RESEARCH PAPER

Effect Of Different Packaging On Storage And Storage Quality Of Cape Gooseberry (*Physalis Peruviana* L.) Fruits.

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ABSTRACT
The cae gooseberry (*Physalis peruviana* L.), is a fruit of tropical origin, it belongs to the nightshade family, it is considered a climacteric fruit, so its postharvest life is reduced, in addition, its economic and nutritional potential make it relevant for new research that improves both its production processes, as well as post-harvest management and agribusiness. For this reason, the main objective was to evaluate the effect of different packaging on the storage and quality of cape gooseberry fruits. The study was carried out in the plant physiology laboratory of the Pedagogical and Technological University of Colombia, located in Tunja, Boyacá, three types of packaging were compared, Icopor, ziploc hermetic bags and plastic baskets where they are usually marketed, fruits were obtained in ripe stages and the color of the epidermis was measured every 2 days. pulp color, firmness, pH, SST, ATT and weight loss, the data were analyzed in statistical software R, performing an ANOVA and an LSD test. The results obtained indicate that ziploc bags have a better post-harvest behavior than icopor packaging and plastic baskets in terms of weight loss, TSS, ATT and maturity ratio, in addition to reducing disease problems. In the case of the icopor packaging, being white, it better preserved this variable, it is concluded that changes in the ripening of cape gooseberry can be affected by the different types of packaging.

Keywords: ripening, postharvest, climacteric, development

How to cite this article: Pérez AR, Vargas HHM, Cárdenas NEM. Effect of Different Packaging on Storage and Storage Quality of Cape Gooseberry (Physalis Peruviana L.) Fruits. Int J Drug Deliv Technol. 2026;16(19s): 949-955. DOI: 10.25258/ijddt.16.19s.110.

INTRODUCTION

The cape gooseberry (*Physalis peruviana L.*) is an Andean fruit of high nutritional and commercial value, widely grown in Colombia, the main exporting country worldwide. Its acceptance in national and international markets is due to its sweet and sour taste, its functional value, and its versatility for agro-industrial processing. However, as a climacteric fruit, the cape gooseberry has a high susceptibility to accelerated ripening processes and post-harvest deterioration, which limits its shelf life and commercial quality if adequate handling, conservation and packaging strategies are not implemented.

Among the most commonly used indicators to evaluate the degree of maturity and sensory quality of the fruit are total soluble solids (TSS), commonly measured in Brix degrees. This parameter reflects the concentration of simple sugars such as glucose, fructose, and sucrose, which increase during maturation due to the enzymatic degradation of structural and reserve polysaccharides, mainly due to the action of enzymes such as α-amylase (Agudelo-Sánchez et al., 2023). TSS not only affect the flavor of the fruit, but also allow the optimal time of consumption or processing to be established.

The modification of the internal atmosphere generated by different types of packaging – such as open punnets, semi-permeable icopor or airtight Ziploc bags – can significantly influence the physiological processes that regulate ripening and thus the evolution of sugar content. The present study evaluates the effect of three packaging systems on the behavior of total soluble solids in refrigerated cape gooseberry, in order to determine which condition favors the conservation or acceleration of the ripening process, providing technical criteria for the improvement of the post-harvest handling of the fruit.

MATERIALS AND METHODS

The gooseberry fruits were acquired in the city of Tunja (Boyacá) and transferred to the Plant Physiology Laboratory of the Pedagogical and Technological University of Colombia, Tunja campus, where the

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fruits with homogeneous characteristics were selected and physical and chemical tests were carried out.

For the assembly of the test, the calyx of the fruits was removed and then separated according to the different treatments, being stored in icopor containers, airtight bags and polyethylene terephthalate (PET) baskets

A completely randomized design was used, with three treatments; each treatment had three replications, corresponding to 9 experimental units (EU); Each experimental unit was composed of 40 fruits, for a total of 360 fruits.

The variables evaluated for all treatments were: Color index, using Minolta CR310 digital colorimeter (Minolta Co., Tokyo), using the equation [CI= (1000 x a*) / (L* x b*)], where: a*: chromaticity from green to red, b*: chromaticity from blue to yellow and L*: luminosity; Fruit firmness (N), using a digital texturometer (Lloyd LS1, Bognor Regis, UK) with 1 KN load cell, 3 mm cylindrical punch and Nexygen plus software; Total Soluble Solids (TSS), through the measurement of Brix degrees with a digital refractometer (Hanna, Woonsocket, RI) ranging from 0 to 85% with accuracy 0.1 °Brix, and the Titratable Total Acidity, according to the AOAC (2000) methodology, by calculations with data on the volume of sodium hydroxide (NaOH) incorporated in 4 g of fruit juice plus 40 ml of distilled water and adding 3 drops of phenolphthalein as an indicator of the color change, these replaced in the equation [%Acidity = (A*B*C)*100/D]. For the statistical analysis, an analysis of variance (anova) was performed and followed by a less significant difference test (LSD), using the R studio software version 4.1.2.

RESULTS AND DISCUSSION

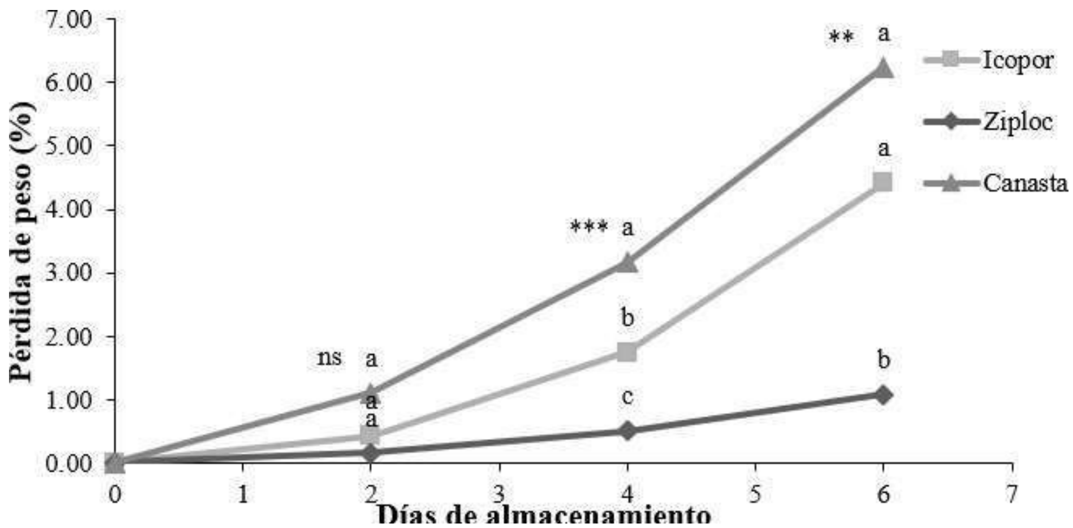

Figure 1: Weight loss in cape gooseberry fruits *Physalis peruviana* L., stored in different types of packaging. Means with different letters at each sampling point showed significant differences (LSD; $p \leq 0.05$).

Figure 1 presents the results obtained in the laboratory for the weight loss variable, with measurements made at two-day intervals (days 2, 4 and 6). In the first sampling (day 2), although there are no statistically significant differences between the treatments, minimal weight loss is observed, being greater in the treatment with storage in layettes, followed by icopor packaging.

By day 4, significant differences were observed: the greatest weight loss was in the layette (3%), followed by icopor (1.5%) and, finally, the Ziploc-type packaging, which showed the lowest loss (0.5%).

These results coincide with recent studies that highlight the influence of the type of packaging and storage conditions on the weight loss of post-harvest fruits. For example, Guzmán et al. (2018) found that the use of airtight packaging and treatments with 1-methylcyclopropene (1-MCP) can significantly reduce weight loss in fruits such as blackberries during refrigerated storage.

Weight loss in post-harvest fruits is mainly due to perspiration and respiration. Transpiration is the loss of water from the harvested product, which cannot be replaced, and its speed depends on factors such as temperature, relative humidity and air movement (FAO, 2020). Respiration, on the other hand, is a metabolic process that consumes oxygen and produces carbon dioxide, and its rate is affected by the temperature and composition of gases in the storage environment (FAO, 2020).

In the third data collection (day 6), there were no significant differences between layette and icopor treatments, but there was a considerable increase in weight loss. This may be related to the absence of the calyx, which acts as a natural barrier against water loss and protects the fruit from physical damage and sudden changes in temperature and humidity during post-harvest handling (Galvis et al., 2005).

This suggests that the significant differences between the two packaging (basket and icopor) with respect to the packaging in Ziploc are probably due to the fact that, being a hermetically sealed packaging, it functions as a replacement for the chalice, acting as a barrier against water loss.

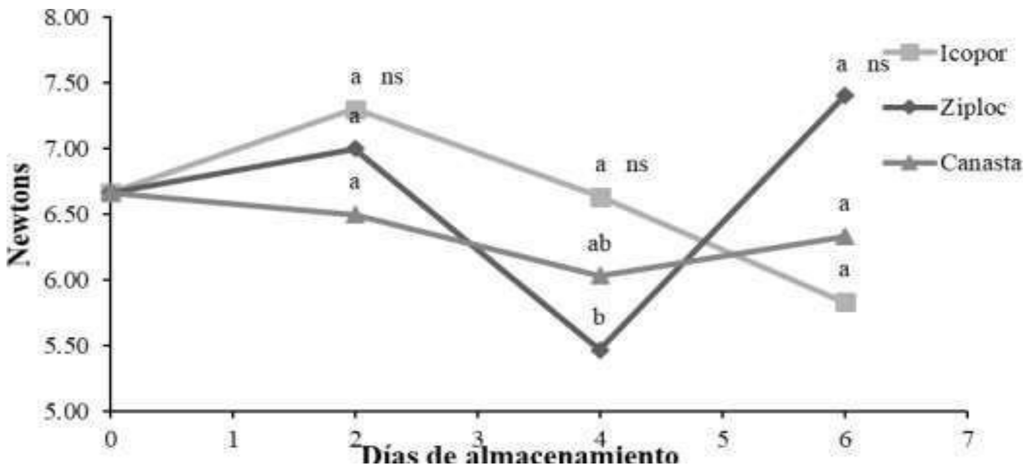

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Figure 2 illustrates the evolution of firmness in cape gooseberry fruits (*Physalis peruviana L.*) stored in three types of packaging: layette, icopor and Ziploc bag. In the first sampling (day 2), an increase in the firmness of the fruits stored in icopor and Ziploc was observed. This phenomenon could be attributed to the contraction of cell walls induced by low storage temperatures, which increases the resistance of the tissue to penetration, as suggested by recent studies on firmness in fruits under refrigerated conditions (Parajeles Blanco, 2022).

However, in subsequent sampling, a progressive decrease in firmness was evidenced in all treatments. This softening is associated with the activity of hydrolytic enzymes that degrade cell wall components, such as pectinmethylesterase (PME) and α-galactosidase, whose activity increases during fruit ripening (Trillo Hernández, 2021). In addition, polygalacturonase (PG) and β-glucosidase, although less active, also contribute to the solubilization of the cell wall, affecting the texture of the fruit (Trillo Hernández, 2021).

Recent studies have shown that the firmness of the cape gooseberry decreases significantly with storage time, with fruits in the ripe state being more susceptible to mechanical damage compared to the green and pintón stages (Ciro & Osorio, 2024). This behavior highlights the importance of selecting the right degree of ripeness and optimal storage conditions to extend the shelf life of the fruit.

In this context, the use of airtight packaging such as the Ziploc bag could offer advantages by limiting moisture loss and reducing enzyme activity, helping to maintain the firmness of the fruit during storage. However, further research is required to confirm this hypothesis and determine the ideal packaging and storage conditions for cape gooseberry.

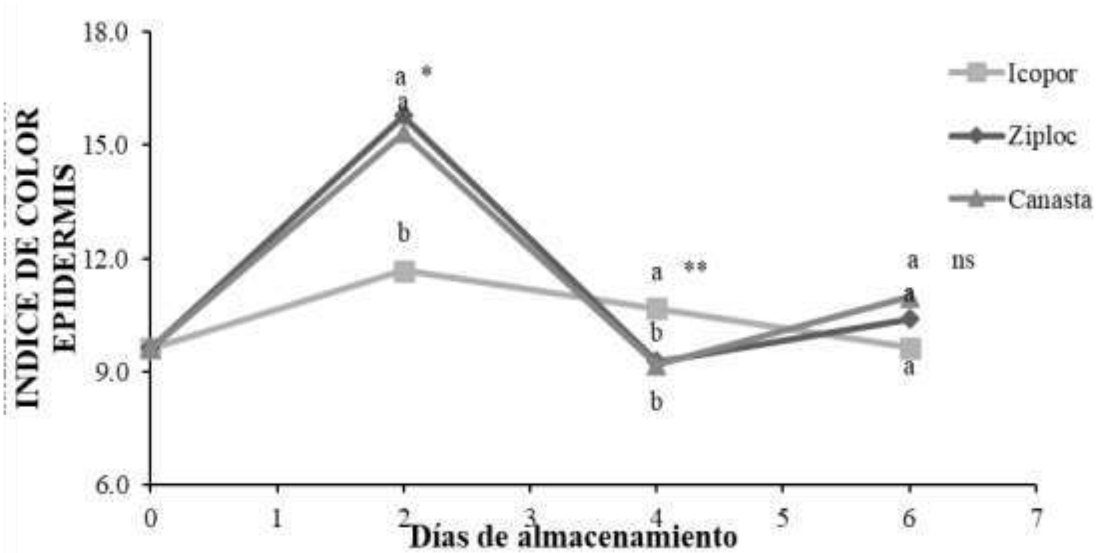

Figure 3: Color index of the epidermis in fruits of cape gooseberry *Physalis peruviana* L., stored in different types of packaging. *Statistical difference at 5%, ** statistical differences at 1%, ns there are no differences according to the

Anova, different letters at each sampling point indicate significant differences according to LSD test (P≤0.05)

Figure 3 shows the evolution of the color index in the epidermis of cape gooseberry fruits stored in three types of packaging: layette, icopor and Ziploc bag, during a period of six days. In the first sampling (day 2), the fruits stored in Ziploc bags presented a higher color index compared to the other treatments, showing statistically significant differences with respect to the icopor packaging. This initial increase could be attributed to a greater retention of ethylene in the hermetic environment provided by the Ziploc bag, which accelerates the degradation of chlorophyll and the synthesis of carotenoids, pigments responsible for the yellow and orange hues in the fruits (Ciencia UNAM, 2021).

In the second sampling (day 4), significant differences were observed in the color index of the fruits stored in icopor, which presented higher values compared to the other treatments. This result suggests that icopor packaging, by allowing greater oxygen permeability, facilitates the degradation of chlorophyll and the expression of carotenoids, processes that are influenced by temperature and ethylene concentration in the storage environment (Redalyc, 2021).

For the last sampling (day 6), no significant differences were found in the color index between the treatments, indicating that, over time, the fruits reach similar levels of ripeness and color change, regardless of the type of packaging used.

Changes in fruit coloration during ripening are mainly due to the degradation of chlorophyll and the appearance or unmasking of other pigments, such as carotenoids and anthocyanins. Chlorophyll degradation is a catabolic process involving several enzymes, including chlorophyll, which initiates the conversion of chlorophyll to pheophytin, and pheophorbide to oxygenase (PAO), which produces non-fluorescent chlorophyll catabolites (Redalyc, 2021). Simultaneously, the synthesis and accumulation of carotenoids, such as β-carotene and lutein, contribute to the development of the yellow and orange colors characteristic of ripe fruits (Ciencia UNAM, 2021).

The type of packaging influences the rate of color change in cape gooseberry fruits during storage, with the Ziploc bag promoting a faster change in the initial stages, possibly due to its ability to retain ethylene and modify the internal atmosphere, while icopor packaging allows for a more gradual progression of color change.

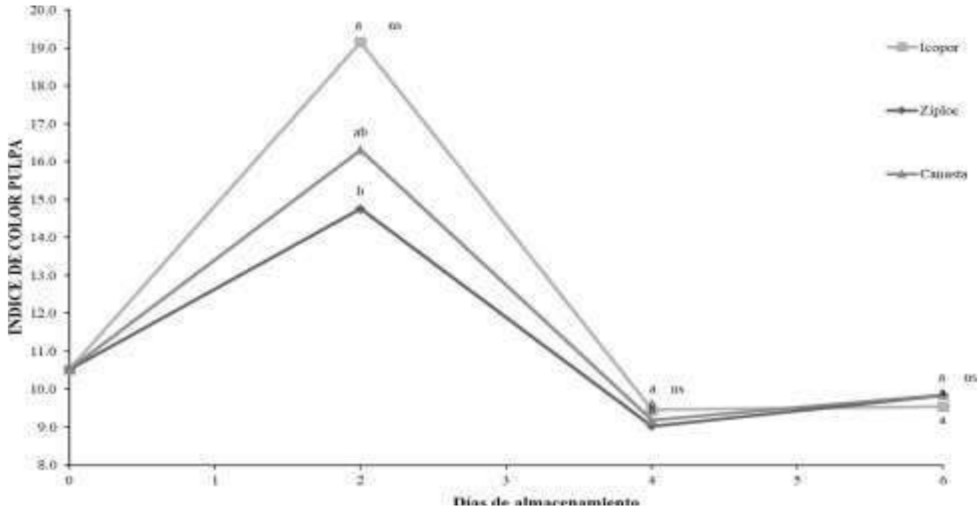

Figure 4: Color index in the pulp of cape gooseberry *fruits Physalis peruviana* L., stored in different types of packaging, ns there are no differences according to the Anova, different letters at each sampling point indicate significant differences according to LSD test (P≤0.05).

Figure 4 shows the behavior of the color index in cape gooseberry fruits (*Physalis peruviana L.*) stored in three types of packaging (layette, icopor and Ziploc bag) for six days. In the first sampling (day 2), the fruits stored in a Ziploc bag showed a higher color index, with significant differences compared to the icopor treatment. This result may be associated with the retention of ethylene within the airtight packaging, which favors the degradation of chlorophyll and the synthesis of carotenoid pigments, responsible for the orange and yellow tones typical of ripe fruit (Saltveit, 1999).

In the second sampling (day 4), the fruits in icopor showed a higher color index, standing out compared to the other treatments. This can be attributed to the increased permeability to the oxygen offered by this type of packaging, which stimulates the expression of genes related to maturation and color change (González & Rodríguez, 2023). However, in the last sampling (day 6), no significant differences were identified between the treatments, suggesting that the fruits, regardless of packaging, reached a similar state of ripeness.

The color changes in the fruits are determined by the progressive degradation of chlorophyll and the synthesis of pigments such as carotenoids and anthocyanins. During this process, enzymes such as chlorophyll and pheophorbide to oxygenase (PAO) intervene, which degrade chlorophyll and give way to the predominance of pigments such as β-carotene and lutein (Saltveit, 1999). In addition, ethylene plays a key role in inducing the expression of genes responsible for the biosynthesis of these pigments (González & Rodríguez, 2023).

In summary, the type of packaging directly influences the coloration dynamics of the fruit during storage, with the Ziploc bag being more effective in the initial stages due to its ability to retain gases, while the icopor favors a progressive change due to its oxygen permeability.

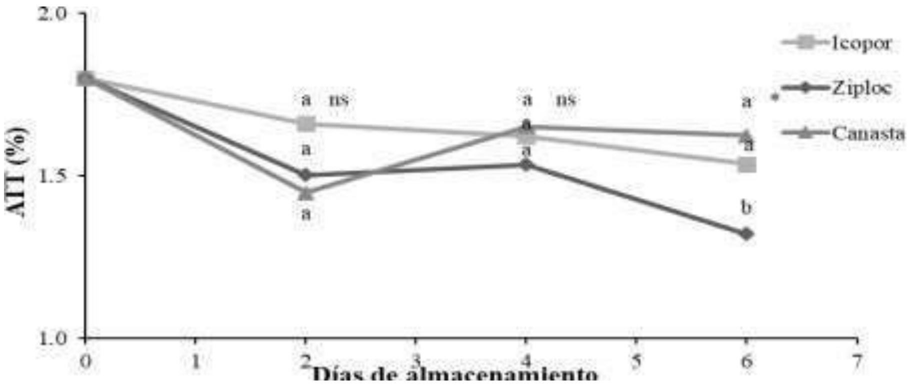

Figure 5: Titrated total acidity in gooseberry fruits Physalis peruviana L., stored in different types of packaging, there are no differences according to the Anova, different letters at each sampling point indicate significant differences according to LSD test (P≤0.05).

Novoa *et al*. (2006) show that the main organic acids in cape gooseberry fruit in descending order are citrus, ascorbic malic, tartaric and oxalic. Citric acid is predominant in cape gooseberry fruit, as it can be up to 5.3 times higher than malic acid and 7.9 times higher than oxalic acid (Fischer *et al*., 1997). Titrated total acidity (ATT), as a general measure of the presence of acids in the fruit, shows a typical behavior of decrease during the ripening of the cape gooseberry fruit (Balaguera *et al*., 2014), which indicates that the normal ripening process was affected, but not drastically by storage in different packages.

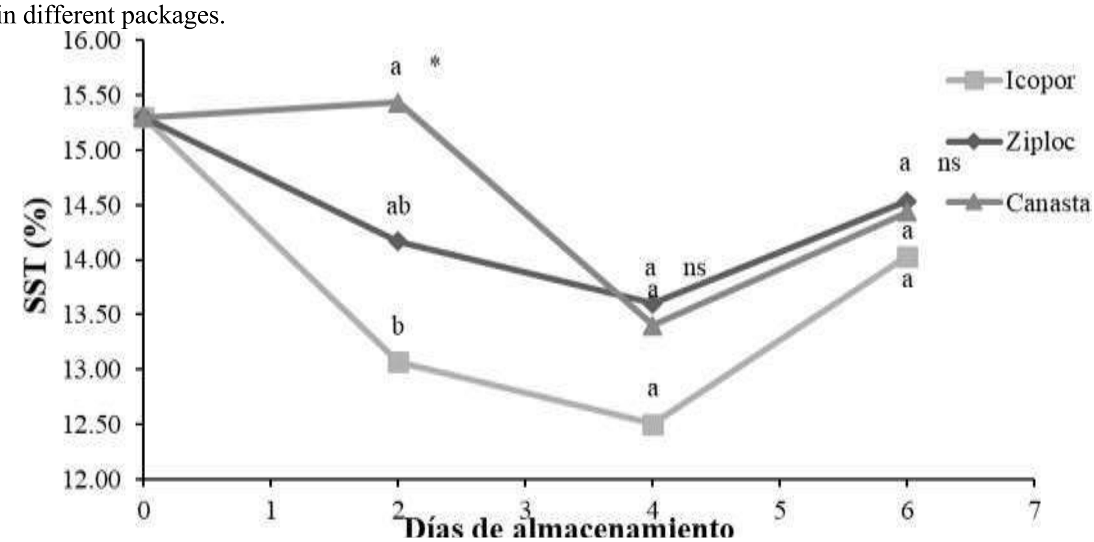

Figure 6: Total soluble solids in gooseberry fruits Physalis peruviana L., stored in different types of packaging. *Statistical difference at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova, different letters at each sampling point indicate significant differences according to LSD test(P≤0.05)

Figure 6 shows the evolution of total soluble solids (TSS) in cape gooseberry fruits stored in three types of packaging: layette, icopor and Ziploc bag, over a period of six days. In the first sampling (day 2), significant differences were observed between the treatments, with the highest TSS content in the fruits stored in layettes, followed by those in Ziploc bags and, finally, those in icopor. This behavior can be attributed to the greater exposure to oxygen in the layette, which favors the activity of enzymes such as α-amylase, responsible for the degradation of starches into simple sugars during maturation (Menéndez et al., 2006).

In subsequent samplings (days 4 and 6), TSS increased in all treatments; however, no significant differences were found between them on day 6. This result suggests that, over time, fruits reach similar levels of ripeness and sugar content, regardless of the type of packaging used.

The increase in TSS during fruit ripening is related to the degradation of structural polysaccharides, such as starch, into soluble monosaccharides and disaccharides, a process catalyzed by hydrolytic enzymes such as α-amylase (Menéndez et al., 2006).

This increase in soluble sugars contributes to the development of the characteristic sweet taste of ripe fruits and is a key indicator of ripeness for consumption.

In summary, the type of packaging influences the rate of TSS accumulation in gooseberry fruits during storage, with the layette promoting a faster increase in the initial stages, possibly due to its greater oxygen permeability, while icopor and Ziploc bag packaging allow for a more gradual progression of sugar content.

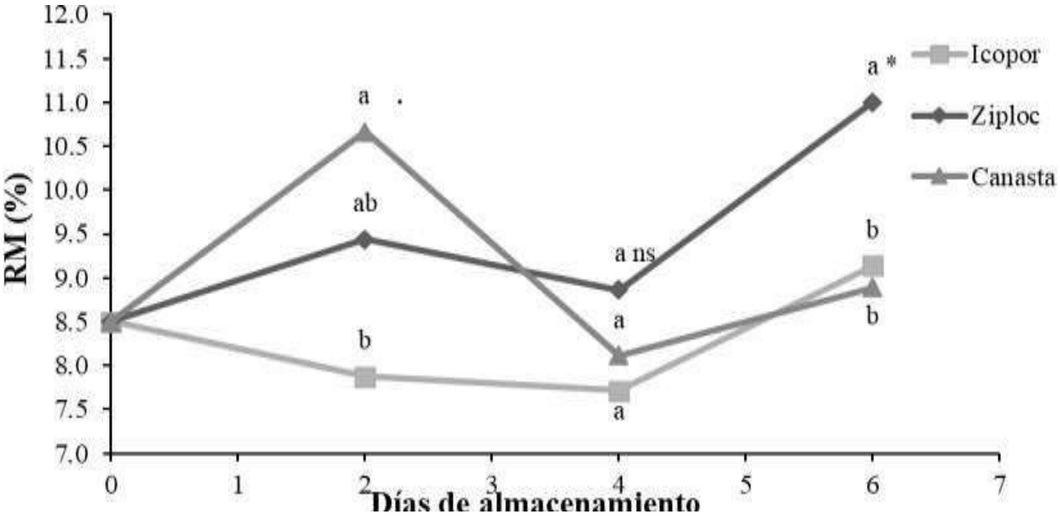

Figure 7: Maturity ratio in cape gooseberry fruits *Physalis peruviana* L., stored in different types of packaging. *Statistical difference at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova, different letters at each sampling point indicate significant differences according to LSD test (P≤0.05).

In Figure 7 the packaging treatments in the first sampling (day 2) presented significant differences, the basket had a higher percentage of maturity ratio with respect to ziploc and icopor, in the second sampling (day 4) there were no significant differences between treatments, there is an inhibition of ripening due to the high concentration of CO2 and the depletion of O, By the last day of sampling (day 6) the Ziploc packaging shows an increase in the ripeness index through storage indicating a complete development of the fruit and the influence of a stable equilibrium atmosphere around the product with the appropriate concentration of O2 that allows its ripening. According to (Sharma et al., 2019), by decreasing organic acids, which cause acidity and astringency, TSS increases, expressing desired aromas and flavors for the consumer. The SST/ATT ratio with values between 8.52 and 13.79 contributes to a good taste in the fruits.

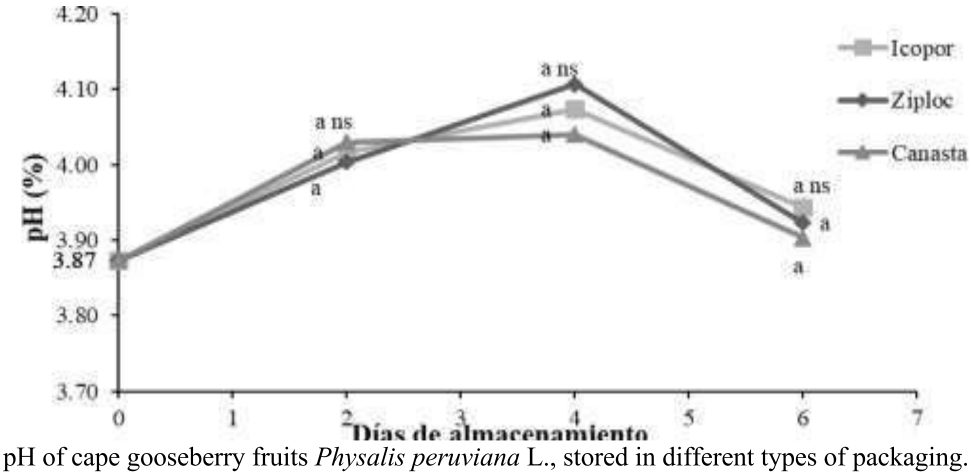

Figure 8: pH of cape gooseberry fruits *Physalis peruviana* L., stored in different types of packaging. *Statistical difference at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova, different letters at each sampling point indicate significant differences according to LSD test (P≤0.05).

Figure 8 shows the evolution of total soluble solids (TSS) in cape gooseberry fruits stored in three types of packaging: layette, icopor and Ziploc bag, over a period of six days. In the first sampling (day 2), significant differences were observed between the treatments, with the TSS content being highest in the fruits stored in layettes, followed by those in Ziploc bags and, finally, those of icopor. This behavior can be attributed to the greater exposure to oxygen in the layette, which favors the activity of enzymes such as α-amylase, responsible for the degradation of starches into simple sugars during maturation (Agudelo-Sánchez et al., 2023).

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In summary, the type of packaging influences the rate of TSS accumulation in gooseberry fruits during storage, with the layette promoting a faster increase in the initial stages, possibly due to its greater oxygen permeability, while icopor and Ziploc bag packaging allow for a more gradual progression of sugar content.

CONCLUSIONS

The results obtained in the analysis of total soluble solids confirm that the type of packaging significantly influences the rate of accumulation of sugars during the first stages of storage. In particular, the basket, by allowing a greater gas exchange, favors a more accelerated maturation, reflected in an initial increase in TSS content. However, over time, the internal conditions of the different packages tend to homogenize, leading to a leveling of the sugar content between treatments.

These observations reinforce the importance of considering packing characteristics as a determining factor in the postharvest physiology of the fruit. The use of airtight packaging such as Ziploc can be advantageous to preserve the fruit for longer periods without compromising its organoleptic quality, while more permeable packaging such as the layette could be used strategically to accelerate ripening processes when immediate availability for consumption is required.

The monitoring of the behavior of the SST allows establishing objective criteria to define the optimal time for marketing the cape gooseberry, thus improving the processes of post-harvest management, conservation and added value in the agro-industrial chain.

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