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ORIGINAL ARTICLE

Development of cellulose-based films from rose stems with potential for food preservation

Desarrollo de películas a base de celulosa extraída de tallos de rosas con potencialidades para la conservación de alimentos

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Abstract Flower production in Ecuador generates a large amount of waste stems. This study aimed to develop bioplastics from rose stems using polyvinyl alcohol (PVA) and corn starch to minimize the use of plastic bags. Cellulose microfibers were obtained through acid and basic hydrolysis and then used to produce bioplastics through a wet method. Mixtures of cellulose-PVA and cellulose-starch were made, resulting in 24 formulations. The films were evaluated for moisture, opacity, thickness, water vapor permeability, and degradability. The raw material contained 48.45% cellulose, 60.64% moisture, 28.28% lignin, and 3.63% ash. The thickness of the bioplastics met the specified standard. The PVA-based bioplastics showed higher water absorption and greater degradability, while the starch-based bioplastics were more opaque than the others. The formulation for producing bags would depend on the intended application.

Keywords biofilms, cellulose, polyvinyl alcohol, corn starch, characterization.

Resumen La producción de flores en Ecuador genera una gran cantidad de desechos, específicamente los tallos. El objetivo del presente trabajo fue desarrollar biopelículas a partir de tallos de rosas con alcohol polivinílico (PVA) y almidón de maíz como envases para minimizar el uso de las fundas plásticas. Los microfilamentos de celulosa se obtuvieron mediante hidrólisis ácida y básica, con los cuales se produjeron las biopelículas mediante el método húmedo. Se realizaron mezclas de celulosa-PVA y celulosa-almidón, con un total de 24 formulaciones. A las películas se le evaluó la humedad, opacidad, espesor, permeabilidad al vapor de agua y degradabilidad. La materia prima presentó 48,45 % de celulosa, 60,64 % de humedad, 28,28 % de lignina y 3,63 % de ceniza. El espesor de las biopelículas cumplió con lo establecido en la norma. Las biopelículas compuestas por PVA presentaron mayor absorción de agua y mayor degradabilidad, mientras que las compuestas de almidón mostraron mayor opacidad. La formulación a utilizar para la obtención de fundas dependería de la aplicación en la que se utilizaría.

Palabras clave biopelículas, celulosa, alcohol polivinílico, almidón de maíz, caracterización.

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Introduction

The floricultural activity in Ecuador began 30 years ago (Sozoranga & Vélez, 2016) and has become one of the country's main agricultural products, alongside bananas and cocoa. The floriculture sector ranks third globally as an exporter (Camino-Mogro et al., 2016). The rose is the most produced flower, with an area of 4,282 hectares in annual production, of which 935 hectares are open-field crops, and the rest are greenhouse crops. The primary residue generated is the stems, with an annual production of 2,557,870,384 cut stems (ESPAC, 2020). These residues can be transformed into a solution for environmental pollutants if converted into value-added products.

In Ecuador, petroleum and non-petroleum income sources are key to the country's economy. The main non-petroleum exports are cocoa, bananas, shrimp, and flowers, contributing to the Gross Domestic Product (GDP) (Freire et al., 2018). The increase in production costs and the economic crisis caused by the depreciation of international markets affected the sector (Poveda, 2021). The COVID-19 pandemic in 2020 impacted various areas, including floriculture, due to a mandatory reduction in exports (Morocho et al., 2021).

Regarding plastic management, they have a complex recycling process. In Ecuador, approximately 261,778 tons of soft plastic waste are generated (López & Miranda, 2024). Many of these plastics end up as pollution in landfills, highlighting the need for alternative solutions. One option is biodegradable plastics based on polymers, such as cellulose combined with polyvinyl alcohol (PVA) and starch, which the environment can absorb as they break down into CO_2, water, or biomass (Avellán et al., 2020).

Conventional plastics derived from petroleum do not degrade quickly in the environment, thus contributing to environmental pollution (Ponce & Zambrano, 2019). This article addresses the need to reduce plastic and flower waste pollution. This research aimed to develop biodegradable films from rose stems with potential applications for food preservation.

Materials and methods

The stems generated at the Guayaquil Flower Market were quantified weekly for 15 days, classifying them according to the leading sales. The rose stems' moisture content, ash, cellulose, and lignin were determined. Cellulose extraction was carried out through alkaline and acidic hydrolysis, following the procedures of Jiménez et al. (2019).

The bioplastic was prepared using the molding method, with 24 formulations and a two-factor design, to determine the effectiveness of the mixtures. To characterize the biofilms, the thickness, water vapor permeability, opacity, water absorption, water contact angle, and biodegradability were evaluated (Kwok & Neumann, 1999; Vicentini, 2003; Joaqui & Villada, 2013).

The biodegradability percentage of the biofilms was determined through a humus degradation experiment, in which external factors such as pH and humidity were controlled. Then, the loss due to degradation was calculated.

Results and discussion

Table 1 shows the results of the characterization of rose stems. During the raw material's collection and storage phases, moisture loss occurred, leading to the concentration of lignocellulosic components, which may explain the differences between the results and the reference values.

Table 1. Composition of rose stems

Indicator	Percentage	Reference
Moisture	60.64	65.3 % (González et al., 2016)
Ash	3.63	3.45 % (Rincón, 2020)
Cellulose	48.45	45-50 % (González et al., 2016)
Lignin	28.28	20-25 % (González et al., 2016)

The bioplastics composed of 10 µm cellulose and PVA were softer, more manageable, and translucent than the cellulose-starch formulations. The films with 200 µm cellulose were discarded due to their paper-like characteristics. According to the INEN 2636 standard (2012), all formulations met the thickness requirement (0.25 mm). The formulations with the thinnest thickness were the cellulose-PVA films, while the thickest were the cellulose-starch films.

As seen in Figure 1, the bioplastics with 10 µm cellulose and starch, at concentrations of 20 and 60 mL, showed similar moisture content. In the case of the bioplastics with 200 µm, the moisture was similar for the 10 and 20 mL concentrations. Both treatments exhibited similar behavior regardless of concentration and thickness.

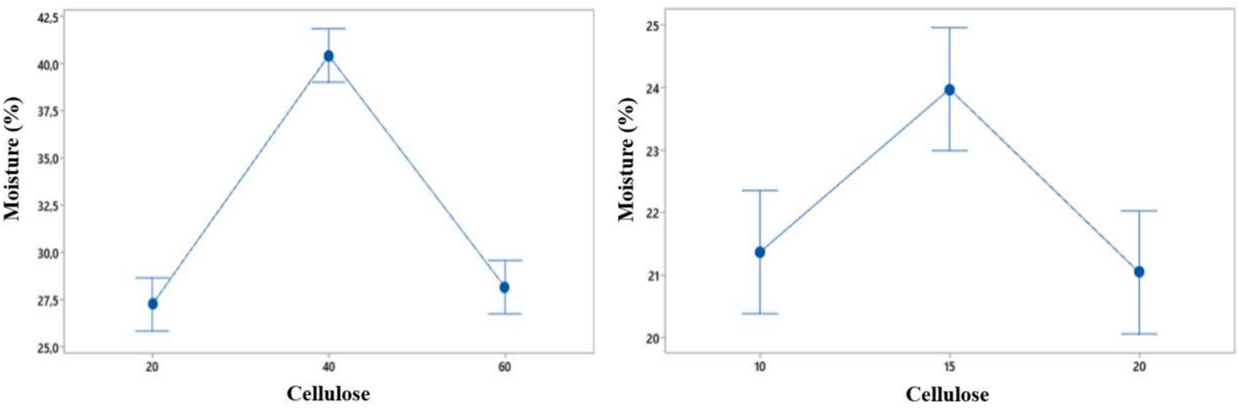

Figure 1. Moisture of 10 and 200 µm cellulose and starch bioplastics. The error bars represent the confidence interval of the mean (95% confidence). The pooled standard deviation was used to calculate the intervals.

The PVA content affected the water vapor permeability of the cellulose-PVA bioplastics. As shown in Figure 2, the mean water vapor permeability of the bioplastics composed of cellulose and starch at 10 and 200 µm showed similarities; the variation in volumes did not affect this property.

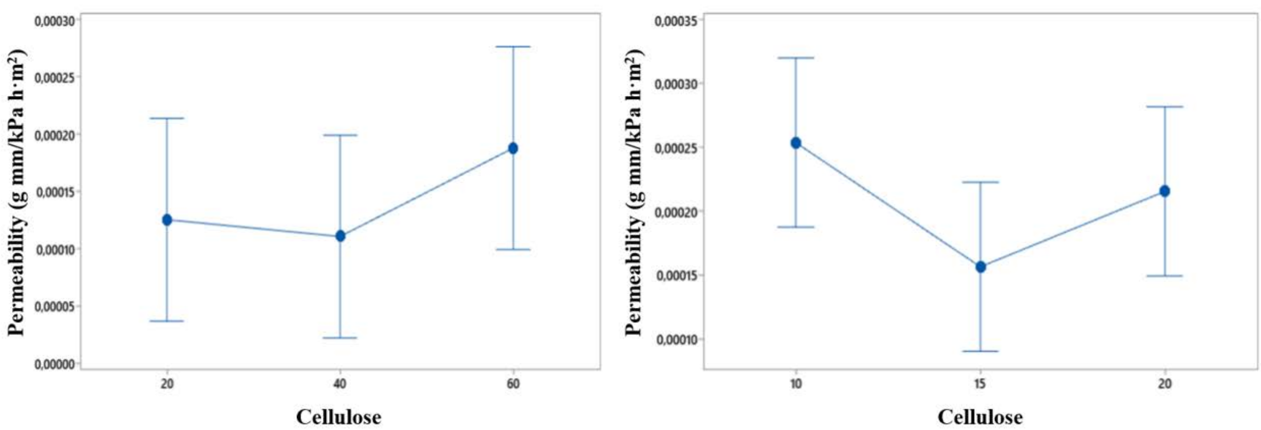

Figure 2. Water vapor permeability of cellulose and starch bioplastics at 10 and 200 µm. The error bars represent the confidence interval of the mean (95% confidence). The pooled standard deviation was used to calculate the intervals.

The PVA and cellulose content and their combination affected water absorption in cellulose-PVA bioplastics. Different behaviors were observed for the cellulose and starch bioplastics of 10 and 200 µm, as shown in Figure 3.

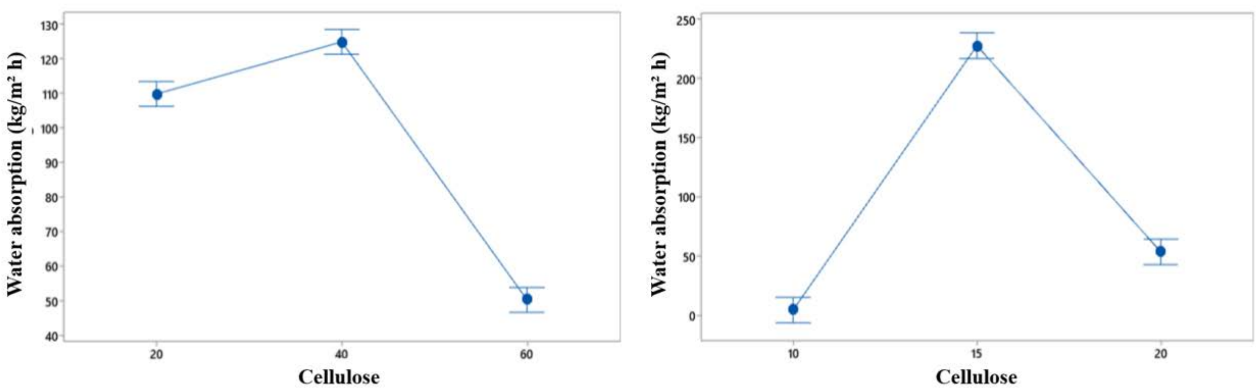

Figure 3. Mean water absorption of 10 and 200 µm cellulose and starch bioplastics. The error bars represent the confidence interval of the mean (95% confidence). The pooled standard deviation was used to calculate the intervals.

The content of PVA and cellulose and their combination affected the water contact angle of the cellulose and starch bioplastics. Figure 4 shows significant differences in the water contact angles of the 10 and 200 µm cellulose and starch bioplastics about the amount of cellulose.

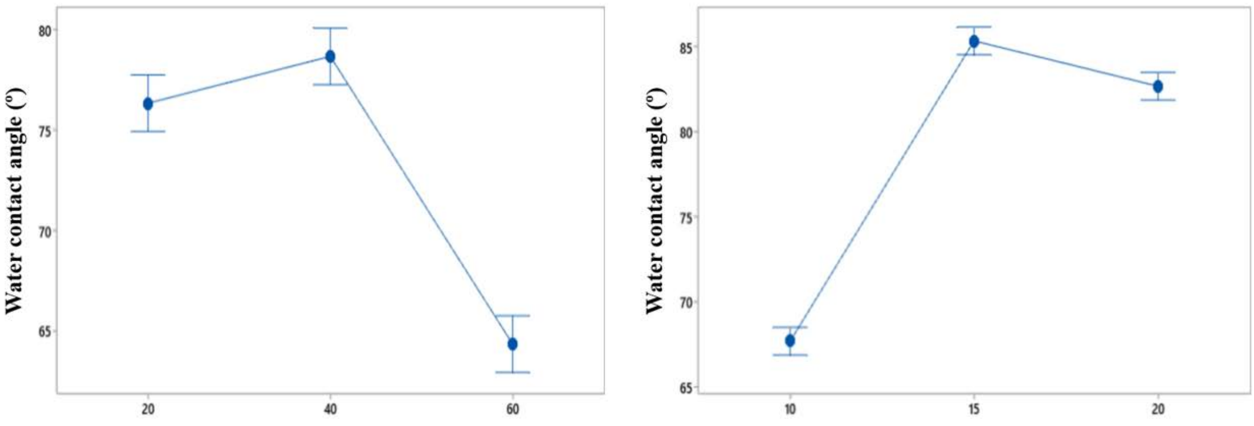

Figure 4. Water contact angle of cellulose and starch bioplastics a) 10 µm and b) 200 µm. The error bars represent the confidence interval of the mean (95% confidence). The pooled standard deviation was used to calculate the intervals.

The factors that affected the opacity of the cellulose-PVA bioplastics were the PVA content and the combination of PVA and cellulose. Figure 5 shows the differences in opacity of the 10 and 200 µm cellulose and starch bioplastics. Among the 10 µm thick films, those containing 60 mL of cellulose showed higher opacity, while for the 200 µm films, those with 15 and 20 mL of cellulose exhibited higher opacity.

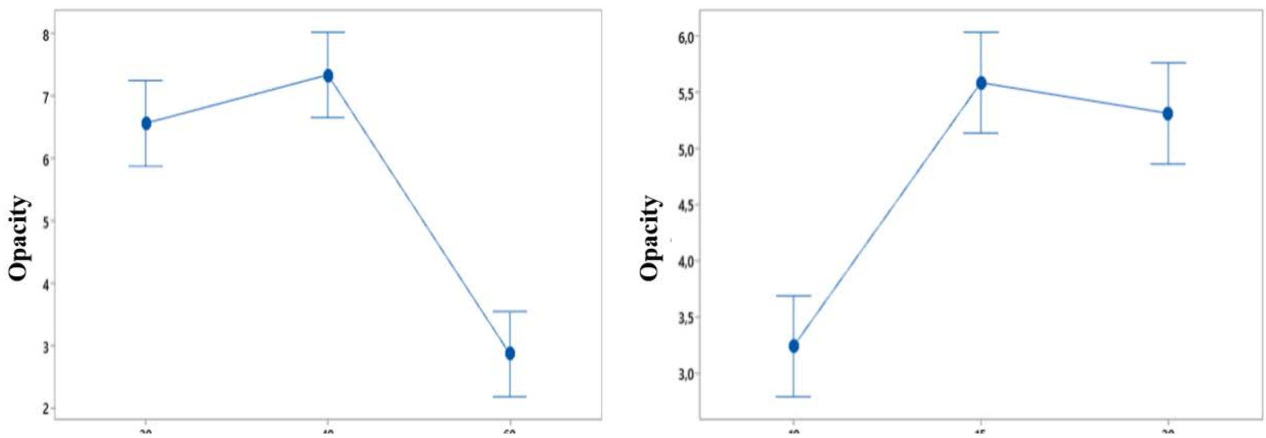

Figure 5. Opacity of cellulose and starch bioplastics: a) 10 µm and b) 200 µm. The error bars represent the confidence interval of the mean (95% confidence). The pooled standard deviation was used to calculate the intervals.

During the biodegradability study, the bioplastics gained weight in the first three weeks, related to their water absorption property. After this period, a progressive weight loss was observed (Figure 6).

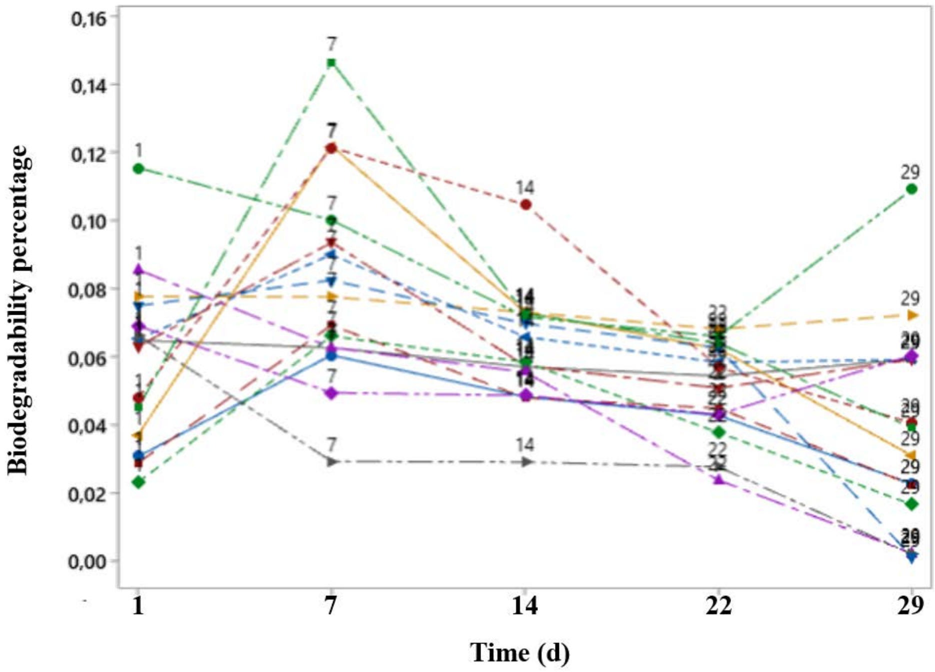

Figure 6. Biodegradability of the bioplastics.

Conclusions

The lignocellulosic content of the stems allows them to produce biopolymers. The formulations with corn starch showed lower water absorption. All formulations were hydrophilic, with water drop angles below 90°. Opacity was higher in formulations containing starch. FTIR spectra showed characteristic peaks in the formulations with PVA and starch. The formulations with PVA showed greater degradability, although all formulations lost weight over time. The bags can be manufactured from any formulation based on the desired properties; formulations with PVA are ideal for greater degradability and translucency, while those containing corn starch are better for resistance, lower degradability, and water absorption.

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Conflicts of interest
The authors declare that they have no conflicts of interest.

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Data availability statement
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Statement on the use of AI
The authors acknowledge the use of generative AI and AI-assisted technologies to improve the readability and clarity of the article.