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EFFECT OF IMMERSION TIME IN 4% CALCIUM CHLORIDE SOLUTION AND PACKAGING ON THE POST-HARVEST PRESERVATION OF BRUSSELS SPROUTS (BRASSICA OLERACEA L.) .

Nohora Esperanza Mogollón Cárdenas[1]* Hugo Hernando Mendoza Vargas[2] Alfonso Rincón Pérez[3]

*1*Pedagogical and Technological University of Colombia Email: Nohora.mogollon@uptc.edu.co*
2Pedagogical and Technological University of Colombia Email: hugo.mendoza@uptc.edu.co
ORCID: https://orcid.org/0000-0003-3664-4505
3Pedagogical and Technological University of Colombia Email: alfonso.rincon@uptc.edu.co
ORCID: https://orcid.org/0000-0003-4710-6665

Resumen

La col de Bruselas (género Brassica, especie Brassica oleracea L.) tiene una limitada vida útil y que junto con una manipulación inadecuada de cosecha y almacenamiento, genera pérdidas en poscosecha alrededor del 30 %, pero es una hortaliza que en los últimos años, se ha incrementado la demanda por factores relacionados con la salud de los consumidores por su alto valor nutricional, especialmente con antioxidantes de diferente tipo, en especial los glucosinolatos y compuestos fenólicos antocianinas, aminoácidos, vitaminas y minerales. La investigación en la fase de laboratorio se desarrolló en el laboratorio de poscosecha de la Facultad de Agronomía de la Universidad Nacional de Colombia-Bogotá, y como material vegetal se utilizó col de Bruselas cosechada en Distrito de Riego del Alto Chicamocha en madurez comercial, cultivo ubicado en el municipio de Duitama Boyacá y se midieron variables relacionadas con pérdida de peso, mediante la medición de la masa fresca en balanza de precisión, para la tasa de respiración en cámaras herméticas de 2L, donde se ubica un sensor infrarrojo de $CO2$, en cuanto la cuantificación de los carotenoides se determinaron por la absorbancia en espectrofotómetro a 450 nm, y la cuantificación se hizo mediante curva de calibración con B-caroteno, respecto a las clorofilas se midieron a 663 y 647nm, Con la aplicación de técnicas de conservación y empaques adecuados, se logra retrasar el deterioro de la col de Bruselas en almacenamiento y evitar alteraciones relacionadas con la pérdida de peso, el cloruro de calcio que se utiliza en poscosecha de frutas y hortalizas ha mostrado buenos resultados en evitar desórdenes fisiológicos, resultados posiblemente porque el calcio inhibe la acción de la poligaracturonasa, enzima encargada de la hidrolisis de la cadena pectídica y así mayor resistencia a la desintegración de las pared celular, la aplicación de calcio durante la poscosecha en la col de Bruselas tiene como objetivo minimizar los efectos de la maduración y controlar el desarrollo de desórdenes fisiológicos, ampliar la vida útil, adicional al calcio se utiliza empaques, este cumple con una función fundamental en la conservación de los productos hortofrutícolas.

Summary

Brussels sprouts (genus Brassica, species Brassica oleracea L.) have a limited shelf life and together with improper handling of harvest and storage, generate post-harvest losses of around 30%, but it is a vegetable that in recent years, the demand for factors related to the health of consumers has increased due to its high nutritional value, especially with antioxidants of different types, especially glucosinolates and phenolic compounds anthocyanins, amino acids, vitamins and minerals. The research in the laboratory phase was developed in the postharvest laboratory of the Faculty of Agronomy of the National University of Colombia-Bogotá, and as plant material Brussels sprouts harvested in the Irrigation District of Alto Chicamocha in commercial maturity, a crop located in the municipality of Duitama Boyacá were used and variables related to weight loss were measured, by measuring the fresh mass on a precision scale, for the respiration rate in hermetic chambers of 2L, where an infrared CO2 sensor is located, as the quantification of carotenoids were determined by absorbance in spectrophotometer at 450 nm, and the quantification was made by calibration curve with B-carotene, regarding chlorophylls they were measured at 663 and 647nm, With the application of conservation techniques and appropriate packaging, it is possible to delay the deterioration of Brussels sprouts in storage and avoid alterations related to weight loss, calcium chloride used in post-harvest of fruits and vegetables has shown good results in avoiding physiological disorders, results possibly because calcium inhibits the action of polygaracturonase, an enzyme responsible for the hydrolysis of the pectide chain and thus greater resistance to the disintegration of the cell walls, the application of calcium during post-harvest in Brussels sprouts aims to minimize the effects of ripening and control the development of physiological disorders, extend the shelf life, in addition to calcium packaging is used, this fulfills a fundamental function in the conservation of fruit and vegetable products.

Introduction

The application of post-harvest technologies are processes that aim to maintain the organoleptic, nutritional and commercial quality of agricultural products and in addition, to extend the shelf life, different technologies are currently used in order to carry out biological control, pre-cooling, refrigeration, chemical treatments retarding maturity 1- MCP, calcium chlorides, organic and physical acids such as coatings and modified atmospheres (Andrade *et al.* , 2019) in relation to Brussels sprouts (genus Brassica, especially Brassica oleracea L.) has a limited shelf life and together with improper handling of harvest and storage, generates post-harvest losses of around 30%, but it is a vegetable that in recent years, the demand has increased due to factors related to the health of consumers, due to its high nutritional value, especially with antioxidants of different types, especially glucosinolates and phenolic compounds anthocyanins, amino acids, vitamins and minerals, crucifers in Colombia have an average planted area of 3767 ha and a production of 98,227 tons, in which around 485,000 jobs are generated (Agronet, 2019). The study will be developed in the postharvest laboratory of the Faculty of Agronomy of the National University of Colombia-Bogotá, for the research Brussels sprouts harvested in the Irrigation District of Alto Chicamocha in commercial maturity, a crop located in the municipality of Duitama Boyacá were used and variables related to weight loss were measured, established by a sample of approximately 100g of fruits, the measurement of the fresh mass was carried out on a precision scale, for the respiration rate approximately 50 g of sample were taken in hermetic chambers of 2L, in the chamber an infrared sensor of CO2 is located, which is connected to a Labquest (data capture equipment), as the quantification of carotenoids were determined by absorbance in spectrophotometer at 450 nm, and the quantification was made by calibration curve with B-carotene, regarding chlorophylls they were measured at 663 and 647nm and were quantified by the formula adapted from Solarte et al. (2010). With the application of conservation techniques and appropriate packaging, it is possible to delay the deterioration of Brussels sprouts in storage and avoid alterations related to the loss of weight, flavor, color, nutritional quality, processes that are possibly achieved by applying ripeness retardants, such as calcium chloride that is used in pre and post-harvest of fruits and vegetables and has shown good results in avoiding physiological disorders. Results possibly because calcium inhibits the action of polygaracturonase, an enzyme responsible for the hydrolysis of the pectid chain and thus greater resistance to the disintegration of the cell wall. Therefore, the application of calcium during the post-harvest of Brussels sprouts aims to minimize the effects of ripening and control the development of physiological disorders, extend shelf life, and protect the development of fruit and vegetable products, in distribution and marketing, protect them from physical, chemical and microbiological actions, in order to maintain quality, studies show that Brussels sprouts stored for 42 days at 0°C with relative humidity greater than 95% and covered with a polyethylene film, were found to be effective for the preservation of quality attributes, based on parameters such as commercial acceptability, weight losses, on the other hand, the immersion time of 10 minutes of Brussels sprouts in 4% calcium chloride solution and packaged in 100-gauge polyethylene packaging, generated less weight loss, higher total carotenoid content, a very important factor in terms of nutritional value, taking into account that carotenoids are antioxidants of great importance for humans.

Materials and Methods

The study in the laboratory phase was developed in the postharvest laboratory of the Faculty of Agronomy of the National University of Colombia-Bogotá, the Brussels sprouts were harvested at commercial maturity, in a crop located in the municipality of Duitama Boyacá, Alto Chicamocha Irrigation District, located at 5º 49, 42" and 73º3' west longitude of Greenwich, the altitude is 2,535 m.a.s.l., average temperature is 15 °C, average rainfall is 1,128 mm, relative humidity of 81.4 % average; evaporation covers a range ranging from 80.63 to 99.53 mm (Duitama Mayor's Office. 2019). Brussels sprouts (compact variety) of homogeneous size and in excellent phytosanitary conditions, free of mechanical damage, were used as plant material. Bioquigen Advanced Chemical reagent type calcium chloride powder was used as a source of calcium. The plastic packaging used was thermoformed from transparent polyethylene terephthalate (PET) light type impermeable to CO2, moisture and O2, and polyethylene (PE) with a capacity of 500g with dimensions of 30 x 15 cm of low density caliber 100 and 200 (Callegariplasticos, 2014). The immersion time of Brussels sprouts in a calcium chloride solution with a concentration of 4% was evaluated, in addition three types of packages stored at 4ºC were evaluated, a completely randomized design with a 3x4 factorial arrangement was used, where the first factor corresponded to the immersion times (0, 10 and 20 minutes) and the second factor, the packaging (PET, PE 100 gauge and PE 200 caliber and the control) 12 treatments with 4 repetitions were used, for a total of 48 (EU) each of these was composed of approximately 1kg of Brussels sprouts. The controls were cabbages with 0 immersion time and for the packaging cabbages packed in trays without any type of sealing and stored at 4ºC. The independent variables used were calcium chloride (4%), immersion times (0, 10 and 20 minutes), thermoformed packaging (PET), polyethylene (PE) 100 gauge and polyethylene (PE) 200 gauge and storage time (29 days). The dependent variables were measured every 3 days for a period of 29 days. For weight loss, a sample of approximately 100g of fruits was measured on a precision ahaus scale, with an approximation of 0.001g. For respiration rate (mg CO2 kg-1 h -1): approximately 50 g of sample were taken in hermetic chambers of 2L, in the chamber an infrared CO2 sensor is located, which is connected to a Labquest (data capture equipment). Every 4 seconds and for 5 minutes the CO2 values are recorded, with these values the slope is calculated, which corresponds to the respiratory rate, the weight of the fruits and the volume of the chamber were taken into account to convert the data to mg of CO2 kg-1 h -1. To determine the carotenoids, the absorbance was determined in a spectrophotometer at 450 nm, and the quantification is done by calibration curve with B-carotene. Chlorophylls were measured at 663 and 647nm and quantified using the following formula adapted from Solarte *et al*., (2010): Total chlorophyll (mg g-1 PF) = ((15xA663nm)+(18.7xA647nm))xV/1000xP V=final volume of the extract in ml (25mL) P=Weight of initial plant material in g. Statistical analysis, with data obtained by factor analysis of variance, to determine the best treatments, a Tukey mean comparison test (P≤0.05) was performed. The analyses were performed with the SAS 9.2 statistical program.

Results and Discussion

Weight loss: Statistically significant differences were found at all sampling points. Cabbages packed in 100 and 200 gauge polyethylene bags and with an immersion time of 10 and 20 minutes, in calcium chloride solution, showed weight loss below 2.5% until day 27 of storage, (Figure 1). Similar results were reported by Erin *et al*. (2013) in bell peppers packed in polyethylene bags stored for 14 days after harvest. Similarly, Ramírez *et al*. (2005) report that 15% calcium chloride reduced the respiration rate of feijoa in storage to 6ºC for 24 days, since calcium allows the stability of the membranes to be maintained and inhibits the metabolism of the midlamina, generating a lower percentage of weight loss.

Brussels sprouts packed in PET packaging and with immersion times in calcium chloride solution of 10 and 20 minutes, showed weight losses of 21.19% and 19.38%, respectively, until day 27 of product storage (Figure 1). The highest percentage of losses was present in the controls around 31.35%, which translates into loss of commercial value (Kraśniewska *et al*., 2014). The combination of treatments immersed in calcium chloride solution, for 10 and 20 minutes, refrigeration at 4ºC and the packaging of Brussels sprouts in a polyethylene bag, contribute to reducing weight loss during post-harvest. According to García *et al*. (2010) there is a positive influence of calcium chloride and a plastic coating on the control of the speed of weight loss in fruits, possibly modulated by the selective permeability created by the plastic film. Therefore, Andrade *et al*., 2019 state that weight loss could be attributed to phenomena caused by dehydration and depend on the storage conditions of the fruits.

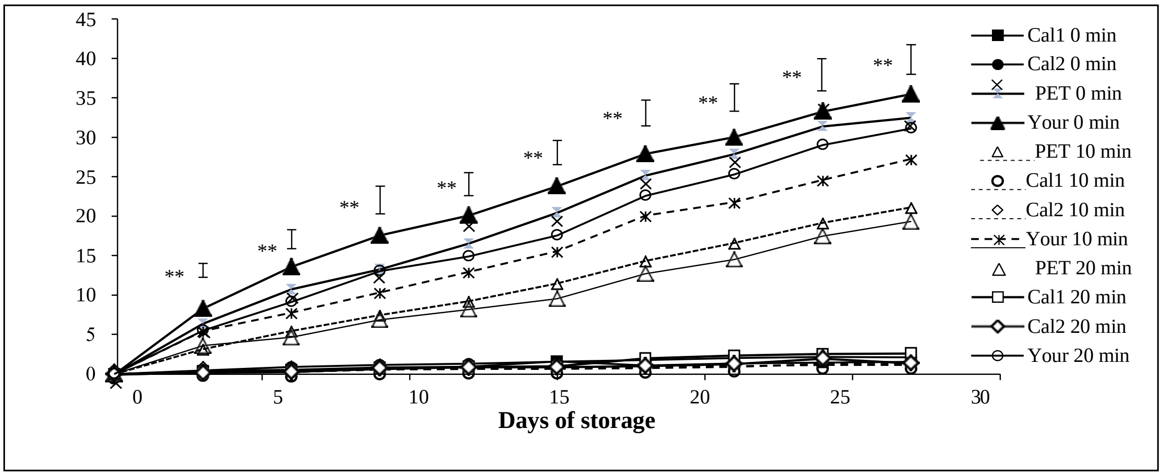

Figure 1. Effect of immersion time in calcium chloride solution and packaging on the weight loss of Brussels sprouts during postharvest. * Statistical differences at 5%, ** statistical differences at 1%, ns There are no differences according to the Anova. The vertical bar represents the statistical value of the minimum significant difference (LSD) of the Tukey test. Cal1 100 gauge PE polyethylene packaging and Cal2 200 gauge PE polyethylene packaging, PET thermoformed packaging. If the difference between two averages at each sampling point is greater than LSD, there will be a difference (*P≤0.05).*

The factor analysis indicated that Brussels sprouts, packed in 100 and 200 gauge polyethylene bags, presented weight losses of less than 2%, results that coincide with those reported by Sonia *et al.* (2007) in refrigerated Brussels sprouts with polyethylene coverage. The cabbages packed in PET packaging presented progressive weight losses throughout storage and at the end of day 27 of storage the losses were 24.38% (Figure 2A), similar behavior presented by the control, but with higher percentages throughout storage and at the end of day 27 it presented weight loss of 31.35% (Figure 2A).

According to Mette *et al.* (2013) vegetables are highly susceptible to water loss and carbon dioxide release through the oxidation of carbohydrates, however, by making adequate packaging it can prevent dehydration and guarantee humidity for longer during storage. As for the controls, they presented losses of 31.35%, which indicates that the packaging fulfills the function of preventing dehydration of the product, since it has a positive effect on the enrichment of the atmosphere with CO2, which contributes to reducing respiratory processes, this is reflected in the lower weight loss (Kader *et al.*, 2008). In addition, it is important to highlight the efficiency, in this sense, of 100 and 200 gauge polyethylene, possibly due to the barrier properties to gas exchange by these materials.

Regarding the immersion times of Brussels sprouts in calcium chloride solution, a constant increase in the percentage of losses was observed at all sampling points, however, cabbages that were treated for 10 and 20 minutes presented weight loss of 12.74% and 13.67%, values lower than those reported by the control, which were 18%, during the 27 days of storage (Figure 2B). Therefore, the immersion time causes a favorable effect in the reduction of the percentage of weight loss of the cabbage, in the same way, there were no differences between the immersion times of 10 and 20 minutes, with the above, it could be considered that 10 minutes of immersion in the calcium chloride solution are enough for the calcium ions to migrate to the interior of the tissue and act on the pectic chain and contribute to form bridges between them, thus increasing the strength of cohesion adhesion between the cells, contributing to strengthen the middle lamina and the cell wall (García *et al.*, 2010), probably these are some of the causes that explain, lower weight loss in Brussels sprouts treated with 4% calcium chloride and with immersion times of 10 and 20 minutes.

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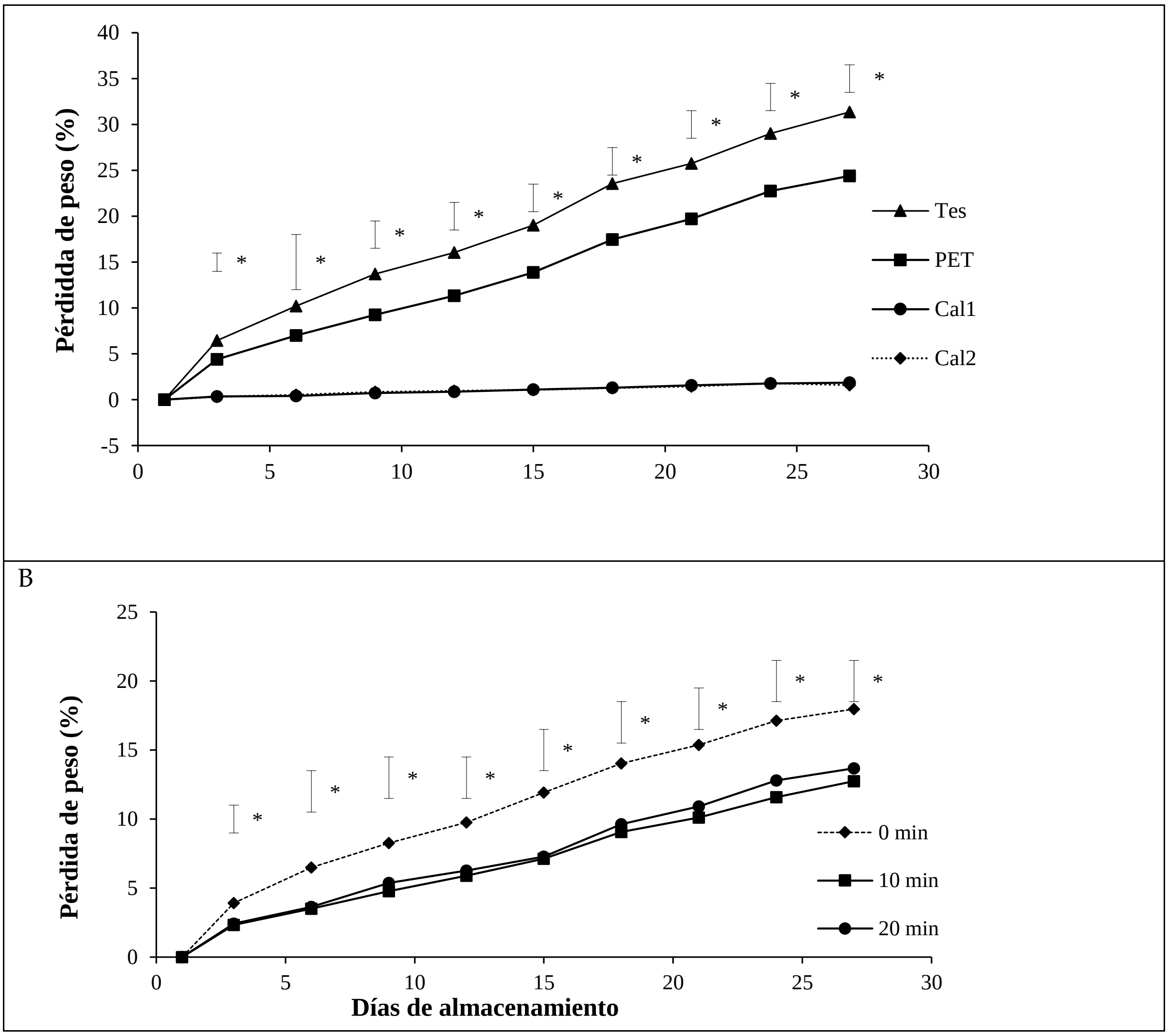


Figure 2. Effect of A). The packaging and B). Immersion time in calcium chloride solution on the weight loss of Brussels sprouts during postharvest and * Statistical differences at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova, Cal1 PE polyethylene packaging 100 gauge and Cal2 PE polyethylene packaging 200 gauge, PET thermoformed packaging. Different letters at each sampling point indicate significant differences according to Tukey's test (*P≤0.05*).

Respiration rate (mg CO2•kg-1•h-1)

Statistically significant differences were presented at all sampling points up to day 27 of storage, the highest respiratory rate during the first 15 days of storage was presented in cabbages packed in 200-gauge polyethylene bags and with immersion time of 20, 10 and 0 minutes in 4% calcium chloride solution, in the same way high respiratory rates were presented in cabbages packed in 100-gauge polyethylene bags and with immersion time of 10 and 0 minutes in 4% calcium chloride solution (Figure 3), this may be related to a change in the atmosphere of the packaging, where oxygen is consumed and carbon dioxide is produced, however, several researchers (Lu, 2007, Martínez *et al.* , 2006) have shown that optimally controlled atmosphere can delay the loss of green color in Chinese cabbage and coriander leaves; but if a design is not made to match the respiration rate of the product, it can lead to anaerobic respiration due to low rates of gas transmission over the packaging material, this can lead to the development of bad odors and tissue degradation due to fermentation and degradation of chlorophylls leading to color changes (Mette *et al* 2013). According to Seefeldt *et al.* (2012) the respiration rate varies depending on storage conditions, biological variation must be considered for the selection of packaging. On the other hand, (Paliyath *et* al., 2018) state that the increase in the TR and production of ethylene after the beginning of ripening and its regulation by the effect of post-harvest treatments is a commonly used strategy to extend the shelf life of fruit and vegetable products.

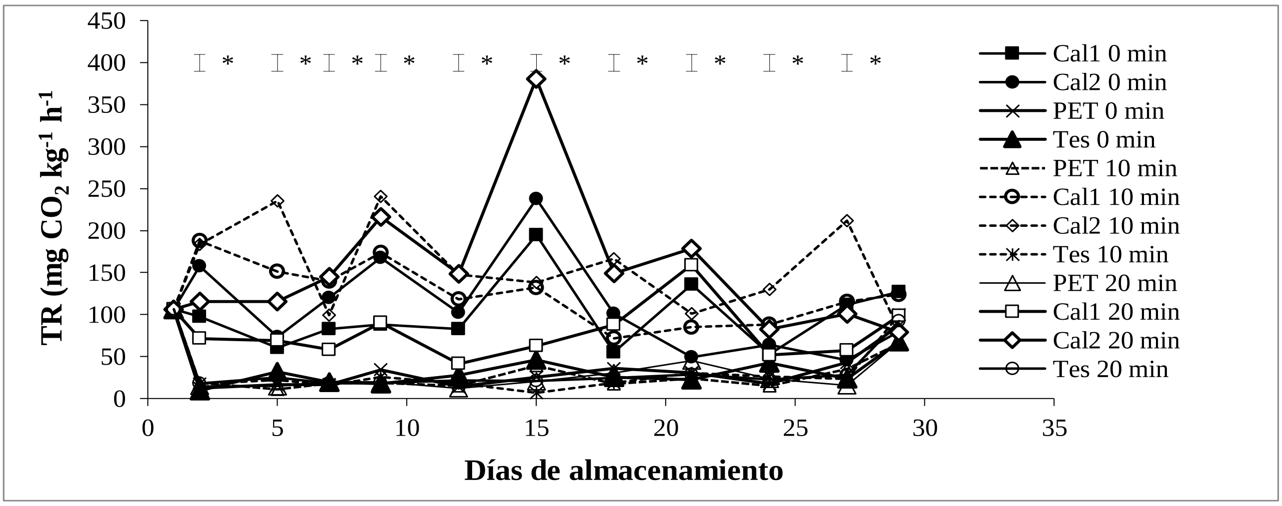
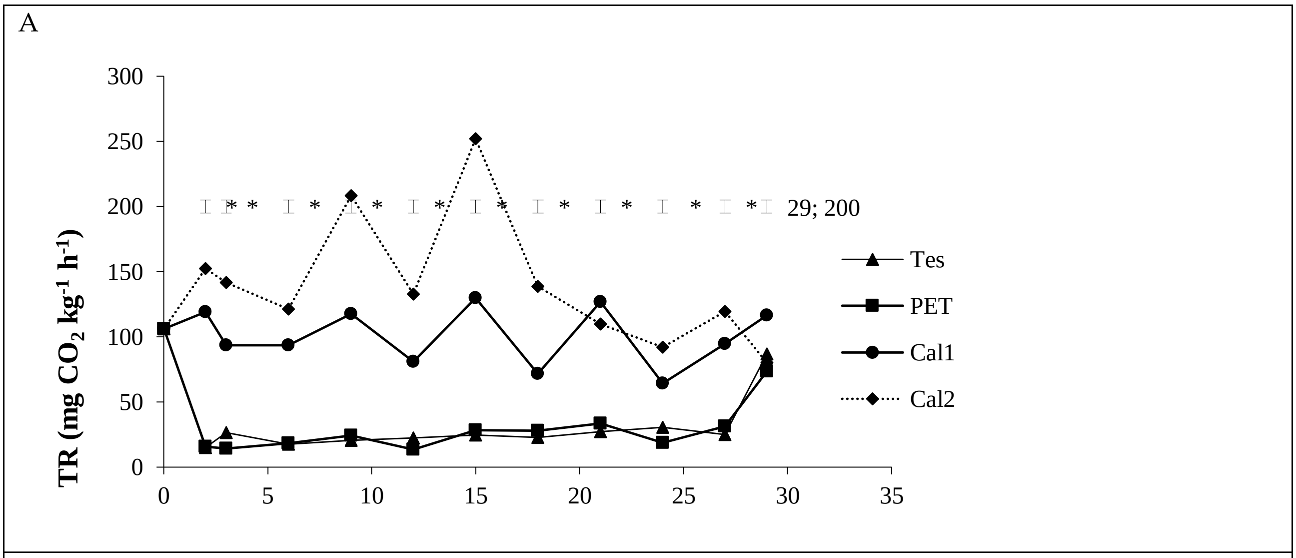


Figure 3. Effect of immersion time in calcium chloride solution and packaging on the TR of Brussels sprouts during post-harvest. * Statistical differences at 5%, ** statistical differences at 1%, ns There are no differences according to the Anova. The vertical bar represents the statistical value of the minimum significant difference (LSD) of the Tukey test. Cal1 100 gauge PE polyethylene packaging and Cal2 200 gauge PE polyethylene packaging, PET thermoformed packaging. If the difference between two averages at each sampling point is greater than LSD, there will be a difference *(P≤0.05).*

It was identified that cabbages packed in PET packaging presented low respiratory rates throughout storage at all immersion times, as for the controls, they presented low respiratory rates throughout the storage process of Brussels sprouts at 4°C. Results that seem to be related to storage temperature, but not to the effect of PET packaging on respiratory rate. These results coincide with what was reported by (Ascensión *et al.*, 2008) in studies on respiratory rate of four leaves of baby Brassica species.



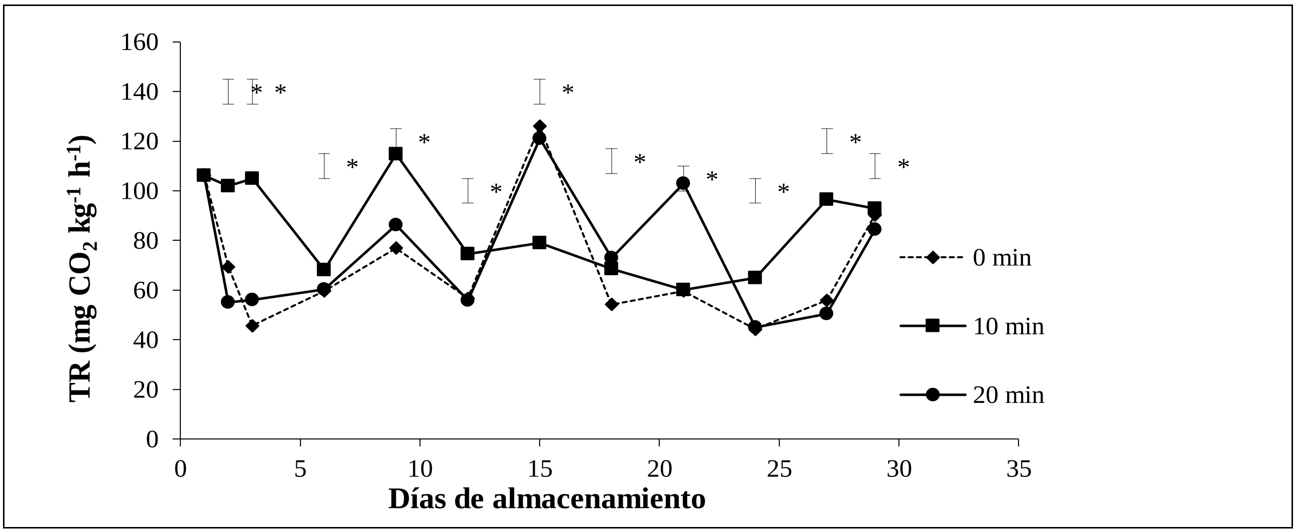


Figure 4. Effect of A). The packaging and B). Immersion time in calcium chloride solution on the TR of Brussels sprouts during postharvest and * Statistical differences at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova. Cal1 100 gauge PE polyethylene packaging and Cal2 200 gauge PE polyethylene packaging, PET thermoformed packaging. Different letters at each sampling point indicate significant differences according to Tukey's test (*P≤0.05).*

The factorial Anova showed that the packaging had a significant effect on the TR, Brussels sprouts packed in a 200 gauge polyethylene bag presented high respiration rates until day 15 of storage with a value of (250CO2 kg-1 h-1), which later from day 15 to day 29 of storage presented a considerable reduction in respiratory rate reporting a value of (80.04 CO2 kg-1 h-1) (Figure 4A). A phenomenon possibly caused by the exposure of cabbages to oxygen levels below and/or carbon dioxide levels above their optimal range, this can cause physiological disorders, such as increased KT irregular ripening, increased susceptibility to browning, and development of bad taste (Susan, 2009).

The cabbages packed in 100-gauge polyethylene bags presented values ranging between 130 and 64 CO2 kg-1 h-1, with respect to the controls and the cabbages packed in PET packaging, reported a considerable reduction in the respiratory rate of 17.85 and 15.48 CO2 kg-1 h-1, respectively, on day 2 of storage, in addition a respiration rate below (31.25 CO2 kg-1 h-1) was observed, during storage until day 27, later there was an increase in the value of the respiratory rate of 80 CO2 kg-1 h-1 until day 29, this indicates that PET packaging has an impact on decreasing the respiratory rate of Brussels sprouts, contrary to the results of cabbages packed in 100 and 200 caliber polyethylene bags in which high respiratory rates were reported. The high TR according to Martínez *et al.* (2006) occurs because in the process of respiration, the energy of the cells is produced, which consists of the oxidative, enzymatic and exothermic degradation of polysaccharides, organic acids that are stored in the cells and that are transformed into simpler substances, this leads to the release of energy.

According to Susan *et al.* (2009) state that vegetables packed in closed packages cause a decrease in TR, transpiration and decreased ethylene biosynthesis, due to the reduction of O2 and the increase in CO2. This possibly explains the low TR in cabbages that were packed in PET packaging.

Regarding immersion times, there were statistical differences, at all sampling points, the respiratory rate of cabbages treated with calcium chloride solution in immersion for 10 minutes, presented a decrease from day 1 to day 6, and later increased until day 9 (114.72 CO2 kg-1 h-1) in the same way from day 9 to day 29 low values (92.84 mg CO2 kg-1 h-1) in respiratory rate are again presented (Figure 4B). Similar results are reported by Yan *et al.* (2014) in research on cherries treated with 2% calcium chloride solution for 5 minutes and stored at 0ºC for 4 weeks, they also state that KT is related to delayed ripeness and senescence of the fruit, in which calcium chloride has a direct effect on the maintenance of the functionality of cell membranes.

The decrease in TR is generated as a consequence of the decomposition by oxidation of organic reserves into simpler molecules, including CO2 and water, with energy release, each of the organic substrates broken down in this process can include carbohydrates, lipids and organic acids, during the process it consumes O2 in a series of enzymatic reactions, such as glycolysis, the tricarboxylic acid cycle, and the electron transport system, are the most important metabolic pathways of respiration (Susana *et al.*, 2002).

Total chlorophylls (mg g-1 PF)

There were no statistically significant differences at all sampling points only from day 15 to day 29 of storage, on day 15 of storage the highest values were reported by the controls that subsequently decreased until day 22 and there was again an increase until day 29 of storage, similar trends were observed in cabbages treated with 4% calcium chloride and packed in PET packaging (Figure 5). This phenomenon is possibly caused by the susceptibility of chlorophylls to many chemical degradation reactions that occur simultaneously due to the action of enzymes, weak acids, oxygen, light and heat, which can lead to the formation of a large number of degradation products (Nuray *et al*., 2007).

Cabbages packed in a 200-gauge polyethylene bag and with an immersion time of 10 and 20 minutes, showed values with an increasing trend from day 15 to day 29 of storage, which indicates that this type of packaging has a favorable effect in contributing to the increase in chlorophyll content during storage, information of great importance, taking into account that the decrease in chlorophyll content is associated with senescence, and is an indicator of the loss of quality of green vegetables (Zhenlei *et al*., 2014).

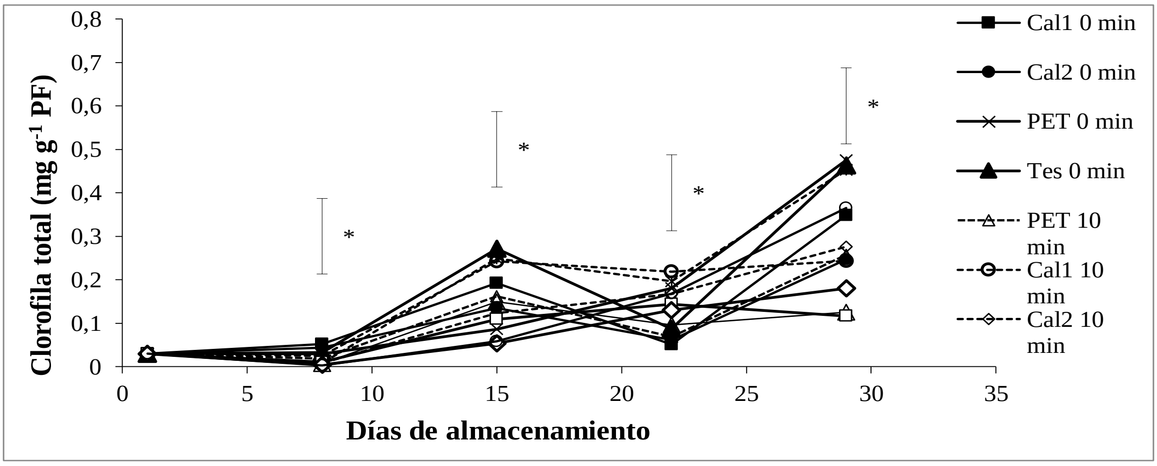


Figure 5. Effect of immersion time in calcium chloride solution and packaging on total chlorophylls of Brussels sprouts during postharvest. * Statistical differences at 5%, ** statistical differences at 1%, ns There are no differences according to the Anova. The vertical bar represents the statistical value of the minimum significant difference (LSD) of the Tukey test. Cal1 100 gauge PE packaging and Cal2 200 gauge PE packaging. If the difference between two averages at each sampling point is greater than LSD, there will be a difference (*P≤0.05).*

According to the factor analysis, there were statistically significant differences only on day 29 of storage, similar results were reported by Luo *et al*. (2004) in which they state that cilantro packed in plastic films did not significantly vary the total chlorophyll content throughout storage. In all treatments, a trend was observed towards increasing the values of total chlorophyll content until day 22 of storage, from day 22 to day 29 the controls reported the highest values and the low values were presented in cabbages packed in 200 gauge polyethylene bags (Figure 5A). Taking into account that there were no significant differences, the increase in chlorophyll content can be attributed to the effect of the storage temperature 4ºC as reported by Chandra *et al*. (2012) who state that, at low temperatures, a greater retention of chlorophylls results, possibly due to the reduction of metabolic activity in the degradation of chlorophyll.

Regarding immersion times, there were statistically significant differences in all sampling points, cabbages treated with calcium chloride for 20 minutes, presented an increasing trend without fluctuations, however, low values were reported at each of the sampling points, the control and cabbages treated with 4% calcium chloride solution for 10 minutes, had similar trends and with fluctuations in each of the sampling points, at the end of storage the highest value in total chlorophyll content was reported by cabbages that were not treated with calcium chloride (Figure 5B). Possibly because in these cabbages there was greater weight loss and the existing chlorophylls are in higher concentration. However, the 4% calcium chloride solution and with immersion time of 10 and 20 minutes contribute to avoid the rapid decrease of the total chlorophyll content during 29 days of storage.

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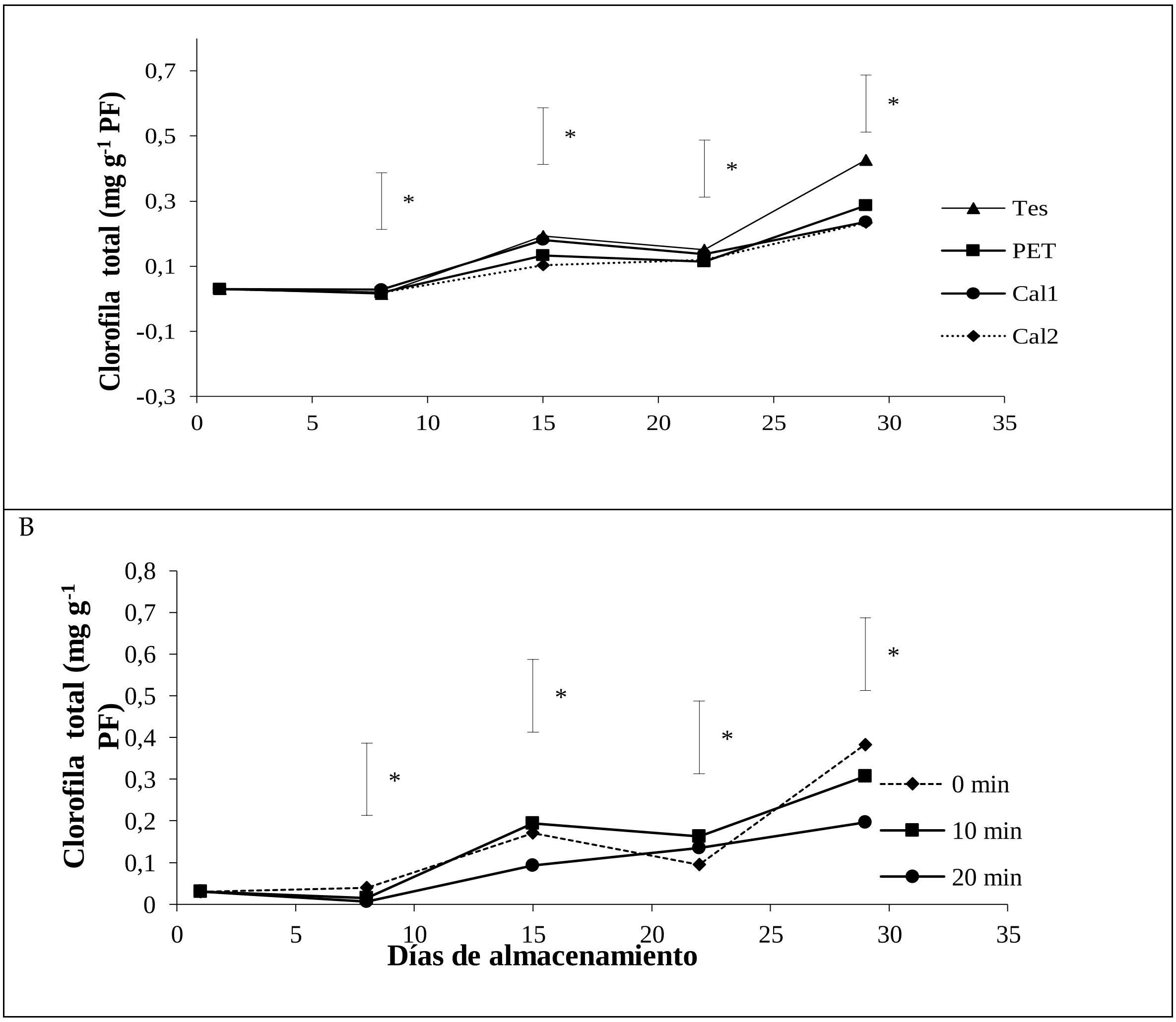


Figure 5. Effect of A). The packaging and B). Immersion time in calcium chloride solution on the total chlorophylls of Brussels sprouts during postharvest and * Statistical differences at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova. Cal1 100 gauge PE polyethylene packaging and Cal2 200 gauge PE polyethylene packaging, PET thermoformed packaging. Different letters at each sampling point indicate significant differences according to Tukey's test (*P≤0.05*).

Carotenoides (mg g-1 PF)

There are statistically significant differences from day 1 to day 8 and from day 22 to day 29 of storage, the controls presented low values in the first 8 days of storage, cabbages treated with calcium chloride for 20 minutes and packed in a 200 gauge polyethylene bag presented a decrease in the first 8 days of storage, but later a constant increase was observed, however they reported lower values with respect to the other treatments throughout storage, cabbages packed in a 100 gauge polyethylene bag and that were not treated with calcium chloride solution, presented higher values, with respect to the other treatments in the first 15 days, with subsequent decrease until day 22 and reported the highest values on day 29 of storage (Figure 6). Jamal *et al*. (2006) state that fluctuations in values are due to changes in phytochemicals, this, in response to the environmental and packaging conditions of fruits and vegetables and that the level of biological and medicinal activities of compounds such as carotenoids can change.

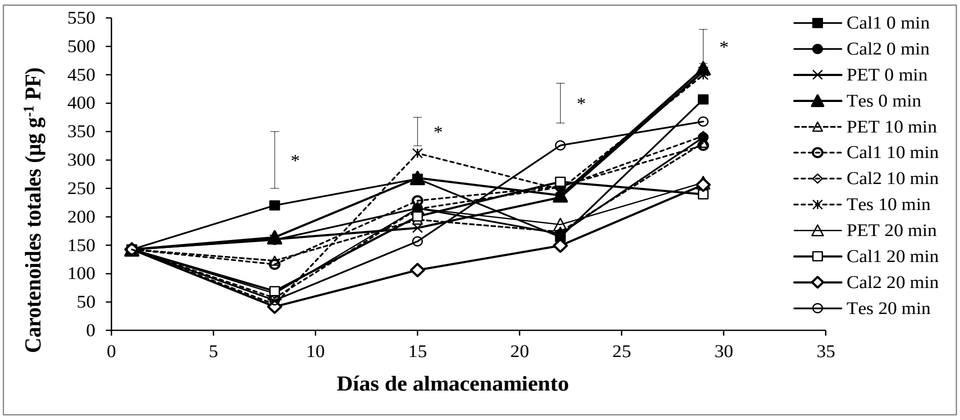
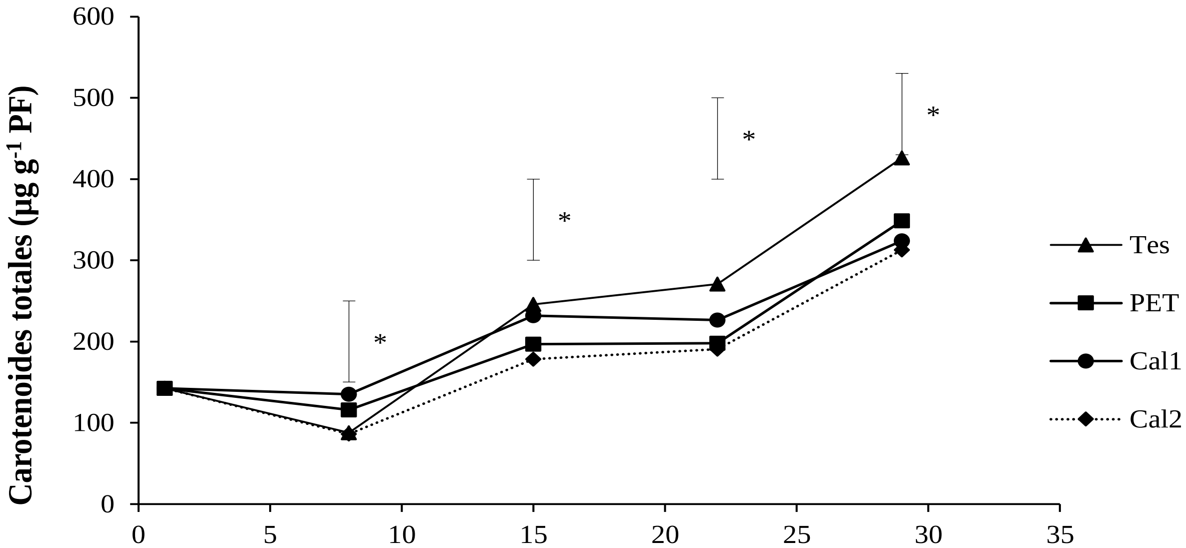


Figure 6. Effect of immersion time in chloride solution and packaging on Brussels sprout carotenoids during postharvest. * Statistical differences at 5%, ** statistical differences at 1%, ns There are no differences according to the Anova. The vertical bar represents the statistical value of minimum significant difference (LSD) of the Tukey test. Cal1 100 gauge PE polyethylene packaging and Cal2 200 gauge PE polyethylene packaging, PET thermoformed packaging. If the difference between two averages at each sampling point is greater than LSD, there will be a difference (*P≤0.05*).

present in cabbages packed in polyethylene bags and PET packaging (Figure 7A). A similar phenomenon is reported by Andrea *et al*. (2008) in spinach refrigerated at 4ºC. Taking into account these results, it can be considered that the packaging contributes to slower metabolic processes, for this reason there is a lower carotenoid content after day 15 of storage, in the packaged cabbages, compared to the controls.

Regarding immersion times, there were significant differences on days 8 and 29 of storage, cabbages

Regarding the effect of packaging on carotenoid content, there was a decrease in values in all treatments in the first 8 days of storage, from day 8 to day 22 the values increased in all treatments in which the controls had the highest carotenoid content, and the lowest carotenoid content was treated with calcium chloride solution for 10 and 20 minutes, during the first 8 days of storage presented values lower than those reported by the control, after day 8 until the end of storage the values increase, however, the control reported the highest carotenoid content and the lowest carotenoid content was present in the cabbages treated for 20 minutes (Figure 7B), which means that calcium with a longer contact time with the product contributes to decrease the metabolic processes of Brussels sprouts.



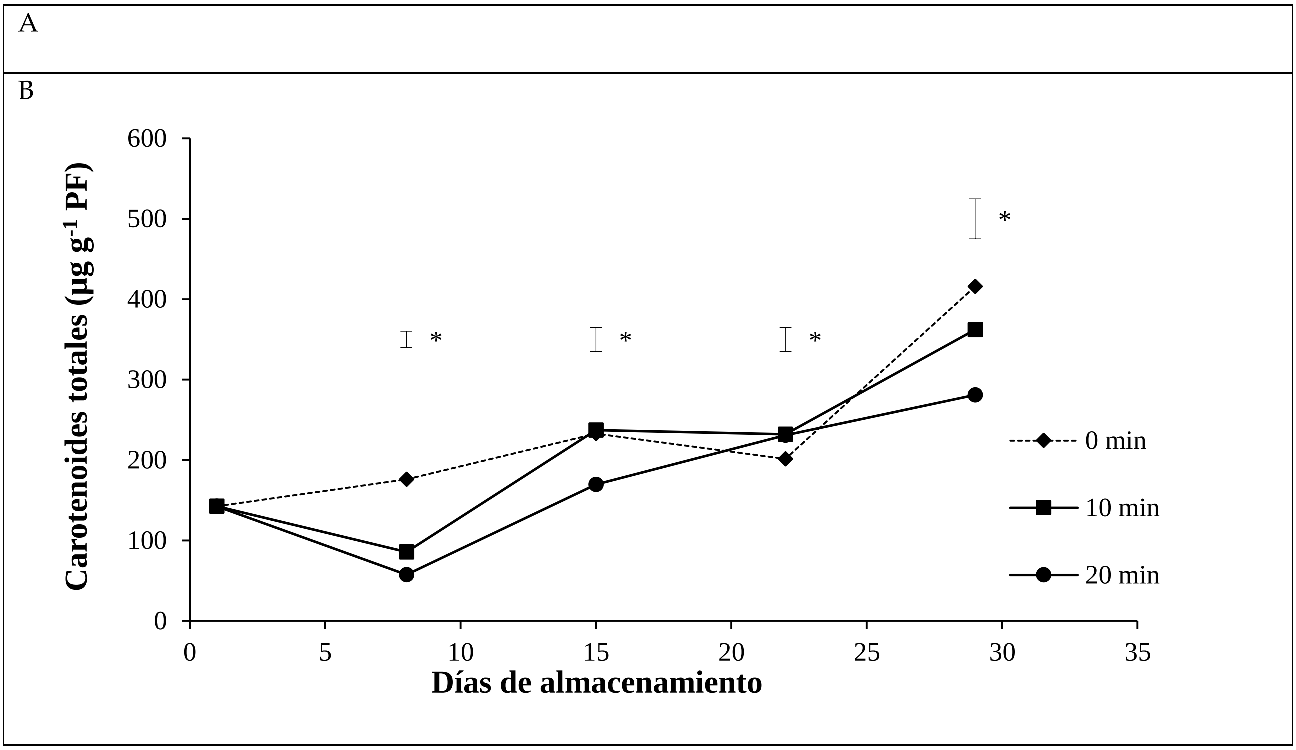


Figure 7. Effect of A). The packaging and B). Immersion time in calcium chloride solution on total carotenoids of Brussels sprouts during postharvest and * Statistical differences at 5%, ** statistical differences at 1%, ns there are no differences according to the Anova. Cal1 100 gauge PE polyethylene packaging and Cal2 200 gauge PE polyethylene packaging, PET thermoformed packaging. Different letters at each sampling point indicate significant differences according to Tukey's test (*P≤0.05).*

Conclusions

The 10-minute immersion time of Brussels sprouts in 4% calcium chloride solution and packed in 100-gauge polyethylene packaging resulted in less weight loss, higher total carotenoid content.

Brussels sprouts packed in PET packaging and with an immersion time of 20 minutes in 4% calcium chloride solution reported lower respiratory rate, therefore it becomes an important alternative technology for applicability in the postharvest process of the vegetable.

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