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Quality and shelf life of blueberry (*Vaccinium myrtillus*) with edible mucilage coating of coffee (*Coffea arabica*)

Calidad y vida útil del arándano (*Vaccinium myrtillus*) con capa de mucílago comestible de café (*Coffea arabica*)

Qualidade e prazo de validade do mirtilo (Vaccinium myrtillus) com revestimento de mucilagem comestível de café (Coffea arabica)

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ABSTRAC

Blueberries are highly valued globally for their high antioxidant content and resilience to diverse agroclimatic conditions. This study examines the effects of coating blueberries (*Vaccinium myrtillus*) with an edible coating (CR) made from coffee mucilage on their shelf life and quality. The coating was applied at three different concentrations of coffee mucilage (3%, 5%, and 7%) and subjected to three storage temperatures (20±2 ºC, 4 ºC, and -1 ºC). The research findings indicate that the utilization of a coating formulation containing 5% coffee mucilage, 2.5% starch, and 20% glycerol effectively reduces weight loss in berries at three storage temperatures (20±2, 4, -1 ºC), diminishes titratable acidity, and preserves sugars in comparison to uncoated berries. This creates the possibility of using the coffee-mucilage-based coating as a viable replacement to prolong the shelf life of blueberry and Andean berry crops.

Keywords: Blueberry; mucilage coffee; storage temperature; edible coating

RESUMEN

Los arándanos son muy valorados a nivel mundial por su alto contenido de antioxidantes y su resistencia a diversas condiciones agroclimáticas. Este estudio examina los efectos de recubrir los arándanos (*Vaccinium myrtillus*) con una capa comestible (CR) hecha de mucílago de café sobre su vida útil y calidad. El recubrimiento se aplicó a tres concentraciones diferentes de mucílago de café (3%, 5% y 7%) y se sometió a tres temperaturas de almacenamiento (20±2 ºC, 4 ºC y -1 ºC). Los resultados de la investigación indican que la utilización de una formulación de recubrimiento que contiene 5% de mucílago de café, 2,5% de almidón y 20% de glicerol reduce eficazmente la pérdida de peso en las bayas a tres temperaturas de almacenamiento (20±2, 4, -1 ºC), disminuye la acidez titulable y conserva los azúcares en comparación con las bayas sin recubrimiento. Esto crea la

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posibilidad de utilizar el recubrimiento a base de mucílago de café como un reemplazo viable para prolongar la vida útil de los cultivos de arándanos y bayas andinas.

Palabras clave: Arándanos, mucílago de café, temperatura de almacenamiento, recubrimiento comestible

RESUMO

Os mirtilos são muito apreciados em todo o mundo pelo seu elevado teor de antioxidantes e pela sua resistência a várias condições agroclimáticas. Este estudo examina os efeitos do revestimento de mirtilos (Vaccinium myrtillus) com um revestimento comestível (CR) feito de mucilagem de café na sua vida útil e qualidade. O revestimento foi aplicado em três concentrações diferentes de mucilagem de café (3%, 5% e 7%) e submetido a três temperaturas de armazenamento (20±2 ºC, 4 ºC e -1 ºC). Os resultados da investigação indicam que a utilização de uma formulação de revestimento contendo 5% de mucilagem de café, 2,5% de amido e 20% de glicerol reduz eficazmente a perda de peso das bagas a três temperaturas de armazenamento (20±2, 4, -1°C), diminui a acidez titulável e preserva os açúcares em comparação com bagas não revestidas. Isto cria a possibilidade de utilizar o revestimento à base de mucilagem do café como um substituto viável para prolongar a vida útil das colheitas de mirtilos e bagas andinas.

Palavras-chave: Mirtilos, mucilagem de café, temperatura de armazenamento, revestimento comestível

INTRODUCCTION

Blueberries (*Vaccinium myrtillus*) are the fourth most economically valuable fruit worldwide due to their antioxidant content and ability to endure diverse agroclimatic conditions (Faria et al., 2005). These nutritional benefits make blueberries a highly desirable fruit (Carpio, 2019). They are low in sodium, rich in fibre, refreshing, tonic, astringent, diuretic, and contain vitamin C and hippuric acid. Numerous studies have examined the advantageous effects of consuming berries, due to their ability to influence cellular metabolism and reduce the impact of free radicals associated with ageing, heart disease, cancer, Alzheimer's and elevated HDL levels (Bilawal et al., 2021). In addition, there is a correlation with a lower incidence of cardiovascular conditions (Habanova et al., 2016).

The climatic diversity of the Andean region facilitates the growth of many native berries (Parodi & Benavides, 2021). This potential extends to 7,000 hectares, thereby presenting substantial commercial opportunities (Sierra and Selva Exportadora, 2016).

On the contrary, coffee production and its processing result in a significant amount of by-products, including 39.4% of pulp, 21.6% of mucilage, and 10.4% of exocarp (Pinto et al., 2013). Sadly, these by-products remain underutilized and are inadequately discarded, thus causing water and soil contamination (Pinto et al., 2013; Dadi et al., 2018). An estimated 82,000 tonnes of coffee mucilage are discharged annually into streams, rivers, or lakes (Pinto et al., 2013; Dadi et al., 2018). This is a problem as the organic content in the effluent reduces the oxygen levels by up to 0.25 mg/L (Dadi et al., 2018). The presence of organic matter and nutrient content poses a significant risk of eutrophication. The primary factors affecting the pollutant parameters of the water resource are the variations in soaking time of coffee beans, the fermentation of pulp, and the absence of suitable treatment facilities (Dadi et al., 2018).

The existence of coffee fermentation by-products has prompted researchers to seek environment-friendly alternatives and strategies by using these substances to create a new type of product like edible films. These films are being put on fruits and vegetables to hinder the proliferation and dispersion of external pathogens, thereby prolonging their preservation (Vázquez-Briones, 2013; Fernández et al., 2017; Aguilar-Duran, 2020). Edible coatings are a sustainable technology used in many products to control moisture transfer, gas exchange, and oxidation processes (Dhall, 2013). They add an extra protective layer to the product and can have the same effect as modified atmosphere packaging by regulating internal gases (Dhall, 2013; Al-Tayyar et al., 2020). One of the main benefits of using edible coatings is the ability to add different active ingredients to the polymeric matrix, which can be safely consumed along with food. This enhances the overall safety, nutritional, and sensory qualities (Aguirre-Vargas, 2015; Fernández et al., 2017). Coatings comprising of carbohydrates, proteins, and lipids have demonstrated a high efficacy in preserving fruits and vegetables (Riva et al., 2020; Al-Tayyar et al., 2020). Furthermore, these coatings are safe for consumption along with the produce (Aguirre-Vargas, 2015).

With the goal of utilizing coffee byproducts, this study aims to evaluate the quality and shelf life of *Vaccinium myrtillus* blueberries coated with edible *Coffea arabica* mucilage. The intention is also to increase the duration of blueberry storage.

MATERIALS AND METHODS

The experiment implemented a completely randomized design (CRD) with a 3Ax3B factorial arrangement of three independent variables. The first factor, A, was the percentage of coffee mucilage (%) at levels 5, 6, and 7. The second factor, B, was the storage temperature (°C), with levels of 20±2, 4, and -1. There were 9 treatments in total, each with 3 replications across 27 experimental units.

Obtaining coffee mucilage and edible coating

Pulped, mature coffee beans from the Lonya Chico district of Luya Province in the Amazonas Region were utilized in this research. The methodology used by González (2011) was followed to acquire powdered mucilage. Similarly, the edible coating was created by adapting the methodology described by González (2011), using mucilage obtained in the Agroindustrial Technology laboratory at the National University Toribio Rodríguez of Mendoza.

Application of the edible coating

The formulation process involved creating a mucilage solution combined with distilled water, with varying concentrations of 5%, 6%, and 7% w/v. This was accomplished through constant stirring over a period of 90 minutes. Additionally, glycerol (20%) and starch (2.5%) were introduced to this blend. To apply the coating, it was cooled in the refrigerator at 4 ºC, a process that was completed by immersing the blueberry berries for 30 seconds. After drying with the aid of a fan for six hours, the berries were spread out and coated before being stored in polyethylene (PET) trays to be preserved at a range of temperatures, including those for refrigeration and freezing [-1, 4, 20±2].

Evaluation of pH and total soluble solids (degrees Brix)

The juice was obtained by crushing the fruits in a mortar, and then measured using a digital potentiometer in accordance with AOAC: Official Methods of Analysis, 2005. The percentage of soluble solids in the obtained juice was determined using a manual ATC refractometer with temperature compensation, based on the same standard.

Blueberry Fruit Weight Loss

The weights of the fruit were determined using the gravimetry method and were expressed in grams. The percentage of weight loss was calculated in relation to the initial weight of the fruits before preservation (100%) using the subsequent equation:

$$\text{Weight loss } = \frac{\text{Initial weight} - \text{final weight}}{\text{fruit weight}} * 100$$

Acidez titulable

The acidity of the fruit extract was determined using the titration method. Citric acid was selected as the acidity indicator due to its prominence according to the AOAC: Official Methods of Analysis, 2005. To a 50 mL container, 1 mL of fruit extract, 9 mL of ultrapure water and 3 drops of phenolphthalein were added. The mixture was subsequently titrated with 0.1 N sodium hydroxide (NaOH) until a change of colour was observed, and the information was carefully documented.

Determination of ashes

The ash percentage was determined by incinerating organic matter in the muffle at 500°C to 600°C until weight stabilization was achieved, using method No. 940.26 and formula specified by the standard (AOAC: Official Methods of Analysis, 2005).

$$\% \text{ Total ashes} = \frac{\text{m2} - \text{m0}}{\text{m1} - \text{m0}} * 100$$

m2 = The mass in grams of the capsule containing the ashes.

m1 = The mass of the capsule containing the sample is expressed in grams

m0 = The mass of the empty capsule in grams.

Sensorial analysis

Twelve consumer type panelists, partially trained, participated in measuring the attributes of color, appearance, texture, flavour, aroma, and acceptance using a 10-point hedonic scale.

Data Analysis

Before carrying out any analysis of variance, it was confirmed that normality and homogeneity of variance prerequisites were met. For data with normally distributed, homogeneous variances, ANOVA and mean comparisons were undertaken employing Tukey (a = 0.05). In case of data not conforming to normality assumptions and showing heterogeneous variances, non-parametric analysis of variance was conducted using the Friedman test.

RESULTS

Physicochemical analysis of mucilage and blueberry

Physical and chemical analyses of both the mucilage and blueberries show similar low pH with close titratable acidity. However, blueberries have a significantly higher Brix value (14.05) compared to mucilage, which only has 4.17 Brix. Moreover, mucilage has a higher ash content of 4.09%, while blueberries have a high percentage of moisture at 70.53% (Table 1).

Table 1. Physicochemical analysis for mucilage powder and fresh blueberry

Parameters	Mucilage powder	Blueberry
pH	3.77	3.52
Titratable acidity (%)	1.21	1.25
ºBrix	4.17	14.05
Fiber	6	1.28
Ashes (%)	4.09	0.44
Humidity (%)	9.67	70.53

Percentage of acidity in blueberry fruits after applying the coating

During the 28-day storage period at commercial maturity, the blueberries exhibited an average titratable acidity of 10.3 g citric acid per 100 g of sample. The percentage of acidity fluctuated between 0.99% and 1.13% of titratable acidity during storage, with T1 (concentration of 5 at -1ºC) and T8 (concentration at 4ºC) treatments having the highest percentage of titratable acidity (1.12% and 1.13%, respectively) compared to the control sample that registered 0.95% (Figure 1).

Table 2. Titratable acidity was measured in the various treatments.

Treatments	Acid percentage
T1 (C5 X 20°C), 5% coffee mucilage + 20 °C Storage temperature.	1.12
T2 (C5 X 4°C), 5% coffee mucilage + 4°C Storage temperature.	1.06
T3 (C5 X -1 °C), 5% coffee mucilage + -1 °C Storage temperature.	99
T4 (C6 X 20 °C), 6% coffee mucilage + 20 °C Storage temperature.	1.06
T5 (C6 X 4 °C), 6% coffee mucilage + 4 °C Storage temperature	1.01
T6 (C6 X -1 °C), 6% coffee mucilage + -1 °C Storage temperature	1.01
T7 (C7 X 20 °C), 7% coffee mucilage + 20 °C Storage temperature	1.08
T8 (C7 X 4 °C), 7% coffee mucilage + 4 °C Storage temperature	1.13
T9 (C7 X -1°C), 7% coffee mucilage + -1 °C Storage temperature	1.03
T0 (Control) without coverage to 20 °C Storage temperature	0.95

C5: Formulated with 50 grams of coffee mucilage, 25 grams of starch, and 200 grams of glycerol.
C6: Formulated with 60 grams of coffee mucilage, 25 grams of starch, and 200 grams of glycerol.
C7: Formulated with 50 grams of coffee mucilage, 25 grams of starch, and 200 grams of glycerol.

Total soluble solids content

Our analysis indicates that blueberries coated with an edible coating and stored at temperatures of 4 ºC and -1 ºC have a higher sugar content as compared to those stored at room temperature (20 ±2 ºC). Among all the treatments, T2 (C5 x4 ºC) showed the highest concentration of °Brix, measuring 14.1. This suggests a significant difference among storage temperatures when concentration and temperature interact. However, the other treatments did not show any significant difference between them (Figure 1).

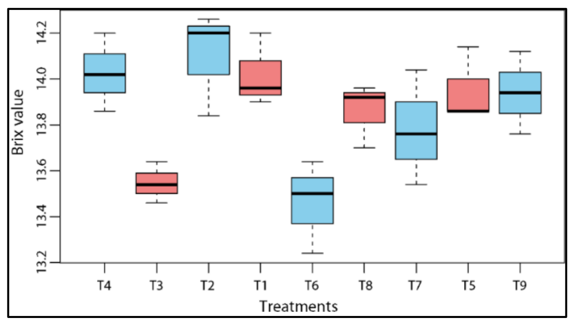

Figure 1. Interaction between concentration and temperature on soluble solids content in blueberries coated with an outer layer.

pH analysis

The pH of blueberries decreases when applying the coffee mucilage coating, resulting in a pH of 1.8. In comparison, the control group had a higher level of 3.7. The group with the lowest pH value was T1 with a concentration of 7 at 20°C, registering a value of 1.8 (Figure 2).

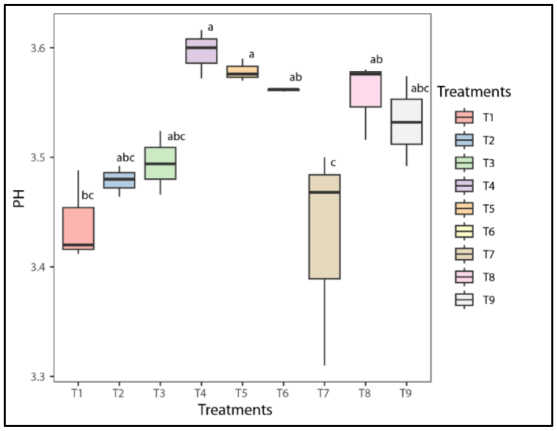

Figure 2. pH variation in coated blueberry.

Weight loss percentage

The weight change percentage during the 28-day storage period is presented. Treatments at room temperature underwent the greatest weight loss during storage. The control treatment (S/R without coating) experienced the highest weight loss percentage at 22.9%, while the best treatment T1 (C5x-1 ºC) had the lowest weight loss percentage at 6.1% when treated with the coating (Figure 3).

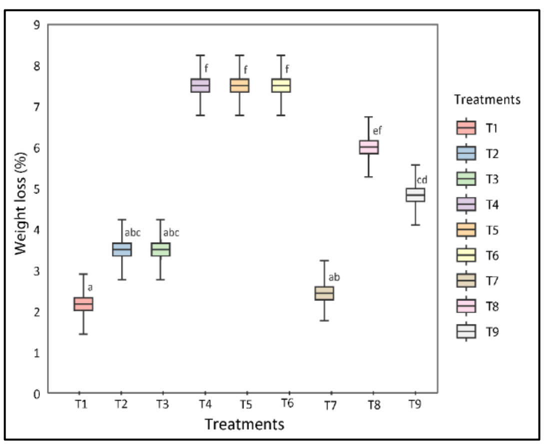

Figure 3. Percentage of weight loss in cranberry-coated berries at different storage temperatures.

Sensorial analysis

Figure 4 shows the results of the Friedman non-parametric test, which reveals a significant difference among treatments with a p-value of less than 0.05 (0.0039). T3, with a 5% concentration and storage at -1ºC, and T2, with a 5% concentration and storage at 4ºC, performed the best in terms of the organoleptic characteristic "Appearance" (Figure 4-A). The treatments T3, T6, and T9, stored at -1ºC with concentrations of 5%, 6%, and 7% respectively, were found to be the most effective for preserving the blueberry fruit's color, according to the organoleptic criterion (Figure 4-B). Therefore, these treatments are expected to yield better results at the given concentrations. On the other hand, T1 (5% concentration) stored at -1ºC was found to be the most successful treatment for preserving the blueberry fruit's aroma, according to the same criterion (Figure 4-C). Finally, the optimal treatments for the sensory attribute "Texture" were T1 with a 5% concentration, maintained at -1°C, and T2 with a 5% concentration, stored at 4°C (Figure 4-D).

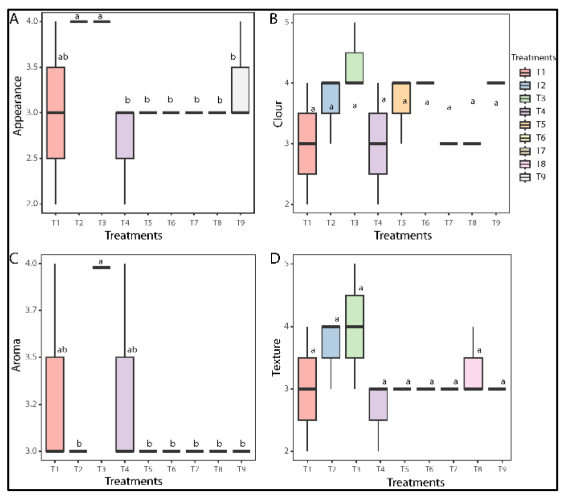

Figure 4. Sensory analysis of blueberry berries treated with edible blueberry coating.

DISCUSSIONS

Blueberries have a high perishability rate, necessitating proper handling for delivering a superior product to consumers (Forney et al. 2022). Although blueberry fruits can endure high levels of

CO_2, prolonged exposure can result in fruit softening and discoloration of the pulp (Alsmairat et al., 2011). Recently, blueberries and other fruits have gained attention from the food industry and consumers due to their highly effective antioxidant properties, which may protect against cancer and aging (Feng et al., 2022). However, transporting these fruits over long distances can decrease their moisture content, rendering current conservation methods inefficient (Feng et al., 2022). Looking for solutions that are product-friendly or easy to use is a common response to such problems. For instance, one possible solution is storing the product in controlled atmospheres (Forney et al. 2022), even though this may result in a considerable increase in acidity (Forney et al. 2022). However, when employing alternative techniques like edible coatings, as utilized in this study, the level of titratable acidity decreases, providing a beneficial characteristic for fruit preservation and enhancing nutritional quality when treated with this natural coating.

Regarding soluble solids (ºBrix), it has been determined that there is an increase in sugars, which is a function of mucilage concentrations and storage temperatures. This increase is due to the conversion of organic acids into reserve carbohydrates and subsequently into simple saccharides, driven by the low photosynthetic capacity (Ayala et al., 2012). Technical terms such as ºBrix will be explained since ripe fruits rely on this type of sugar for the formation of organic compounds that determine their color, flavor, and quality (Liu et al. 2016; Li et al. 2022). Therefore, while fruits treated with RC and stored at low temperatures maintain their sugar content, their sugar content increases as the temperature rises (20°C), despite the coating treatment. This effect also corresponds to weight loss. Blueberries treated with coatings and stored at three different temperatures (-1, 5, and 20 °C) exhibited significant differences in weight loss after 28 days of storage in comparison to untreated berries, which experienced greater weight loss at all three storage temperatures. This indicates that dehydration occurs in untreated fruit due to the transpiration process, while treated fruit retain their weight better. (Triunfo et al. 2023): The edible coating (RC), such as coffee mucilage, produces a semi-permeable effect that acts as a barrier for the passage of CO_2 and RH (Relative Humidity). This effect bestows the fruits with the desired marketable and consumer-oriented characteristics.

As storage time increases, the pH decreases due to accelerated degradation of cellulosic substances, resulting in loss of firmness and an increase in soluble sugars (Lupano, 2013). The study revealed pH variations and increases (from 3.4 to 3.7) among different treatments compared to the initial measurement of 3.52. This could possibly be due to the ripening of the fruits, since as time passes the soluble solids increase and the pH also increases. It is not unusual, since the shelf life of blackberry fruits can be extended for 15 days at 4 ºC of storage, preserving the physicochemical and physiological properties by using a coating based on hydroxypropyl methylcelluloseH (PMC) with the inclusion of bee era (CA). (Villegas & Albarracín, 2016). These ways of preserving fruits or vegetables guarantee food security and quality food for consumption or for agricultural export.

This study emphasizes the significance of employing natural coatings like coffee pulp mucilage as an alternative to extend the shelf life of

Andean fruits like blueberries. Additionally, aloe vera gels present themselves as another conservation option (Vieira et al., 2016; Ates et al., 2022). Therefore, this study provides support and reliability to the demonstrated results regarding the utilization of coffee mucilage as an alternative solution to address dehydration problems. The proliferation of fungi and bacteria due to dehydration results in degradation and subsequent economic losses for the producers and other stakeholders in the Andean fruit production chain.

CONCLUSIONS

The coffee mucilage and plasticizer in the coating significantly reduce blueberry fruit weight loss, potentially extending their shelf life. Concentrations of the three coating components - coffee mucilage, cassava starch, and glycerol-cause rapid changes in weight, texture, appearance, color, aroma, and flavor. Thus, the optimal mixture for the coating consisted of 5% coffee mucilage, 2.5% starch, and 20% glycerol, resulting in decreased weight loss at temperatures of -1, 4, and 20 ºC. Thus, the optimal mixture for the coating consisted of 5% coffee mucilage, 2.5% starch, and 20% glycerol, resulting in decreased weight loss at temperatures of -1, 4, and 20 ºC. This lays the foundation for potential future utilization on diverse Andean fruits.

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