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# Plastic film bags on the refrigeration of table grapes

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**ABSTRACT:** Refrigeration is the most effective method for storing fruit, important in controlling humidity and gas concentration in order to allow a greater conservation. The objective of this study was to evaluate the use of different plastic film bags on cooling table grapes. Were evaluated three types of plastic film bags in three palletizing levels during rapid cooling and storage, and its influences on temperature, cooling time, relative humidity, weight loss and berry abscission. The temperature and relative humidity was influenced by the type of plastic film bags and palletization levels in rapid-cooling chamber. The non-perforated plastic film bag and the intermediate level provided the highest temperature values, 4.0 and 5.13 °C, respectively. The non-perforated plastic film bag and the superior level had the highest relative humidity values, 89.48 and 85.56%, respectively. The non-perforated plastic film bag needed a longer cooling time. The micro perforated plastic film bag associated with the intermediate level had the lowest berry abscission (0.43%). The non-perforated plastic film bag had the least weight loss, 4.84%. Therefore, the non-perforated plastic film bag allows for a better conservation of the table grape during the cold-chamber cooling.

**Key words:** ambience; fruit growing; fruit quality; modified atmosphere; *Vitis vinifera* L.

# Bolsões plásticos na refrigeração de uva de mesa

**RESUMO:** A refrigeração é o método mais eficaz para o armazenamento de frutas, sendo importante o controle da umidade e concentração de gases, para permitir maior conservação. Sendo assim, o objetivo desta pesquisa foi avaliar o uso de diferentes bolsões no resfriamento de uvas de mesa. Foram analisados três tipos de bolsões em três níveis de paletização durante o resfriamento rápido e armazenamento, e suas influências sobre temperatura, tempo de resfriamento, umidade relativa, degrana e perda de massa. A temperatura e a umidade relativa foram influenciadas pelos bolsões e níveis de paletização na câmara de resfriamento rápido. O bolsão sem perfuração e o nível intermediário proporcionaram os maiores valores de temperatura, 4,0 e 5,13 °C, respectivamente.  O bolsão sem perfuração e o nível superior apresentaram maiores valores de umidade relativa, 89,48 e 85,56%, respectivamente. O bolsão sem perfuração obteve maior tempo de resfriamento. O bolsão micro perfurado associado ao nível intermediário possui a menor degrana, de 0,43%. O bolsão sem perfuração teve a menor perda de massa, de 4,84%. Dessa maneira, o bolsão sem perfuração permitiu melhor conservação das uvas de mesa durante a refrigeração em câmara fria.

**Palavras-chave:** ambiência; fruticultura; qualidade do fruto; atmosfera modificada; *Vitis vinifera* L.

## Introduction

Fruit and vegetables refrigeration is the most economical method for prolonged storage, deemed as extremely important in maintaining the quality of table grapes. As according to Berry et al. (2016), the inadequate cooling can provoke the deterioration of the product, as fruit use their own reserves for supplying the metabolic reactions.

Implementing the cold chain is important as it promotes the rapid cooling of fruits recently arrived from the field, as well as their conditioning, where the post-harvest quality and the shelf life are both influenced by the product temperature, for it regulates the physiological processes, and enzymatic and chemical reactions, in addition to slowing down microorganism activity (Defraeye et al., 2015; Rao, 2015; Franco et al., 2017).

Besides the refrigeration, other factors also affect the quality maintenance of table grapes. The relative humidity and the concentration of gases, such as oxygen and carbon dioxide, also directly influence the fruit biochemical processes (Castellanos & Herrera, 2015).

Controlling the relative humidity during cooling directly affects fruits, which, when exposed to inadequate values, result in the water loss and a significant drop in quality, thus impairing the product commercialization (Franco et al., 2017; Spagnol et al., 2018).

Another factor is using packages that promote modification of the atmosphere, where gas exchange is limited due to the polymer properties, acting as barriers and assuming an essential role in preserving fruit metabolism (Admane et al., 2015).

Some of these atmosphere-modifying packages in table grapes are known as plastic film bags. Most of them hinder the $CO_2$ escape and the $O_2$ entry. In that context, according to Camargo et al. (2012), higher $CO_2$ and lower $O_2$ concentrations contribute to a lesser loss of fresh weight and a greater berry firmness.

Thereby, the present study aimed to verify the influence of using three types of plastic film bags on the cooling of table grapes in a rapid-cooling chamber and a cold room.

## Materials and Methods

The experiment was conducted from June to August 2018, in a packing house from a commercial agricultural farm located in the lower-middle region of the São Francisco Valley, with the geographical coordinates of 9º23’ south latitude and 40º30’ west longitude. The table grape used hailed from the Arra 15 variety.

The experiment was designed in randomized blocks (RCB), arranged in a 3 x 3 factorial design, with 3 blocks, each one represented by different palletization days. The first factor corresponds to the plastic film bag type used in palletizing (BMI – traditional micro-perforated plastic film bag used by the market with 1% perforated area; BSP – non-perforated plastic film bag; and BMA – macro-perforated plastic film bag with 0.6% perforated area), and the second factor was the pallet height levels (lower = 0.20 m; intermediate = 1.16 m; and upper = 2.04 m).

The cardboard boxes used for palletizing could hold 5 kg of grapes at once, with 10 plastic bowls with capacity for 500 g inserted into them. The complete pallet supports 24 cardboard boxes levels, where the lower, intermediate and upper levels were in position 1, 13 and 24, respectively.

For evaluating the influence of plastic film bag types during forced-air cooling in the rapid-cooling chamber and in the cold room, both temperature and humidity information was obtained through the Hobo® U12-013 Temp/RH 2EXT data loggers, with measuring range temperature between -20 and 70 °C and accuracy of + 0.35 °C, and relative humidity range between 5% and 95% with accuracy of + 2.5%. These mentioned equipments were placed in the bowls, in a central position within the boxes, with the grapes. The device collected data every 5 min.

The pallets were formed in the packages sector, totaling 3 pallets per block, having 1 for each plastic film bag. They were then taken to an antechamber, in order to be bent, and subsequently enter, simultaneously, in the forced-air cooling chamber. Furthermore, data loggers were set up in the chamber rooms at the height of 1 m, on the walls, the entrance and the back of the room.

Data were collected during the time the pallets remained in the rapid-cooling chamber, which were 14 h and 30 min, and for 24 h inside the cold room. These data were treated by taking the means from the temperature and relative humidity of the environment and the inside of the bowls, in both enviroments every 1 h.

The cooling curve simulation was by using the Dimensionless Temperature Rate (DTR), determining the times of half and seven octaves, according to Teruel (2008). The pulp temperature was obtained by the data logger and the ambient temperature was 0 °C, the default temperature programmed in the rapid-cooling chamber.

The percentages of weight loss and berry abscission were evaluated during the storage days. The first data collection was 24 h after palletization, then it occurred every 15 days, for a period of up to 60 days. Each pallet level contained 5 cardboard boxes with 10 bowls each, which were properly weighed and identified during the packaging. A complete box was used every fortnightly analyzes, weighing the grapes within the 10 tanks forming a box.

The results were subjected to analysis of variance with application of the T test ($p < 0.05$), in which significant isolated effects and interactions between the sources of variation were tested. In presence of a significance, the means were compared with the Scott-Knott test using the SISVAR Version 5.6 software (Ferreira, 2011).

## Results and Discussion

As soon as the rapid-cooling chamber was on, there were no significant differences between the plastic film bag types, only between the palletization levels in relation to the temperature (Figure 1), evidencing the propensity in losing heat from the upper level, where the coefficient of variation was 3.77%. In relation to relative humidity (RH), there were significant differences only between the plastic film bag (Figure 2), with a coefficient of variation of 8.85%.

The lower and intermediate levels had the highest temperatures, 22.34 and 22.59 °C, respectively, with the upper having the lowest (20.33 °C), mainly due to the association of convective loss by refrigerated air and its speed. According to Damasceno et al. (2015), the temperature decreases where cold air is drained faster, with the upper level being the closest to the air outlet and, therefore, the speed is higher and, consequently, a greater convective heat loss happens.

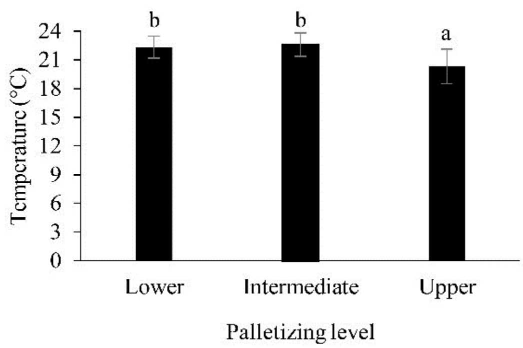


**Figure 1.** Initial temperature for palletizing levels in the rapid-cooling chamber. Means followed by the same letter do not differ according to the Scott-Knott test (p ≥ 0.05).

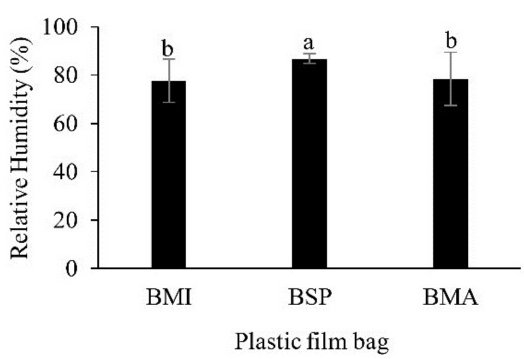


**Figure 2.** Initial relative humidity for the plastic film bags in the rapid-cooling chamber. Means followed by the same letter do not differ according to the Scott-Knott test (p ≥ 0.05). BMI-micro perforated, BSP-non-perforated and BMA-macro perforated.

The BMI and BMA plastic film bags have the lowest initial humidity values in the rapid-cooling chamber, 77.68 and 78.41%, respectively, whereas BSP has the largest value (86.87%). According to Mantilla et al. (2010), in packages that promotes a modified atmosphere, fruits consume $O_2$ and produce both $CO_2$ and water vapor. This produced vapor remains in the plastic film bag environment, which can delay the weight loss of the grapes, as well as causing condensation and facilitating microorganism development in the long term. Considering this, the BSP, since it is non-perforated, prevents the water outflow, thus keeping the RH at higher levels.

As illustrated in Figures 3A and 3B, there was no interaction between the plastic film bags and palletizing levels for the final temperature in the rapid-cooling chamber. However, there are significant differences among plastic film bags and among palletization levels, with a variation coefficient of 52.79%. In a similar fashion, there was no interaction between plastic film bags and palletizing levels concerning the final RH in the rapid-cooling chamber, but there are significant differences among plastic film bags and among palletizing levels (Figures 4A and 4B), with a variation coefficient of 3.90%.

BMI and BMA plastic film bags had the lowest temperatures, 2.51 and 1.88 °C, respectively, whereas the non-perforated bags had the highest value (4.0 °C) due to the difficulty in heat exchange when compared to the others. The treatments located at the intermediate level had the highest temperature values, 5.13 °C, while at the lower and upper levels the temperature was of 2.18 and 1.09 °C, respectively. In their results, Pham et al. (2019), when characterizing the pallet heat transfer, found that the central levels cool down more slowly.

Temperatures are higher in the intermediate level due to the lower airflow, although the air passes through 3 sides of the pallet, there is a flow deviation in this region. According to Barbin et al. (2009), the cooling rate is influenced by the contact surface area of the product with the cooling medium. According to Damasceno et al. (2015), in regions with lesser air flow, the heat exchange through convection is reduced. The lower level has lower temperatures than the intermediate

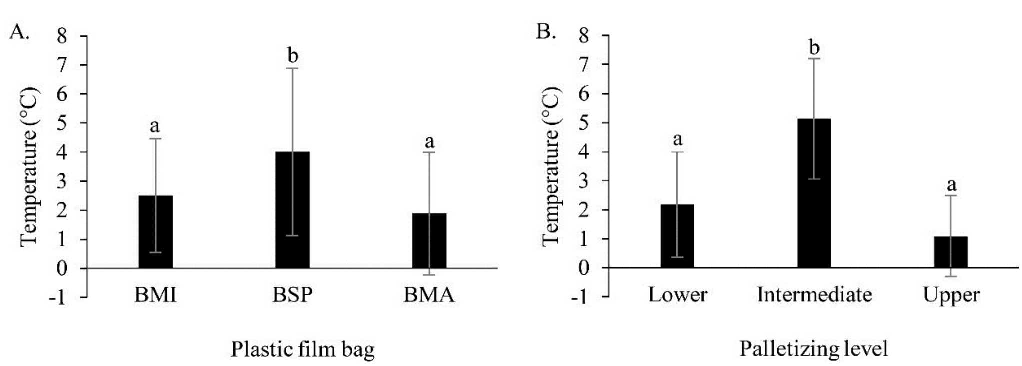


**Figure 3.** Final temperature for the plastic film bag (A) and palletizing levels (B) in the rapid-cooling chamber. Means followed by the same letter do not differ according to the Scott-Knott test (p ≥ 0.05). BMI-micro perforated, BSP-non-perforated and BMA-macro perforated.

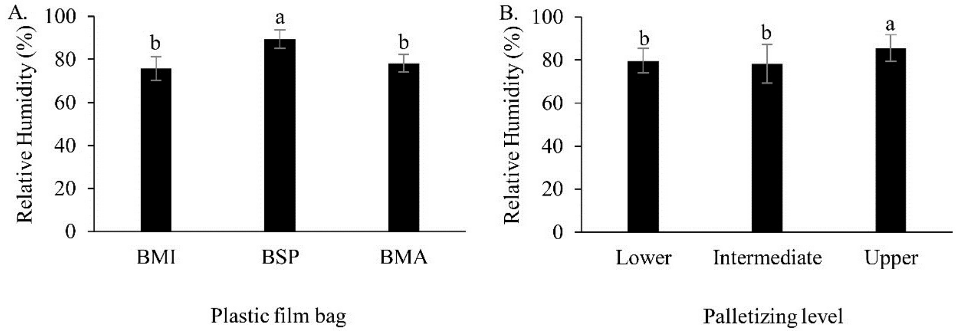


**Figure 4.** Final relative humidity for the plastic film bag (A) and palletizing levels (B) in the rapid-cooling chamber. Means followed by the same letter do not differ according to the Scott-Knott test ($p \geq 0.05$). BMI-micro perforated, BSP-non-perforated and BMA-macro perforated.

by reason of the greater airflow in this region, due to the cold air density being higher and thus staying at the bottom.

It is worth emphasizing that the opening area of the cardboard boxes is another factor associated with the heat transfer between the product and the cooling medium. These orifices, when arranged in strategic positions, allow the adequate passage of the cold air; however, the excess of openings can influence negatively the structural resistance of the boxes. In short, striving to improve these packages can provide greater heat exchange between table grapes and the environment.

The rapid cooling process aims to quickly remove heat from the fruit just arrived from the field so that the later storage at reduced temperatures is possible. According to Carvalho et al. (2015), this process facilitates the fruits adaptation to the refrigerated environment. According to Senhor et al. (2009), the best way to cool a palletized load is with forced air, as cold air comes in direct contact with the fruit and exchanges heat more efficiently.

The desired temperature in the rapid-cooling chamber is of 0 °C. According to Neves (2016), table grapes are kept at this temperature for a long period of time, which may vary between 3 and 6 months. These said values were only attained at the upper level, approximately 8 h after its disposition in the chamber, where, as according to Inestroza-Lizardo et al. (2016), the product with more contact with the air flow cools in less time.

According to Neves (2016), during rapid cooling, the environment humidity should be around 90-95% so that there is no water loss from fruit to the environment. When the environment RH is in adequate levels, the excessive fruit transpiration is reduced, thus minimizing the water loss to the environment.

The RH for the BMI, BSP and BMA plastic film bags was of 75.77, 89.48 and 78.3%, respectively. Only the non-perforated plastic film bag attained humidity values close to the considered as ideal. For the lower, intermediate and upper levels, the RH was of 79.68, 78.31 and 85.56%, respectively.

It is important noting that, in the environment, the RH had peaks (Figure 5) and the BSP was the only one that was not much influenced, with the other plastic film bags following the variations. The humidity in the rapid-cooling chamber was

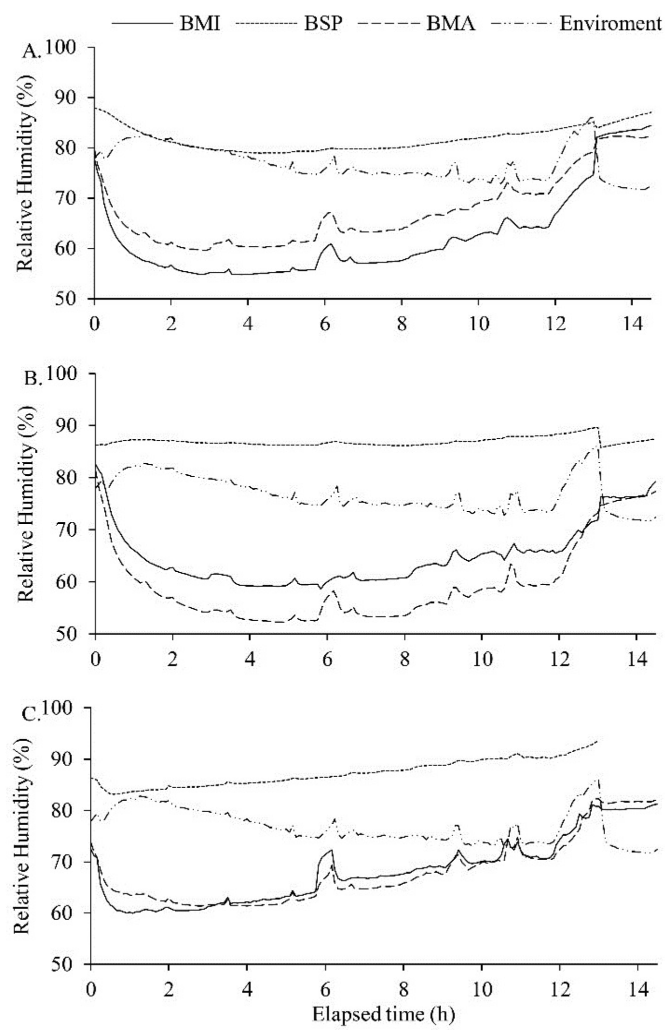


**Figure 5**. Relative humidity inside the pallet at the lower (A), intermediate (B) and upper (C) levels in the rapid-cooling chamber. BMI-micro perforated, BSP- non-perforated and BMA-macro perforated.

78.0%, which is less than ideal, evidencing that in order to use micro and macro plastic film bags, the chamber RH must be in adequate values.

The ideal, concerning the RH, is that it stays within the proper limit and no variations occur, since it has a direct influence on maintaining fruit quality. According to Miguel et al. (2009), the consumers look for juicy grapes, and reducing this moisture causes damage to the appearance and quality, resulting in the depreciation of the product.

The cooling time, indicated by the half and seven octave times, was calculated using the Dimensionless Temperature Rate (DTR) in the 3 palletization levels, as illustrated by Figure 6. The rate, after 12 h, is discontinued due to defrosting occurring in the rapid-cooling chamber.

In the lower level pallets, it took 3 h and 50 min, 4 h and 10 min and 6 h for the BMA, BMI and BSP plastic film bags reaching the half-cooling time, respectively. In the intermediate level pallets, it took 6 h and 20 min to reach the half-cooling time for the BMI plastic film bag, 5 h and 50 min for the BMA and 8 h and 50 min for the BSP. In the upper level pallets, it took 2 h and 10 min, 2 h and 25 min and 2 h and 55 min for the BMI, BMA, and BSP plastic film bags, respectively.

The time of seven octaves (DTR = 0.125) indicates the time to transfer the grapes to the cold room. At the lower level, the DTR reached this value for the BMI and BMA plastic film bags, between 9 and 10.5 h. At the intermediate level, only the BMA plastic film bag, in 13 h, reached this DTR value. At the upper level, all plastic film bags reached this DTR value at around 6 h and 30 min, except for the BSP, which took another 1 h and 30 min.

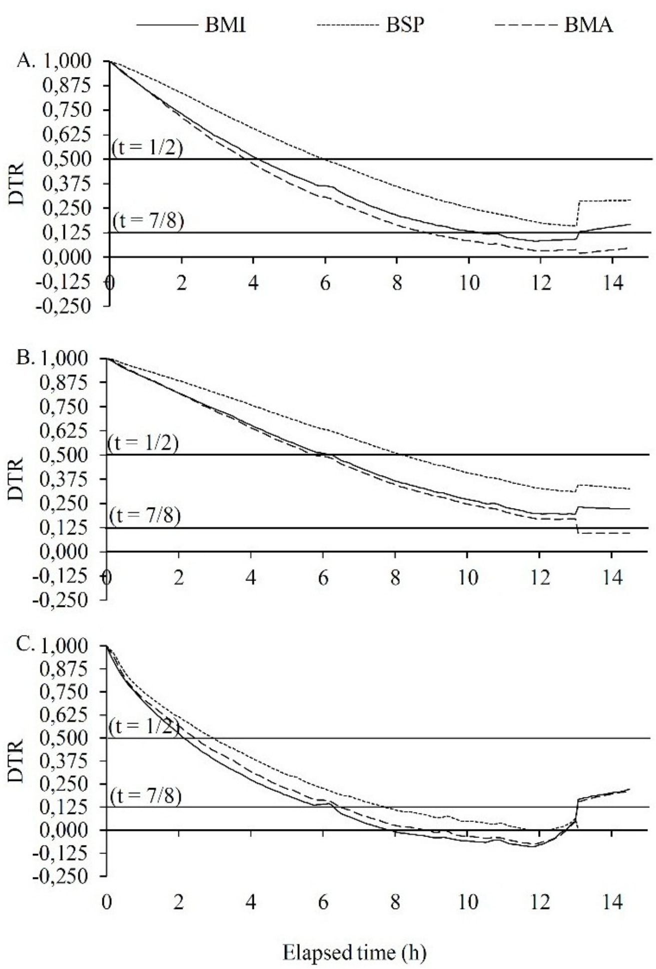


**Figure 6**. Dimensionless Temperature Rate (DTR) at the lower (A), intermediate (B) and upper (C) levels. BMI-micro perforated, BSP-non-perforated and BMA-macro perforated.

This information on the cooling time explains that, on the pallet, there are differences in heat loss according to the palletization levels, thus indicating that the grapes are transferred to cold room storage without each one having attained the ideal temperature during the rapid cooling. Moreover, the BSP needs a longer cooling time when compared to other plastic film bags.

After 14.5 h in the rapid-cooling chamber, the pallets were transported to the cold room in order to be stored. The initial temperatures and relative humidity in the cold room were similar to the final temperatures and relative humidity in the rapid-cooling chamber, due to the low time interval for transferring the pallets.

The mean temperature of the cold room environment during the analyzed period was of 2.95 °C. According to Neves (2016), the storing temperature in the cold room for table grapes should vary between -0.5 and 0.0 °C so its quality can be kept for up to 6 months. The temperature values after 24 h in the cold room did not have significant differences between the plastic film bags and the levels, indicating that the temperature remains in the same condition for all of them.

At the end of 24 h of analysis in the cold room, it was possible verifying that the RH is equal between the palletization levels, having differences only between the plastic film bags, with a 3.55% coefficient of variation. According to Figure 7, the BSP plastic film bag had the highest humidity values, 94.16%, when compared to the BMI and BMA plastic film bags, which had 86.09 and 88.67%, respectively.

Figure 8 illustrates the RH behavior in the plastic film bags in relation to the pallet levels. Overall, only the BSP maintains the ideal relative humidity over the allotted time.

Even with the environment RH below the ideal and fluctuating, regarding the storage and post-harvest conservation, it tends to reach adequate values between the plastic film bags over time. It is necessary keeping the environment RH in the ideal range so that inside the plastic film bags it can be adequate.

RH is one of the factors that directly affect fruit quality. The variables analyzed to verify the maintenance of this quality were fruit abscission and weight loss. The abscission

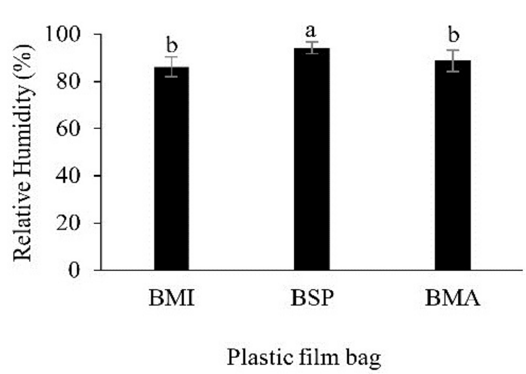


**Figure 7.** Final relative humidity (%) for the plastic film bags in the cold room. Means followed by the same letter do not differ according to the Scott-Knott test ($p \geq 0.05$). BMI-micro perforated, BSP- non-perforated and BMA-macro perforated.

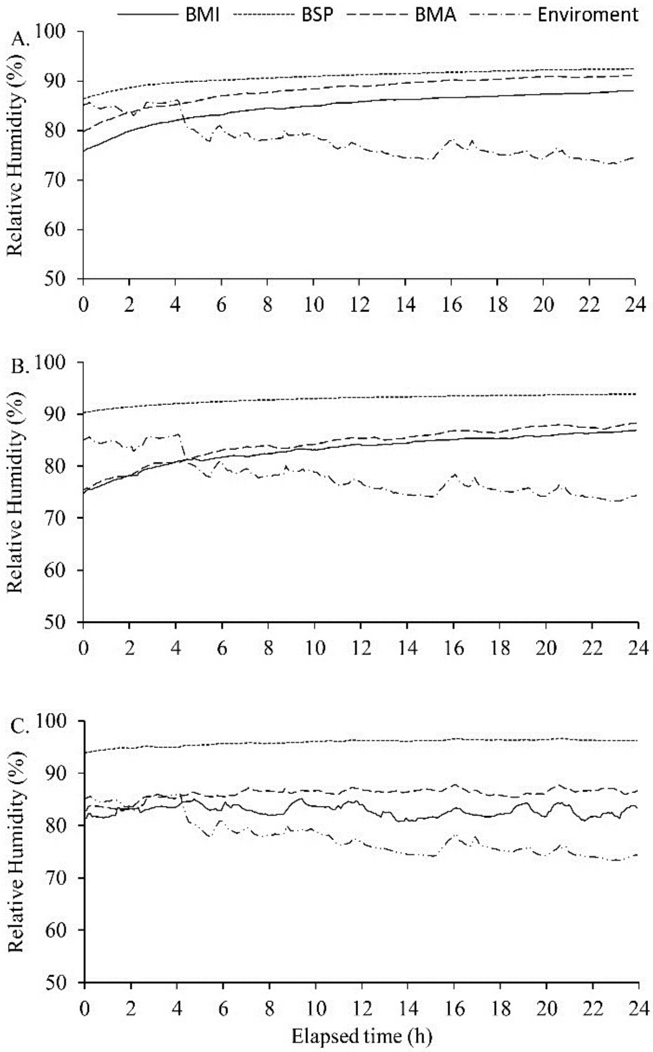


**Figure 8.** Relative humidity inside the pallet at the lower (a), intermediate (b) and upper (c) levels in the cold room. BMI-micro perforated, BSP- non-perforated and BMA-macro perforated.

on the palletization day did not present any significant differences between plastic film bags and levels, with mean values of 6.77%, illustrating that the grapes went in the same conditions and with high values. The statistic differences

**Table 1.** Fruit abscission percentage (%) after 60 days of storage.

| Plastic film bag | Palletizing Level | | |
|---|---|---|---|
| | Lower | Intermediate | Upper |
| BMI | 1.88 bA | 0.43 cB | 2.71 aB |
| BSP | 3.61 aA | 2.72 bB | 3.61 aA |
| BMA | 2.85 aB | 5.60 aA | 3.26 aB |

Means followed by the same letter do not differ according to the Scott-Knott test ($p \geq 0.05$). Lowercase letters refer to the comparison between plastic film bags. Uppercase letters refer to the comparison between levels. BMI-micro perforated, BSP-non-perforated and BMA-macro perforated.

for this variable appeared after 60 days of storage, where significant interactions between plastic film bags and levels (Table 1) took place, with a coefficient of variation of 16.52%.

The BMI plastic film bags at the intermediate level had the lowest rate. The BMA plastic film bags at the intermediate level and BSP at the lower and upper levels demonstrated the highest values found. In a study by Ferreira et al. (2017), when evaluating the effect from the pre-harvest application of foliar fertilizers and bioregulators, they found the 0.56% abscission value of the control after 56 days after storage. For the present study, the abscission at 60 days of storage under similar conditions was between 0.43 and 5.60%.

The weight loss after the rapid-cooling chamber does not present any statistical differences between the plastic film bags and levels, representing an average loss of 5.43%. In a study by Youssef et al. (2015) with 'BRS Vitoria' table grapes, the weight loss during 30 days of cold storage varied from 1.9 to 3.8%, these values  lower than those found during 24 h in the rapid-cooling chamber, demonstrating a great weight loss for not working with adequate RH values.

After 60 days of storage, there was no interaction between the plastic film bags and pallet levels concerning the weight in the cold room; however, there are significant differences between plastic film bags and between pallet levels (Figure 9), with a coefficient of variation of 11.33%.

BMI and BMA plastic film bags had weight losses of 8.3 and 7.59%, respectively, whereas the BSP presented the lowest percentage, with 4.84%, especially because it presents higher humidity values, thus preventing the water loss to the environment. According to Castellanos & Herrera (2015), when the environment relative humidity is less than that of

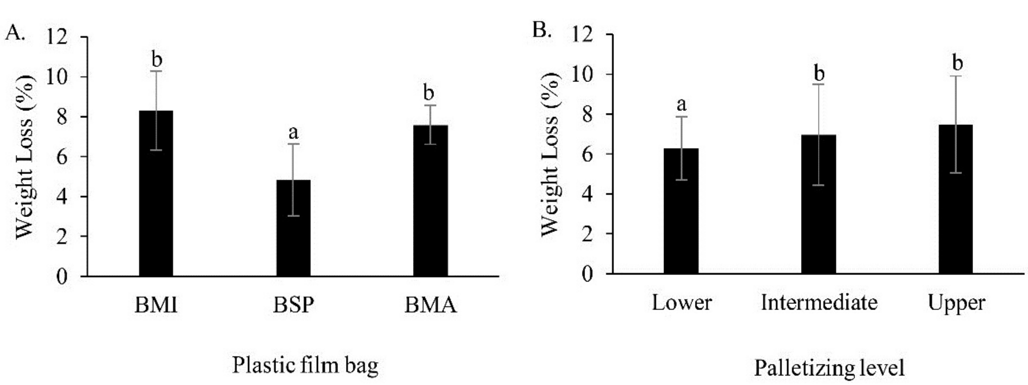


**Figure 9.** Weight loss (%) after 60 days of storage between plastic film bags (A) and between palletization levels (B). Means followed by the same letter do not differ according to the Scott-Knott test ($p \geq 0.05$). BMI-micro perforated, BSP-non-perforated and BMA-macro perforated.

the product, the first absorbs water from the second, which is what happened with the other plastic film bags.

When evaluating the weight/loss mass of ‘Romana’ grapes, Lulu et al. (2005) found an index of 6% during 21 days of storage and 10% after 36 days, when stored in a cold room at the temperature of 3 °C and relative humidity between 90-95%. Silva et al. (2012), analyzing the quality of ‘Isabel’ grape at a temperature of 12 + 1 °C and 85 + 2% relative humidity, verified weight losses of 4% for the modified atmosphere and 10% for the ambient atmosphere during 12 days. In this study, along the 60 days of storage in the cold room, these losses varied between 4.84 and 8.30%, demonstrating that there were low losses in relation to other studies and that they may be much smaller when put under a rapid cooling with a proper RH.

## Conclusions

Considering the smallest weight loss in the non-perforated plastic film bag, using BSP allows better conservation of the table grape stored in a cold room.

The micro and macro perforated plastic film bags demonstrated equivalent results in terms of weight loss.

As for the BSP, it is worth noting that water condensation may occur, and additional studies are needed for verifying the microorganism development due to this humidity.

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