

# EVALUACIÓN DE UN RECUBRIMIENTO COMESTIBLE A BASE DE ALMIDÓN DE YUCA PARA LA CONSERVACIÓN POSTCOSECHA DE FRESAS

## EVALUATION OF A CASSAVA STARCH-BASED EDIBLE COATING FOR POSHARVEST PRESERVATION OF STRAWBERRIES

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### RESUMEN

La industria de frutas y hortalizas se enfrenta al apremiante desafío de la elevada perecibilidad inherente a estos productos alimenticios, lo que se traduce en cuantiosas pérdidas a lo largo de toda la cadena de suministro a escala mundial. El problema de investigación se da por la importancia comercial de las fresas, ya que existe la necesidad imperiosa de encontrar soluciones efectivas y sostenibles que permitan extender la vida útil y preservar la calidad de este preciado fruto. El objetivo de presente estudio tiene como propósito principal evaluar de manera exhaustiva la calidad sensorial y microbiológica de fresas sometidas a recubrimientos comestibles formulados con diferentes concentraciones de almidón de yuca. Adicionalmente, se realizará un análisis detallado de los costos asociados a la elaboración de estos recubrimientos a base de almidón de yuca. La metodología de la investigación adoptó un enfoque cuantitativo con un diseño experimental, analizando muestras de fresas con y sin recubrimiento. Se llevaron a cabo pruebas sensoriales, microbiológicas y de costo-beneficio, con el fin de caracterizar de manera sistemática y objetiva el desempeño de estos recubrimientos comestibles. Los hallazgos revelan que el recubrimiento a base de almidón de yuca mejoró de manera significativa la aceptación sensorial y la vida útil de las fresas, presentando una carga microbiana notablemente menor en comparación con las muestras sin recubrimiento. Asimismo, el análisis de costos permitió identificar que la formulación al 15% de almidón de yuca presenta una mayor rentabilidad. En conclusión, se evidencia que el uso de un recubrimiento comestible a base de almidón de yuca se perfila como una alternativa viable y sumamente prometedora para mejorar la conservación postcosecha de fresas, optimizando tanto su calidad como su rentabilidad en el mercado.

### Palabras clave

Recubrimiento comestible, película, firmeza, postcosecha



## ABSTRACT

The fruit and vegetable industry faces the pressing challenge of the high perishability inherent to these food products, which translates into significant losses throughout the entire supply chain on a global scale. The research problem is given by the commercial importance of strawberries, since there is an urgent need to find effective and sustainable solutions that allow extending the shelf life and preserving the quality of this precious fruit. The main objective of this study is to comprehensively evaluate the sensory and microbiological quality of strawberries subjected to edible coatings formulated with different concentrations of cassava starch. Additionally, a detailed analysis of the costs associated with the development of these coatings based on cassava starch will be carried out. The research methodology adopted a quantitative approach with an experimental design, analyzing samples of strawberries with and without coating. Sensory, microbiological and cost-benefit tests were carried out, in order to systematically and objectively characterize the performance of these edible coatings. The findings reveal that the cassava starch-based coating significantly improved the sensorial acceptance and shelf life of strawberries, presenting a significantly lower microbial load compared to the uncoated samples. In addition, the cost analysis allowed to identify that the 15% cassava starch formulation presents a greater profitability. In conclusion, it is evident that the use of an edible coating based on cassava starch is emerging as a viable and extremely promising alternative to improve the post-harvest conservation of strawberries, optimizing both their quality and their profitability in the market.

## Keywords

Edible coating, film, firmness, postharvest

## INTRODUCTION

The fruit and vegetable industry stands as one of the most dynamic and in-demand sectors worldwide, surpassed only by cereals and meat products. However, these foods are characterized by their high perishability, attributable to their high water activity and the incessant metabolic processes that continue even after harvest, facilitating the living conditions necessary for the development of fungi and bacteria, thus causing the rapid and extensive destruction of tissue throughout the anatomy of the product. This inherent physiological condition entails considerable food and economic losses throughout the entire supply chain (2).

It is estimated that post-harvest losses of fruit and vegetable products produced in the world exceed 20%, due to microbiological and physiological deterioration, as a consequence of technological factors due to their inadequate harvesting process, inappropriate packaging and insufficient transportation routes, which translates into a short storage period. (1)

Currently, fruit consumption has increased, which represents a benefit for producers. However, we must take into account the problem that they continue to breathe and



perspire after being harvested, causing wilting, sagging, weight loss, changes in color, simultaneously decreasing their quality and therefore their commercial value.

In this challenging context, edible coatings emerge as a highly promising technological alternative to address the problem of post-harvest conservation of fruits and vegetables. The fundamental purpose of these coating materials is to control the transfer of gases, aromas and oils, thus preventing premature loss of firmness and moisture. In this way, the maturation and senescence processes are effectively delayed, preserving the quality and notably extending the useful life of these fresh plant products (3).

Worldwide, post-harvest losses of fruits and vegetables caused by microorganisms are of the order of 5-25% in developed countries and 20-50% in developing countries. The difference is that developed countries have greater availability of technological and economic resources to prevent losses. However, in developing countries where post-harvest losses are high due to the lack of technological resources and the absence of protection systems, which causes the low competitiveness of this value chain, seriously limiting its improvement and directly affecting the economy of traders.(2)

To reduce these changes, conservation methods such as controlled atmospheres and modified atmospheres have been used, which combined with refrigeration have managed to maintain the quality characteristics of the fruits for longer. However, these techniques have limitations such as: high costs and special facilities, as well as the use of poorly biodegradable polymers that cause great environmental impact, awakening the interest of researchers in the search for solutions (4).

Therefore, an edible coating (CR) is defined as a thin layer of material that is formed as a coating on the food, with the aim of prolonging its shelf life. On the other hand, an edible film (PC) is a thin, preformed layer, also made with edible material, that can be placed on the food or between its components (5). It should be noted that, although edible films and coatings are often presented as synonyms, what differentiates them is their application. Films are formed independently of the food and then applied to it, while coatings are formed directly on the surface of the food, either by dipping or spraying, providing surface sterility and preventing the loss of other important components.

In the last 10 years, numerous scientific studies have been carried out that demonstrate that PC and CR are a useful tool to improve the quality of minimally processed plant foods because they form a semipermeable barrier that reduces the loss of water and solutes, control gas exchange including respiration rate (O<sub>2</sub> and CO<sub>2</sub>) and ethylene emission, and reduce the risk of microbiological contamination, physiological disorders and biochemical changes related to oxidative reactions. (enzymatic browning) and loss of firmness.(5)

This translates into a longer shelf life in storage and better conditions for transportation and marketing, maintaining quality by minimizing moisture loss, representing an economic benefit for producers and distributors, as it minimizes shrinkage and increases commercial performance. They also act as a physical barrier against bumps, scratches and handling, reducing the incidence of mechanical damage that can affect the



appearance and quality of the fruit. Additionally, they can improve the appearance and quality of the coated product, making it more attractive to the consumer due to its shine, color or low development of microorganisms on the surface (6).

PC and RC can be prepared from a wide variety of polysaccharides, proteins and lipids, alone or in combinations that take advantage of the advantages of each group. These formulations can jointly include plasticizers and emulsifiers that are used of diverse chemical nature in order to help improve the final properties of the film or coating. They have benefits such as edibility, hardness, transparency, and good barrier properties against oxygen and water vapor.(6)

Polysaccharides and proteins are polymers that form cohesive molecular networks due to a high interaction between their molecules. These give them good mechanical and gas barrier properties (O<sub>2</sub> and CO<sub>2</sub>), which is why they slow respiration and aging of many fruits and vegetables, being the most used hydrocolloids in the food industry, since they are part of the majority of the formulations that currently exist on the market. However; One disadvantage they have is that they are hygroscopic and therefore constitute a poor barrier to moisture loss. Those used in the formation of edible coatings are: high and low methoxyl pectins, cellulose and its derivatives, alginate, chitosan, dextrin, carrageenan, and gum arabic, among others (7).

Mango, being a perishable food and susceptible to attack by harmful microorganisms, which cause large losses in post-harvest, requires the use of an edible coating, which will help maintain and preserve its texture, physicochemical characteristics (pH, soluble solids and titratable acidity), and sensory characteristics (color, smell, flavor, texture) during its useful life.(7)

Yucca (*Manihot esculenta*), also known as cassava, is a perennial woody shrub that belongs to the Euphorbiaceae family and is native to tropical America. This crop adapts well to tropical areas, even in poor quality soil, and can withstand prolonged periods of drought. In addition, cassava is considered one of the most efficient species in the production of starch, which makes it a versatile and reliable product for human, animal and various industrial applications. This can be presented in the form of fermented (modified) or non-fermented products. Non-fermented products include flour and starch, which are obtained from processed cassava in the form of pellets (8).

Starch is the main source of energy in human nutrition and, due to its viscosity, retrogradation and adhesive properties, it is used as a thickener, gelling agent and stabilizer in various food products. In addition, cassava starch stands out for having excellent barrier properties against gases, thanks to its hydrogen bonds, and for being colorless, odorless and impermeable to aromas, added to its high amylose content (approximately 17%), making cassava starch an ideal material for the production of edible films and coatings, since it can form a continuous polymer matrix (9).

Cassava starch can be classified as sour and native (sweet). The sour undergoes a fermentation process that gives it desirable properties for food; The native or sweet one is not subjected to a fermentation process, and is the one generally used in the industry. In the cassava starch granule, its size can vary from 5 µm to 35 µm, its shape is between

round and flattened and its amylose content is around 17%. Therefore, the gelatinization of cassava starch is a physicochemical phenomenon, which occurs when the starch is heated in an excess of water, with swelling of the amorphous parts of the granule first occurring; If this heating is continued, the amylose diffuses into the aqueous medium and subsequently begins to dissolve so that the granules lose their crystalline structure, until they are irreversibly destroyed at temperature ranges of 100-150°C (10).(10)

Strawberries (*Fragaria x ananassa* Duchesne) are a very important fruit that is mainly grown in the province of Tungurahua, Ecuador. These fruits are characterized by their high nutritional content and are part of the family basket, being marketed locally and nationally, with 12% exported. Among the main strawberry varieties grown in the country are Diamante, Oso Grande, Monterrey and Albion. For this reason, the technique of using edible films or coatings emerged (11).

Therefore, the main objective of the present study is to exhaustively evaluate the sensory and microbiological quality of strawberries subjected to edible coatings formulated with different concentrations of cassava starch. Additionally, a detailed analysis of the costs associated with the production of these coatings based on cassava starch will be carried out.

## MATERIALS AND METHODS

### Research methodology:

The present study adopted a quantitative approach to carry out a systematic and objective evaluation of the performance of a cassava starch-based edible coating in the postharvest preservation of strawberries. This methodological design allowed numerical data to be collected and analyzed in a rigorous manner, in order to obtain reliable and comparable results.

### Sample selection:

We worked with a total of 60 strawberries, which were distributed equally into three experimental groups:

1. Uncoated strawberries (control group),
2. Strawberries coated with a 15% cassava starch formulation
3. Strawberries coated with a 25% cassava starch formulation.

This random assignment of sampling units sought to guarantee the statistical representativeness of the treatments evaluated and the possibility of making significant comparisons between them.

### Around:

The research was carried out in the specialized laboratories of the Faculty of Livestock Sciences of the Higher Polytechnic School of Chimborazo (ESPOCH), located in the



city of Riobamba, Ecuador. This controlled environment and properly equipped with advanced technical instruments and resources allowed the various required analyzes to be carried out with rigor, precision and reliability.

The cassava was obtained in Santo Domingo, Ecuador. The selection criterion was based on a visual inspection. The cassavas that were used for starch extraction were obtained from the same site, the harvested roots were 9 months old, those that did not present mechanical damage, pests, diseases or other defects were selected.

### Measurements:

The study included an exhaustive sensory analysis of both the raw materials (cassava starch and strawberries) and the final treatments, in order to characterize the chemical composition of the inputs and the products obtained.

Additionally, the count of molds and yeasts in the strawberry samples with and without coating was evaluated over 8 days of storage, with the purpose of determining the effect of the coating on the shelf life and microbiological safety of the product.

Finally, a preference test was carried out with an untrained panel of 70 consumers, who evaluated the appearance and sensory acceptability of the coated and uncoated strawberries.

### Analysis of the collected data:

Descriptive statistics were used to characterize and compare the different treatments in a systematic and objective manner. In the case of sensory evaluation, non-parametric tests suitable for this type of subjective analysis were used.

### Methodology used:

To carry out the procedure or the experimental development of the practice, it will begin with the reception of the raw material, the benefits of receiving the raw material is to ensure quality raw material that is safe, a procedure based on the Food Analysis Practice Manual (5).

Which mentions two methods or types of analysis that must be carried out on food:

The first method is to carry out the sensory analysis, which will be carried out in the food laboratory, among which four attributes will be evaluated in specific color, smell, flavor and texture.

The second method to carry out the microbiological analysis, since in most foods there is a low or high microbial load, this factor must be controlled, due to the microbial load that the product has, it should not exceed the limits specified by the regulations, since when passing the permitted limits the deterioration of the food occurs immediately, when carrying out the microbiological evaluation of the matter it will be possible to identify whether it is acceptable or not.



The counting of molds and yeasts was carried out on Petrifilm quick-read plates and the procedure was as follows:

2 g of sample was taken (strawberry with coating and another without coating) and homogenized in 9 ml of distilled water. With the help of a pipette, 2 ml of the diluted sample was taken and cultured on the plates, labeling them with the value of  $10^1$ . For the following exponents, 1 ml of diluted sample was taken and 9 ml of distilled water was added, in the same way it was cultured on the plates and labeled with the value of  $10^2$  (12).

Once these parameters have been made to evaluate the quality of the basic raw materials for the production of this product, water and glycerol will be received. The water will act as a humectant in the mixture of the ingredients and the glycerol as an additive to improve the characteristics of the mixture.

Once the mixture is made, it will be cooked at a temperature of 70 °C, with the purpose of a state of gelation and retrogradation since the starch will give it these characteristics. Once the cooking process is finished, with the help of a brush, a portion of the mixture will be taken to coat the strawberries, performing three treatments, such as: strawberry without edible coating, with a 15% concentration of starch and with a 25% concentration of starch (13).

Once the process of placing the coating on the strawberries is completed, it will be left to rest for eight days from that day on. The microbiological, bromatological and sensory evaluations will begin. This will help us determine if the product made or if the formulations that have been taken into account for this experimental process are adequate. Through the results obtained, the efficiency of the edible coating on strawberries can be determined.

## RESULTS

### Preference test

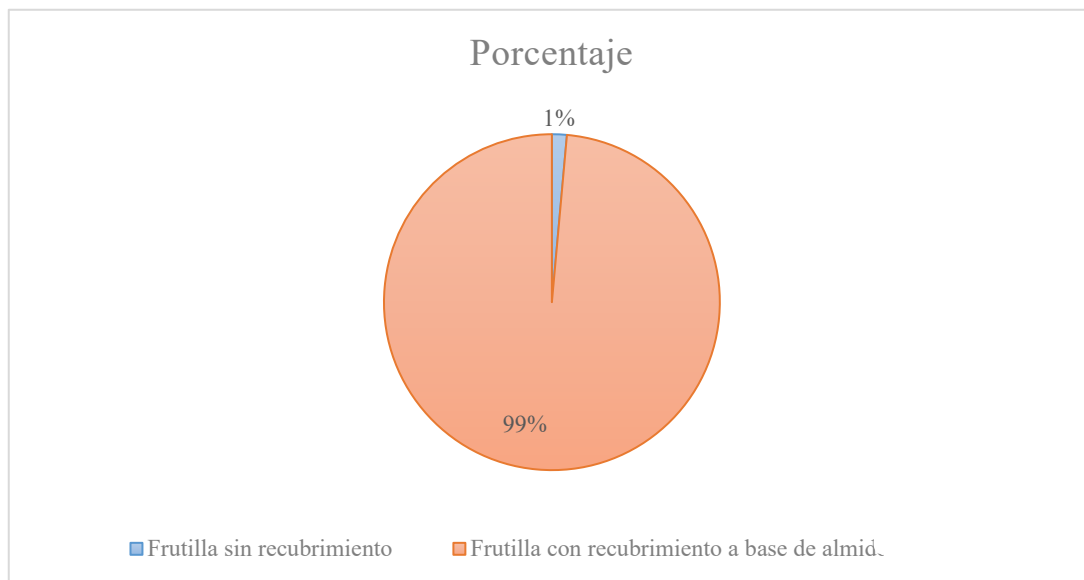
**Table 1. Evaluation of appearance**

| Sample              | Percentage (%) |
|---------------------|----------------|
| Uncoated strawberry | 1              |
| Coated strawberry   | 69             |
| TOTAL               | 70             |

In the preference test carried out, the appearance of a total of 70 strawberries was evaluated, which were classified into two groups: uncoated strawberries and coated strawberries. According to the data presented in Table 1, the results are eloquent,



revealing a notable inclination towards coated strawberries, since 69% of the participants opted for this group. This finding indicates that the coating has a positive impact on the aesthetic perception of strawberries, suggesting that consumers may associate this characteristic with greater freshness or quality of the product. In contrast, only 1% of respondents showed a preference for uncoated strawberries, which highlights the effectiveness of the coating in improving the visual acceptance of this fruit. These results are fundamental for future marketing strategies and presentation of strawberries in the market.



**Graph 1. Results obtained**

In the analysis of the results obtained in Graph 1, the appearance of strawberries with and without coating was evaluated using an untrained sensory panel composed of 70 panelists. The samples were presented randomly and coded on disposable plates, which guaranteed objectivity in the evaluators' choices. The findings are compelling, since 99% of the participants showed a clear preference for strawberries with a starch-based coating. This high percentage of acceptance suggests that the coating not only improves the visual aesthetics of the fruit, but can also positively influence the general perception of quality among consumers. This result highlights the importance of presentation characteristics in the marketing of strawberries, indicating that the coating could be an effective strategy to increase the acceptance of the product in the market.

#### Microbiological analysis

**Table 2: Analysis of molds and yeasts**

| Days | Uncoated strawberry  | Strawberry with cassava alido (15%) | with coating | Strawberry coated with cassava starch (25%) |
|------|----------------------|-------------------------------------|--------------|---------------------------------------------|
| 1    | 1.7 x10 <sup>1</sup> | <10                                 |              | <10                                         |



|   |                   |                   |                    |
|---|-------------------|-------------------|--------------------|
| 2 | $2.1 \times 10^2$ | $<10$             | $<10$              |
| 3 | $3.2 \times 10^4$ | $1.2 \times 10^1$ | $1.1 \times 10^1$  |
| 4 | $1.9 \times 10^5$ | $1.7 \times 10^2$ | $1.45 \times 10^2$ |
| 5 | $2.3 \times 10^7$ | $2.3 \times 10^3$ | $2 \times 10^3$    |

The results obtained from the microbiological tests described in Table 2, carried out in the biological sciences laboratory of the faculty of livestock sciences from the first day to the 5th day with and without coating, show that the data obtained from the coated strawberry meets the requirements that they should have according to INEN 2427 - 772 for fresh fruits, while the uncoated fruit does not comply due to its high pathogenic microbiological content, so we can say that the edible coating complies. with the appropriate conditions for its proper preparation (14).

### Costs

**Table 3. Cost analysis**

| Category                     | Qty | unit | Unit price  |
|------------------------------|-----|------|-------------|
| <b>DIRECT COSTS</b>          |     |      |             |
| Cassava starch               | 6   | g    | 0,65        |
| Bottled water                | 200 | ml   | 0,5         |
| Glycerin                     | 3   | ml   | 0,8         |
| <b>Total</b>                 |     |      | <b>1,95</b> |
| rice starch                  | 6   | g    | 0,8         |
| Bottled water                | 200 | ml   | 0,5         |
| Glycerin                     | 3   | ml   | 0,8         |
| <b>Total</b>                 |     |      | <b>2,1</b>  |
| <b>INDIRECT COSTS</b>        |     |      |             |
| Petri dishes                 | 10  |      | 3           |
| Aluminum Foil                | 1   |      | 0,5         |
| Film Paper                   | 1   |      | 0,75        |
| Labour                       | 4   | h    | 1,25        |
| Glass Plate                  | 1   |      | 2,5         |
| Electricity                  | 6   | w    | 0,1         |
| <b>Total</b>                 |     |      | <b>8,1</b>  |
| <b>TOTAL EXPENSES (15%)</b>  |     |      |             |
| Edible coating               |     |      | <b>1,95</b> |
| Production cost/coating unit |     |      | 20          |
| Utility                      |     |      | 0,15        |



|                                |            |
|--------------------------------|------------|
| <b>TOTAL INCOME</b>            | <b>3</b>   |
| Benefit/Cost                   | 1,05       |
| <b>TOTAL EXPENDITURE (25%)</b> |            |
| Edible coating                 | <b>2,1</b> |
| Production cost/coating unit   | 20         |
| Utility                        | 0,15       |
| <b>TOTAL INCOME</b>            | <b>3</b>   |
| Benefit/Cost                   | 0,9        |

Table 3, presented, provides a comprehensive breakdown of the costs associated with the production of an edible coating, possibly starch-based, covering both direct and indirect costs. Direct costs detail expenses related to essential raw materials, including cassava starch, rice starch, bottled water, and glycerin. Two coating variants are compared, highlighting that the option based on rice starch has a slightly higher total cost than its cassava starch counterpart. Regarding indirect costs, the materials necessary for production are considered, such as Petri dishes, aluminum foil, plastic wrap and glass plates, as well as the cost of labor and other expenses, including electricity (15).

The results reflect a projection of the total costs per coating unit, which integrates both direct and indirect costs, and provides an estimate of the profit per unit, considering two scenarios of total expenses of 15% and 25%. This projection suggests that the profit margin can fluctuate based on various factors, such as production volume and sales prices. In addition, the table allows evaluating the sensitivity of the profit to variations in production costs, which is crucial for making strategic decisions.

## DISCUSSION

The results obtained in the present study show that the application of an edible coating based on cassava starch had an extremely favorable and statistically significant effect on the sensory acceptance of strawberries, compared to the control group that lacked said coating. This finding is in complete agreement with what was reported by (11), (13), who point out that the high carbohydrate content present in cassava provides an important energy value and facilitates the formation of a protective layer on the surface of the product, as was evident in the case of coated strawberries.

However, although the coated group obtained a significantly higher preference (99%) in the sensory test carried out with a panel of untrained consumers, the control group achieved a higher average sensory acceptance. This suggests that, although the coating significantly improved the appearance and overall acceptance of strawberries, it may have had a slight negative impact on some of the specific sensory properties, as indicated by the findings of the study by (17), who found that edible coatings can slightly alter certain sensory characteristics of fruits, but still maintain satisfactory overall acceptability by consumers (18) and (19).



Regarding the shelf life of the strawberries, the microbiological results showed that the coated samples had a significantly lower microbial load of molds and yeasts compared to the control group. These data strongly correlate with what was reported by (20), (21) and (22), who found that coatings based on compounds such as chitosan, glycerol and gum arabic have a high potential to extend the useful life of fruits such as bananas and strawberries, thanks to their proven properties that inhibit the growth of microorganisms.

Subsequently, the cost-benefit analysis revealed that the 15% cassava starch-based coating presents greater profitability compared to the 25% formulation, with a profit margin of \$1.05 per unit. This highlights the crucial importance of optimizing the coating composition to achieve an appropriate balance between production costs and the benefits obtained in terms of product quality and shelf life (23) and (24).

Finally, the use of an edible coating based on cassava starch proved to be a viable and extremely promising alternative to improve the sensory acceptance and shelf life of strawberries, while offering a profitable option from the point of view of cost analysis. These findings open the door to future research that delves into the effect of different starch concentrations and the addition of other components in the coating formulation, in order to further optimize its performance and commercial viability in the post-harvest conservation of this type of fruit (17).

## CONCLUSIONS

The preference test carried out with a panel of untrained consumers revealed that 99% of participants showed a clear inclination towards coated strawberries, suggesting that this treatment significantly improves the appearance and overall perception of quality of the product.

Regarding shelf life, microbiological analyzes showed that the coated samples had a notably lower microbial load of molds and yeasts compared to uncoated strawberries. This shows that the cassava starch-based coating has an inhibitory effect on the growth of microorganisms, which translates into a longer shelf life and safety of the product.

Subsequently, the cost-benefit analysis indicated that the coating formulation with 15% cassava starch presents greater profitability, with a profit margin of \$1.05 per unit, compared to the 25% variant. This highlights the importance of optimizing the composition of the coating to achieve an appropriate balance between production costs and the benefits obtained in terms of quality and conservation of the strawberries.

Furthermore, the use of an edible coating based on cassava starch is emerging as a viable and extremely promising alternative to improve sensory acceptance, extend shelf life and optimize profitability in the postharvest conservation of strawberries. These findings open the door to future research that delves into the effect of different starch concentrations and the addition of other components in the coating formulation, in order to further enhance its performance and commercial viability.

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