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# Brazil plum fruit (*Spondias tuberosa*) stored under refrigeration with different types of packaging

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**Abstract**

The objective of this work was to evaluate the use of packaging to maintain quality and extending the postharvest life of umbu tree fruits in different storage periods, stored at 14 ° C and 90% UR. The experimental design used was completely randomized, in a 4 x 4 factorial scheme, with four evaluation periods (0, 4, 8 and 12 days after storage) and four packaging systems (PET, PET with holes, PVC and LDPE), with four replicates and four fruits per experimental unit. The physical and chemical characteristics were evaluated, such as, objective color of the peel, firmness of the intact fruit, soluble solids, titratable acidity, pH and loss of fresh mass. The results were submitted to analysis of variance and regression, using the SISVAR software program. The characteristics of the quantitative factor (types of packaging) were compared by the Tukey's test at 5% probability, while for those of the qualitative factor (storage period), the adjustment was made to the regression model. There was a significant interaction between packaging and storage periods only for loss of mass. The luminosity characteristic was significant only for the type of packaging. For the other variables such as chroma, HUE angle, firmness, titratable acidity and pH, there was no significant interaction between the factors tested, having significance only for storage period. For soluble solids, there was no significance for packaging and storage period. The PVC and PET packaging were effective in delaying the loss of mass, and withering of the fruits up to 12 days, which kept under refrigeration at 14°C. It was verified that along the storage time, physical and chemical changes occur in the umbu tree fruits.

**Keywords:** Anacardiac; modified atmosphere; package; postharvest conservation; *Spondias tuberosa* Arr. Câm.
LDPE_low density polyethylene, PVC_polyvinyl chloride, PET_tereflated polyethylene.

**Introduction**

Umbu tree (*Spondias tuberosa* Arruda) is a native fruit tree of the Brazilian Semi-arid region (Northeast and North of Minas Gerais), belonging to the family Anacardiacea (Saturnino et al*.,* 2019). Its production chain demands research that selects genotypes with a propensity for fresh commercialization and processing, as well as adaptation of technologies for handling and methods of propagation that anticipate production, which facilitates the expansion of the product (Batista et al., 2015; Lima et al., 2018).

Although traditionally consumed by the regional population, little is known about the chemical composition and the potential for food use of this fruit. Such limitation opens the opportunity for the inference of coordinated actions that cover product quality, insertion of appropriate techniques to the regional context and reduction of postharvest losses (Drumond et al., 2016).

Nowadays, the umbu tree fruits have gained ground in national and international markets because of the pleasant aroma and unique flavor, in addition to being a good source of bioactive compounds, source of vitamins B1, B2, B3, A and mainly C, antioxidant compounds, in addition to minerals such as calcium, phosphorus and iron (Moura et al., 2013; De Menezes et al., 2017). It is a drupe type fruit, indeiscent, monopartic and monospheric, round, elliptical or oval, with smooth or slightly hairy skin with yellowish-green color, fleshy (Saturino et al., 2019). However, due to its high perishability and the lack of knowledge and techniques that enable the production and postharvest conservation, there is a limitation on the insertion of the product on the market (Lima et al., 2018).

The use of conservation techniques, such as the modified atmosphere, contributes to increase the lifespan and reduce losses caused by the deterioration of the fruit, thus reducing postharvest losses (Serpa et al., 2014). This technique is based on the change of the gas concentration inside plant tissues, due to respiration. Ideally, the film used should reduce the available $O_2$ concentration to levels low enough to delay the respiration process, without allowing anaerobic respiration, and prevent the accumulation of $CO_2$ at levels that cause physiological disturbances (Araújo et al., 2009). This technique consists of using plastic films capable of reducing the concentration of O2, increasing that of $CO_2$ and inhibiting the production and action of ethylene (Morais et al., 2010).

In the search for the best forms of food preservation, storage with packaging is a promising alternative. Due to its practicality, relatively low cost and high efficiency packaging based on polyvinyl chloride (PVC), polyethylene terephthalate trays (PET) and low-density polyethylene (LDPE), have been widely used, especially when associated with cold storage to avoid fruit losses. Tropical fruits can have a prolonged postharvest life, due to the reduction of

the respiratory rate, the ethylene production, and consequently, the delay of ripening through the modification of the atmosphere (Chitarra and Chitarra, 1990).
Among the films most used commercially, there are low density polyethylene (LDPE) films with different thicknesses, which have good permeability characteristics, polyvinyl chloride (PVC) based packaging, tereflated polyethylene (PET) trays (Chitarra and Chitarra, 2005).
These films have different degrees of permeability to water vapor and CO2 and O2 and ethylene gases (Batista et al., 2007), which is a promising alternative associated with cold storage to prolong the post-harvest life of the fruits, due to the practicality, relatively low cost and high efficiency of these films.
Therefore, the objective of the present work was to evaluate the effect of different packaging and storage periods in maintaining the quality and postharvest conservation of umbu tree fruits stored under refrigeration.

**Results and Discussion**

There was a significant interaction ($p < 0.05$) between packaging and storage periods only for the characteristic loss of mass. The luminosity characteristic was significant ($p < 0.05$) only for the type of packaging. For the other variables such as chroma, HUE angle, firmness, titratable acidity and pH, there was no significant interaction ($p > 0.05$) between the tested factors, with significance ($p > 0.05$) only for storage period. For soluble solids there was no significance ($p > 0.05$) for packaging and storage period.

***Fresh weight of fruits***
There was a significant increase in the loss of fresh weight of fruits as the storage period for all treatments, being higher than the 12 days of storage (Figure 1). The greatest losses were observed for the fruits of the LDPE (low density polyethylene) packaging. At the 12th evaluation day of this treatment, the loss of fresh mass was 5.23 (%), being greater during the whole experimental period when compared to the other treatments. The LDPE packaging showed this result, probably due to the low density of the packaging, favoring the ripening of these fruits when compared to other treatments.
The fruits with the other packages showed less loss of fresh mass, and the PET and PVC packaging were the most efficient in delaying the loss of mass of the fruits, due to the fact that these packages exhibit high density and do not have holes in the lids. Polymeric films are used to form a modified atmofesra (MA) around the fruit through a protective film capable of reducing respiration and limit the transfer processes of the fruit water vapor to the environment, which provides a longer period of quality preservation (Lima and Silva, 2016; Lima and Castricini, 2019). Corroborating with the present work, Moura et al. (2013), worked on umbu harvested at different maturation stages and stored under modified atmospheres and environments. They observed that umbus packed with PVC showed less loss of fresh mass than unpackaged fruits, and remained in optimum conditions for consumption for up to six days.
According to Chitarra and Chitarra (2005), some fruits with loss of mass of only 4% have their commercialization compromised, while others are only affected with losses of mass above 7%. In this work, the mass losses varied from 5.23%; 4.77%; 4.15% and 4.07%, in LDPE, PET.H, PVC and PET packaging, respectively on the 12th day of storage. Taking as a reference, the loss of 4%, only fruits packaged with PET could be marketed until the 12th day of storage. The loss of fresh mass provides significant economic losses in the quantity and quality of fruits to be commercialized.
In the results obtained for the evaluation of luminosity (brightness, L*) the PET.H packaging was more efficient in conserving the luminosity of the fruits compared to the other packages that presented more opaque fruits (Table 1). It probably could have happened due to a lower amount of $CO_2$ present in this package, since it has a perforated lid "holes" allowing gas exchange with the external environment, which interferes with the luminosity due to less degradation of anthocyanins. According to Kader (2010), the value of Luminosity (L*) during storage is an indicator of darkening, which can be caused, both by oxidative reactions and by increasing the concentration of pigments.

***Chromaticity***
With regard to chromaticity, there was a significant decrease in fruits during storage (Figure 2), indicating a reduction of color intensity, reaching at 12 days, 33.39; 32.11; 31.92; 30.88, respectively for PVC, PET, PET.H treatments, the lower these values, the more impure the color is. Packaging did not affect the preservation of color. It looks that packaging delayed degradation of chlorophyll during storage along with reduced normal respiration rate. Since the difference from the first to the last evaluation was negligible, the enzymes that cause color degradation depend on the concentration of ethylene, which in turn is reduced due to the low concentration of oxygen.
Umbu-laranja fruits kept refrigerated lost their vitality (decline in C*) during different types of storage. However, under a modified atmosphere, the chromaticity was higher, keeping vividness the yellow color of the peel for longer (Lopes, 2007). Moura et al. (2005) in work with cashew stalk under modified atmosphere, observed that for the color variable, CCP 76 was the only clone to suffer interference from time regarding to chromaticity, even so the loss was quite small (1.70%) during storage.

***Hue ° angle***
The color angle (°hue) can vary from 0° to 270°, with 0° corresponding to red, 90° corresponding to yellow, 180° to green and 270° to blue. During storage, the values of the hue angle were significantly reduced (Figure 3), showing the evolution of the de-greening of fruits during storage as a result of maturation. This behavior is in agreement with Pinheiro et al. (2015), who verified the maintenance of light green to yellow color in umbu, with values in the range of 82.4 to 100.7°.

***Firmness***
Fruit firmness decreased from 30.24 N to 23.88 N during 12 days of storage, with no difference between the type of packaging (Figure 4). This result may be associated with the temperature and the storage period, so the temperature of 14ºC maintained the quality of the umbu, observing greater firmness until the 12 days of storage. Silva et al. (2009) working with different storage temperatures observed that at a temperature of 14ºC the umbu tree fruits value was promoted from 30 to 16.7; while at a temperature of 25ºC, the fruit was totally softened at 13 days of storage.

**Table 1.** Luminosity of umbus stored under refrigeration with different PVC, PET, PET.H and LDPE packages (stretchable polyvinyl, polyethylene terephthalate trays with and without perforated lid “holes”, low density polyethylene) for 12 days at 14 ° C, Ja naúba-MG – 2018.

| Packages | Luminosity |
|---|---|
| PVC | 53.84 b |
| PET | 52.97 b |
| PET.H | 49.65 a |
| LDPE | 53.90 b |
| CV (%) | 7.26 |

Means followed by the same letter do not differ by Tukey's test, at the 5% probability level.

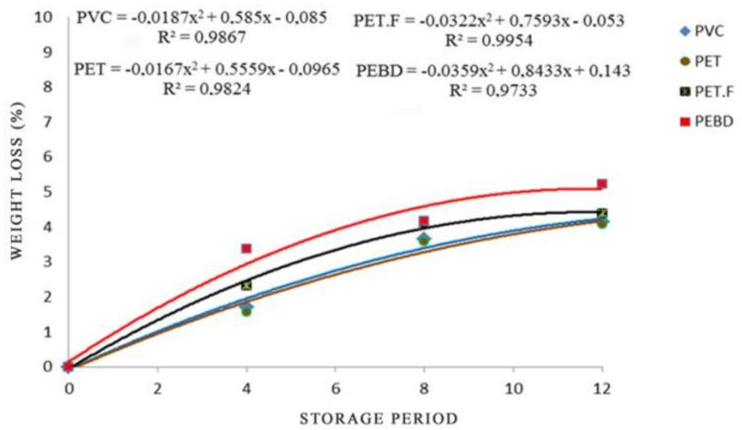


**Fig 1.** Loss of fresh mass from umbus stored under refrigeration with different PVC, PET, PET.F and LDPE packaging (stretchable polyvinyl, polyethylene trays with and without perforated lid, low density polyethylene) for 12 days at 14°C, Janaúba MG – 2018.

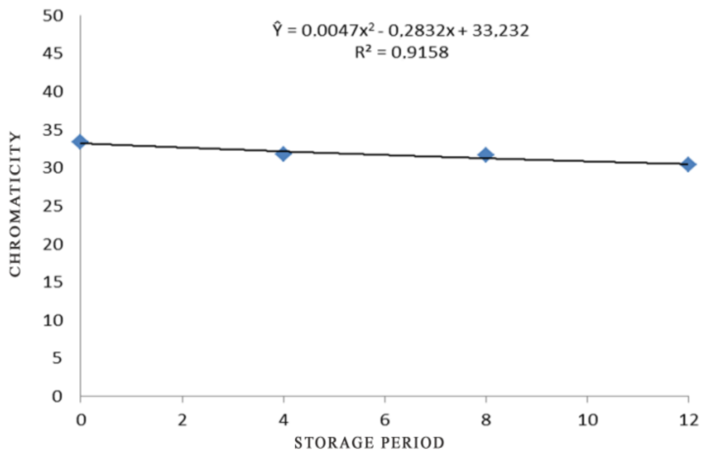


**Fig 2.** Chromaticity of umbus stored under modified passive atmosphere for 12 days at 14°C, Janaúba-MG – 2018.

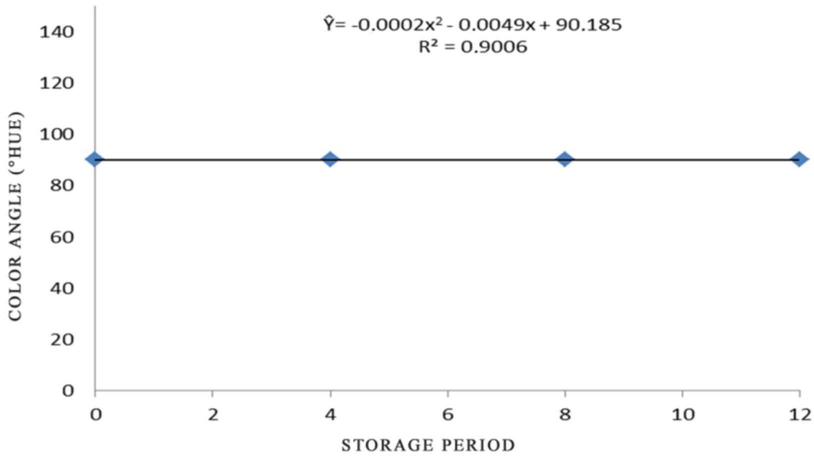


**Fig 3.** Hue ° angle of umbus stored under modified passive atmosphere for 12 days at 14°C, Janaúba-MG – 2018.

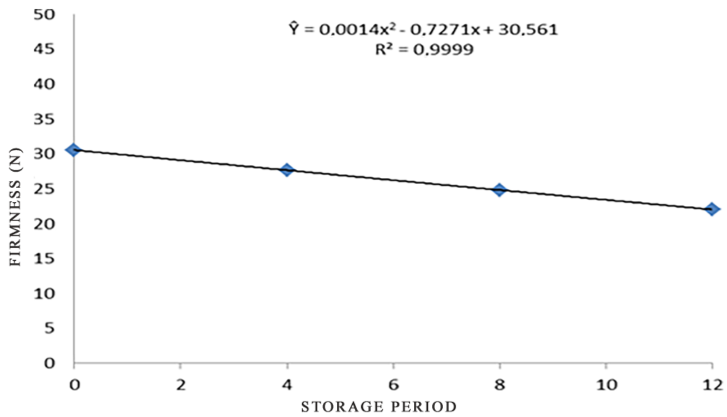


**Fig 4.** Firmness of umbus stored under modified passive atmosphere for 12 days at 14°C, Janaúba-MG – 2018.

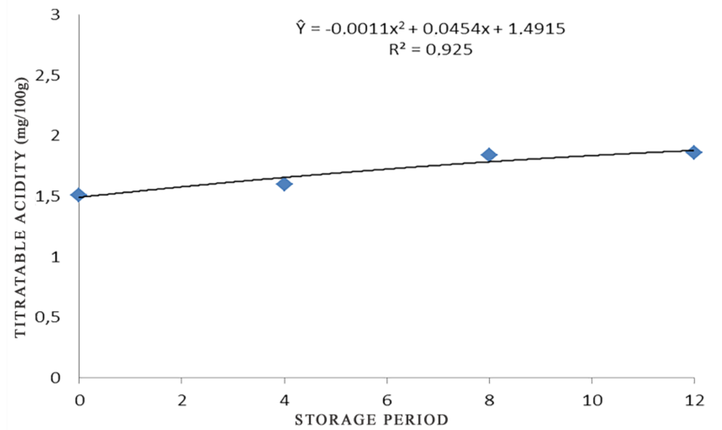


**FIG 5.** Titratable acidity of umbus stored under modified passive atmosphere for 12 days at 14°C, Janaúba-MG – 2018.

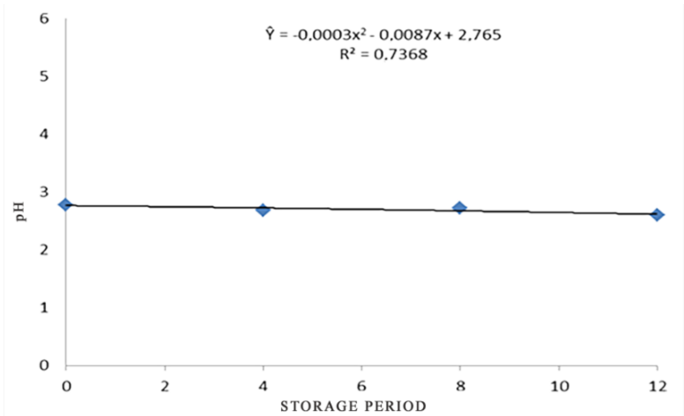


**FIG 6.** PH of umbus stored under modified passive atmosphere for 12 days at 14°C, Janaúba-MG – 2018.

The decrease in firmness or softening of tissues results from several physiological processes that may be associated with the reduction of cell turgidity and degradation of starch and cell wall compounds (Lima and Castricini, 2019).

Oliveira et al. (2014) evaluated modified atmosphere and refrigeration for postharvest conservation of camu-camu for 25 days of storage. They only observed a difference between packages after the 13th day of storage. Therefore, the umbu fruits would present a difference between the packages if stored with a longer period, because until the 12th day the fruits remained firm.

***Titratable acidity***

The umbu's titratable acidity (TA) increased during storage, varying from 1.46 to 1.89 until the 12th evaluation day (Figure 5). This behavior was the opposite to pH results. According to Chitarra and Chitarra (2005), during ripening most fruits quickly lose their acidity. However, in some cases like umbu, an increase in the contents was observed upon ripening. In turn, the increase in acidity is due to the action of enzymes in the Krebs cycle, which in some cases may decrease its activities during ripening. So, the decrease in enzymatic metabolism favors the delay in fruit ripening. Therefore, the increase in acidity is common in immature fruits causing the fruit to taste sour. Ferreira et al. (2009) found an increase in acidity during the ripening of acerola. These authors explained that this result is biochemically similar to that of bananas during ripening, in which a reduction in the activity of the enzyme malate oxidase, results in the accumulation of malic acid.

***PH***

Unlike TA, the umbu's pH was decreased during storage (Figure 6), which suggests the synthesis of organic acids in agreement with the increase in titratable acidity. Lopes (2007) evaluated the physiology of ripening and postharvest conservation of umbu-laranja access. They observed that fruits harvested in the greenest stage showed a decrease in pH, while fruits that were in a more advanced stage of maturation showed increases in pH values. Therefore, it appears that the present work on the 12th day of storage was not yet in the advanced maturation stage, so higher values were not observed.

The content of soluble solids provides an indication of the amount of sugar present in the fruits. During maturation the content of total soluble solids tends to increase due to the biosynthesis of soluble sugars or the degradation of polysaccharides, such as starch (Chitarra and Chitarra, 2005). In the present work, packaging and storage period had no effect on this factor and may be related to the short evaluation period. This fact was also found by Silva et al. (2009), working with different storage temperatures for 13 days, who did not observe an increase in the SS content. Oliveira et al. (2014) evaluated modified atmosphere and refrigeration for postharvest conservation of camu-camu, and only observed difference between packages on the 25th day of storage. According to these authors, this fact can be justified by the lower loss of turgor with consequent concentration of the pulp, due to the less water loss in these treatments.

**Materials and Methods**

***Obtaining plant material***

The umbu tree fruits were harvested from plants of the EPAMIG-1 clone of the Agricultural Research Company of Minas Gerais - EPAMIG, in Nova Porteirinha, North of Minas Gerais, 2018 harvest, and packed in plastic boxes suitable for harvesting.

Then they were sent to the laboratory of Postharvest Physiology at the Agronomy Campus of the State University of Montes Claros-UNIMONTES, located in Janaúba/Minas Gerais, to perform the selection of fruits, sanitization and execution of the experiment.

***Treatments***

The experiment was conducted in a completely randomized design (CRD), in a 4x4 factorial scheme, with 4 types of packaging (stretchable polyvinyl, polyethylene terephthalate trays with and without perforated lid “holes”, low density polyethylene) and 4 evaluation periods (0, 4, 8 and 12 days after installation of the experiment). Four replications and four fruits per replication were used.

The fruits were packed in Neoform® model N 92 polyethylene terephthalate trays (PET and PET.H), with a lid, with dimensions of 19.0 x 16.5 x 4.5cm and a volume of

500mL; Meiwa expanded polystyrene trays (PVC) model M-54, with dimensions of 10.0 x 20.0cm and 0.5cm of thickness, covered with stretchable polyvinyl chloride film (Goodyear, 0.017mm of thickness); low density polyethylene (LDPE) bags with a thickness of 25µm of single wall, dimensions of 35 X 45cm, stored in a cold chamber at 14ºC (± 1ºC) and 90% (± 5%) of relative humidity for 12 days.

***Conduction of experiment***

The color analysis was performed by the colorimeter Color Flex 45/0 (2200), stdzMode: 45/0 with direct reflectance reading of the coordinates L* (luminosity) a* (red or green color) and b* (yellow or blue color), of the Hunterlab Universal Software system. From the values of L*, a * and b*, the hue angle (°h*) and the saturation index chroma (C*) were calculated. The loss of fresh mass was calculated through the difference in mass between the accumulated evaluations during the evolution of the experiment and the result of the loss of fresh matter in relation to the initial mass of the fruit, expressed as a percentage. Firmness of the intact fruit (N) was measured in the middle region of the fruit, using a texture analyzer from Brookfield model CT3 10KG, determined by the penetration force necessary for the tip of 2.5 cm in length and 4 mm in diameter to penetrate the fruit pulp, measured in Newton (N). Titratable acidity was determined according to the AOAC method (1995) using 10g of the pulp diluted in 90mL of distilled water followed by titration with standardized 0.1M NaOH solution, with phenolphthalein as an indicator. The result was expressed in grams of citric acid per 100g of sample. The pH was determined directly in the juice using a DIGIMED Digital pH meter, model DM20, after preparing the samples as in the previous analysis. The soluble solids were determined by refractometry, using a bench refractometer (ATAGO, model N1) with a wide measurement range (Brix: 0-95%), the result was expressed in °Brix.

***Experimental design***

The results were submitted to analysis of variance through the SISVAR program (Ferreira, 2011). The characteristics of the qualitative factor (types of packaging) were compared using the Turkey test, at the level of 5% probability, while for those of the quantitative factor (storage period), the adjustment was made to regression models.

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**Conclusions**

The PVC and PET packaging were effective in delaying the loss of mass, and withering of the fruits in up to 12 days, kept under refrigeration at 14 ° C. It was verified that along the storage time, physical and chemical changes occur in the umbu tree fruits.

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