabrida* as a blueberry packaging alternative, which presents sensitivity to deterioration, a suitable packaging with an abundance of starch can delay this phenomenon, on the other hand, synthetic polymer packaging deteriorates the product. A mixed analysis was performed, applying the quantification and estimation of the biopolymer for the packaging's development according to the control variables such as biodegradability, functionality, breathing rate, and weight loss of the fruit. The technical data obtained from the biopolymer were the basis of the decision-making process for the implementation of packaging as a replacement for existing synthetic polymers. The characterization will be the reason for future works for its optimization.

Biopolymers, Packaging, Blueberries

Resumen

La necesidad actual de reducir el deterioro ambiental y buscar alternativas de embalaje amigables con el medio ambiente ha fomentado investigar nuevos productos basados en recursos biológicos como los biopolímeros (polisacáridos) por ejemplo, el almidón contenido en las papas. El objetivo de esta investigación fue identificar propiedades de la cáscara de papa junto con un plastificante natural obtenido del exudado de árbol *Capparis scabrida* como alternativa de embalaje de blueberries, el cual presenta sensibilidad al deterioro, un embalaje adecuado con abundancia de almidón puede retardar este fenómeno, por otro lado, los embalajes de polímeros sintéticos deterioran el producto. Se realizó un análisis mixto donde se aplicó la cuantificación y estimación del biopolímero para el desarrollo del embalaje en función de las variables de control como la biodegradabilidad, funcionalidad, tasa de respiración y pérdida de peso de la fruta. Los datos técnicos obtenidos del biopolímero fueron la base de la toma de decisiones para llevar a cabo la implementación de un embalaje como sustitución del existente constituido de polímeros sintéticos. La caracterización será motivo de trabajos futuros para su optimización.

Biopolímeros, Embalaje, Blueberries

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Introduction

Polymers are monomers with an abundance of interconnected atoms (carbon, sulfur, nitrogen, or oxygen) that form long chains (the backbone of the polymer). (Wagner et al., 2014). Those that are biologically based, biodegradable, or both (derived from biological resources or fossil fuels), are known as biopolymers. They can be naturally derived from renewable or synthetic resources from fossil fuels. (Niaounakis, 2015, 2019). Polysaccharides are a classification within natural or biological biopolymers that have a high molecular weight and can be of animal, microbial, algae, and plant origin. Among the most common polysaccharides is starch. (BeMiller, 2019; Maji, 2019; Niaounakis, 2015). It is composed of amylose (crystalline linear polymer) and amylopectin (branched and amorphous polymer). One of the main sources from which it is extracted is the potato. (BeMiller, 2019; Vroman & Tighzert, 2009).

This tuber represents the fourth most produced crop worldwide, below corn, wheat, and rice. From it, the peel is obtained as essential organic matter because it is nourished with antioxidants and microbial compounds, also is convenient to use in the field of food processing and storage. (Gebrechristos y Chen, 2018; Thakur et al., 2021). However, in its natural form, it has high fragility, sensitivity to water and is devoid of mechanical properties. To solve this problem, mixtures of starch with synthetic polymers are made. (Vroman, & Tighzert, 2009). And natural plasticizers (resins, trementines, gums, and rubbers) based on tree exudates (Gonzaga et al., 2019).

This research aimed to identify the properties of potato peel joined with a natural plasticizer obtained from tree exudate *Capparis scabrida* as a blueberry packaging alternative that is sensitive to deterioration, a suitable packaging with an abundance of starch may delay this phenomenon, however, synthetic polymer packaging deteriorates the product. On the other hand, the use of low-cost waste that is created and converted into high-value products generates a positive impact on the environment. (Thakur et al., 2021).

Methodology

This research had a mixed approach due to the use of quantitative and qualitative methodologies based on biopolymers books, journals, and research articles. The current need to reduce environmental degradation and seek environmentally friendly packaging alternatives has encouraged research into new products based on biological resources such as biopolymers (polysaccharides), like the starch in potatoes. Due to previous studies, it was identified that quantitative variables were relevant to obtaining data on water sensitivity, barrier properties, respiration rate, and weight loss of blueberry packaging through experimentation and laboratory tests. On the other hand, in the development of the theoretical perspective concerning qualitative variables were estimated, the point of view of the authors where marketing costs and product life. This research aimed to identify the properties of potato peel joined with a natural plasticizer obtained from tree exudate *Capparis scabrida* as an alternative to blueberry packaging, which is sensitive to deterioration, suitable packaging with an abundance of starch can slow this phenomenon, on the other hand, synthetic polymer packaging deteriorates the product. However, the results of the relationship between quantitative and qualitative data in an analysis of the mixed parameters determine that a packaging made with biopolymer represents a product with better storage conditions for natural products, which is appreciated throughout society based on previous studies. Therefore, it is proposed to carry out packaging for blueberries with a higher degree of biodegradability than those existing in the market by adding a natural plasticizer (Sampieri et al., 2010).

Biopolymers: polysaccharides

Polymers are monomers with an abundance of interconnected atoms (usually carbon, sulfur, nitrogen, or oxygen) that form long chains (the polymer's backbone). The combination of atoms in each of them has a unique configuration. (Wagner et al., 2014). Polymers that are biologically based, biodegradable, or both (derived from biological resources or fossil fuels), are known as biopolymers. They can be natural from renewable or synthetic resources from fossil fuels. (Niaounakis, 2015, 2019).

Polysaccharides are a classification within natural or biological biopolymers that have high molecular weight. The term saccharide is derived from sucrose, which is an ancient concept for cane sugar. They are bound with glycosides in amounts greater than 20 to 60,000. They are abundant in nature and their main sources of origin are the animal, microbial, algae, and vegetable. Among the most common polysaccharides is starch. (BeMiller, 2019; Maji, 2019; Niaounakis, 2015).

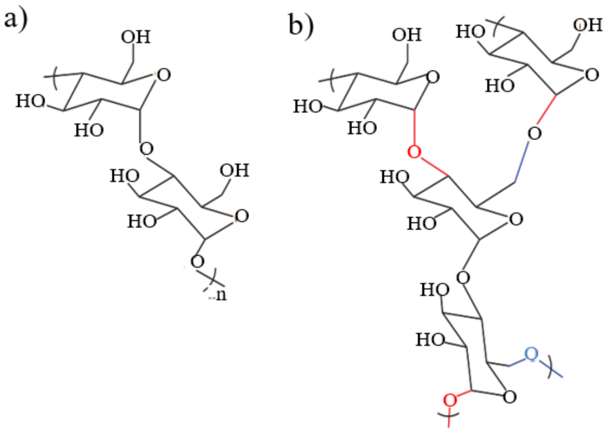

Figure 1 The chemical structure of (a) amylose showing only the most common type of linkages, (1,4)-α-D linkages and (b) amylopectin consisting of both (1,4)-α-D linkages (highlighted in red) and (1,6)-α-D linkages (highlighted in blue). *Source Lauer & Smith (2020)*

Starch and packaging

The present society seeks to reconsider its decisions at buying, taking as a priority the environmental factor. (Romojaro et al., 2021). Reducing the use of raw materials and non-renewable energy will improve people's lifequality. (Pardave, 2007). The starch is biodegradable, environmentally friendly, and has low cost due to its high availability. It is produced in the form of hydrophilic granules (affinity to water) by agricultural plants. It is composed of amylose (crystalline linear polymer) and amylopectin (branched and amorphous polymer). The amounts of these depend on the type of starch. However, it cannot have many uses in its natural form as it is devoid of mechanical properties, has high fragility and sensitivity to water. (Bolívar, 2020; Vroman, & Tighzert, 2009).

Plastic starch films are used for food packaging because of their low permeability. They protect from exposure to the environment and seal the contained products. These films have great advantages, as they are: good optical and mechanical properties. Moreover, they have sensitivity to moisture and deficiency in water barrier properties. To solve it, mixtures with different polymers are made. (Niaounakis, 2015; Vroman & Tighzert, 2009).

Improvement of mechanical properties

The improvement of mechanical properties can be obtained by the acetylation process (a common modification technique with acetic anhydride) joined with a mixture of pyridine (liquid used for the synthesis of compounds) and acetic acid (polar solvent capable of creating hydrogen bonds). In this process, starch acetate is generated with high amounts of linear amylose, which has higher hydrophilia (decreased sensitivity to water). (Bolívar, 2018, 2020; Mehboob et al., 2020; Vroman, & Tighzert, 2009).

To increase the molding capacity of starch (by injection or extrusion), thermoplastic polymers are added. These can be fossil, renewable, biodegradable, or non-biodegradable. (Niaounakis, 2015). One of the viable mixtures to use is that of starch-poly alcohol: At mixing thermoplastic starch with polyvinyl presents improvement in its elongation, tensile strength, and processability since both materials are compatible. (Vroman & Tighzert, 2009).

Another way to improve the properties of starch is to mix it with different polymers. The advantage of this technique is that the properties to be obtained are adjusted according to the needs of the desired product, and developing it has a lower cost than generating new synthetic materials. However, the most important problems are the compatibility of the components and achieving complete biodegradation. (Niaounakis, 2015)

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Biodegradation

The function of disintegrating polymers under the action of microorganisms at a specific time in the environment is called biodegradation. It is conducted under the action of enzymes (proteins that catalyze chemical reactions) and/or chemical wear related to living organisms. For this to occur, polymers are first fragmented by abiotic reactions to lower molecular mass species. These fragments are then bio assimilated by microorganisms and their mineralization. It is important to note that the biodegradability of the polymer depends not only on the source factor but also on its chemical structure and favorable environmental conditions. (Niaounakis, 2015; Vroman & Tighzert, 2009; Zhu et al., 2019).

Potato starch

Starch is the highest carbohydrate in potatoes. (Dupuis & Liu, 2019). Potato is the fourth most produced crop worldwide, below corn, wheat, and rice. From the potato, the peel is obtained as essential organic matter, because it is nourished with antioxidants and microbial compounds, also contains polyphenols, phenolic acids, lipids, and fatty, therefore is convenient to use it in the field of food processing and storage. There are different methods for obtaining potato peel. Currently the most used are steam and abrasion. The method of abrasive peeling works with a specialized drum for peeling that has protrusions on the inner surface (rotating removes peel), This has a water spray unit where potatoes are washed. On the other hand, in the steam method it is fed directly to the drum (at a lower pressure), the product is heated continuously for a certain time and most of the removed peel is cleaned with an industrial process of abrasive rollers and then removed with water any residue. (Gebrechristos & Chen, 2018; Pathak et al., 2017; Thakur et al., 2021).

Parameters	Dry weight%
Moisture	85.06
Total de carbohydrate	68.70
Total soluble sugar	1.00
Reducing sugar	0.61
Starch	52.14
Nitrogen	1.30
Protein	8.00
Fat	2.60
Ash	6.34

Table 1 Potato peel content
Source: Pathak et al., (2018)

Potato variety	Lipid content (% on dry weight)	Total polyphenols (% on of freeze-dried extracts)
Kennebec (brown)	0.21	22.4
Russet Burbank (brown)	0.20	15.8
Norchip (brown)	0.17	19.2
Red Norland (Red)	0.21	24.5
Red Pontiac (Red)	0.19	27.5
Viking (Red)	0.18	32.2

Table 2 Total lipid and polyphenol contents of different varieties of potato peel. Source: *Pathak et al., (2018)*

Extraction of starch

In the study conducted by Thakur al., (2021) to extract starch from potatoes, they were first peeled and washed manually. Then they ground the peel with a grinder to filter it. To this peel were added 100 ml of water to squeeze it in muslin (type of fabric) to recover the grains of starch that are filtered. Once this process was carried out, they added sodium hydroxide to the granules, thus dividing the proteins and lipids that are obtained from the starch. This whole sample was washed a certain number of times until it was completely filtered. Finally, to achieve the drying of the starch, they placed it in an oven at 40°C for 24 hours.

Blueberries packaging

Once the starch has been obtained, it can be used as packaging. In the packaging industry, care for the environment and the need to reduce the environmental impact of irresponsible human activity is one of its main interests. They seek to reduce their negative impact on the planet by generating ecological packaging. (Naranjo, 2020; Zamora, 2012). In the research of Bof et al., (2021).

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They analyzed the packaging of blueberries in corn starch and chitosan films (with the addition of grapefruit seed extract). These plastic and biodegradable films were suitable for proper conservation for 37 days (under transport and marketing conditions) due to the barrier properties developed. Biodegradable packaging reduced antioxidant capacity during storage. They also managed to control the breathing rate of the fruit and its weight loss (compared to PET). To evaluate this loss, the following control variables were considered: the respiratory rate of the fruit and the water vapor permeability of plastic films.

Sustainable development seeks to meet the needs of today's population without affecting future generations. (Alcalde, 2008). In another study developed by Janik et al., (2021) they generated a film based on three biopolymers: chitosan, furcellaran, and a hydrolyzed skin jelly from carp fish *(Cyprinus carpio)* for the conservation of blueberries. This film showed good results in the protection of food since the advantage of this packaging is that the fruit did not lose weight and there was no presence of mold in a test of 10 days, compared to synthetic packaging.

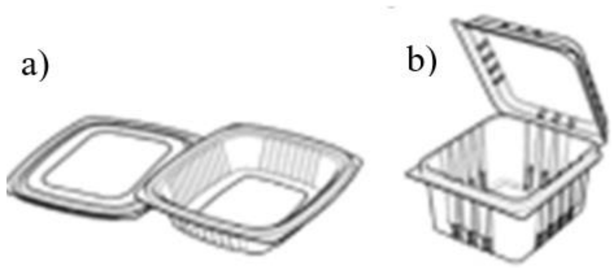


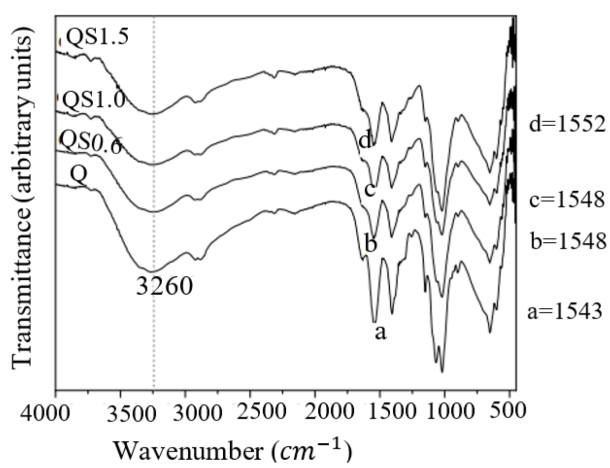
Figure 2 Design of the containers used for packaging blueberries: (a) biodegradable non-vented container and (b) commercial petroleum-based vented clamshell container
Source Almenar et al., (2008)

In the study by Giuggioli et al., (2017) they showed the use of starch-based plastic films for storage in a modified atmosphere (packaging of food that changes the gaseous atmosphere of the product for preservation) for the stage following the harvest of blueberries. This type of packaging managed to regulate the Physico-chemical properties at this stage of blueberry production, as well as the nutritional and antioxidant values, which did not vary after being monitored for 15 days, even when temperature changes occurred.

Plasticizers

The synthetic plasticizers that are normally used (polyols: sorbitol and glycerol) bind to the polymer chains preventing the bond with hydrogen (divides the chains). This process increases the flexibility and permeability of water vapor in its different phases. In the case of starch, the plasticizer used is glycerol because it is compatible with amylose and manages to dissolve in starch solutions. (Ballesteros-Mártinez et al., 2020; Syaubari et al., 2022).

The study by Gonzaga et al., (2019) analyzed natural plasticizers (from tree exudates) and polyvinyl alcohol to determine their impact on chitosan films (belonging to polysaccharides). Films obtained from *Capparis scabrida* tree exudate had higher levels of biodegradability than those of polyvinyl alcohol. Operating with chitosan, (belonging to the same classification of starch) and having similar characteristics, could be a viable option as a plasticizer with a higher percentage of biodegradability for starch films compared to those on the market.



Graphic 1 FTIR analyses of the film with *Capparis scabrida* tree. *Source Gonzaga et al., (2019)*

Results

This research agrees with the view of Vroman et al., (2009) which indicates that the packaging of starch-based biopolymers has become relevant in the search for ecological alternatives due to their origin and abundance. Adding this information, the study by Bof et al., (2021) focused on blueberries can be the beginning of the development of improved technologies for packaging. The scope will depend on mixtures and modifications in its chemical structure to achieve its optimization.

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Conclusions

This potato-exudate base biopolymer packaging proved to have adequate characteristics of biodegradability, fruit respiration rate, and minimal weight loss, in addition to the estimate of cost improvement concerning existing packaging on the market. Although biopolymer packages derived from different materials of natural origin already exist, using starch from potato peel and adding a different plasticizer obtained from *Capparis scabrida* tree exudate, increases the biodegradability of the packaging. This contributes positively to the market focused on the packaging because it presents innovation.

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