Journal of Agricultural Science; Vol. 12, No. 9; 2020
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Post-Harvest Conservation of Green Maize in Different Packages

Victória Azevedo Monteiro[1], Francielly Rodrigues Gomes[1], Pedro Henrique Magalhães de Souza[1], Ricardo Carvalho Ribeiro[1], Cláudia Dayane Marques[1], Moab Acácio Barbosa[1], Givanildo Zildo da Silva[1], Angelita Lorrayne Soares Lima Ragagnin[1], Américo Nunes da Silveira-Neto[1], Simério Carlos Silva Cruz[1], Hildeu Ferreira da Assunção[1], Cláudio Hideo Martins da Costa[1] & Danielle Fabíola Pereira da Silva[1]

[1] Universidade Federal de Jataí, Jataí, Goiás, Brazil

Correspondence: Angelita Lorrayne Soares Lima Ragagnin, Universidade Federal de Jataí, Campus Jatobá, BR 364, km 195, n° 3800, CEP 75801-615, Jataí, Goiás, Brazil. E-mail: angelitaragagnin@gmail.com

Received: June 7, 2020 Accepted: July 24, 2020 Online Published: August 15, 2020

doi:10.5539/jas.v12n9p208 URL: https://doi.org/10.5539/jas.v12n9p208

The research is financed by CAPES and CNPq.

Abstract

Maize is the second most produced grain in Brazil, which has the potential to produce green maize, which is maize harvested before physiological maturation. Aimed with this work evaluate three packages for postharvest conservation of green maize at room temperature in the conditions of the Brazilian cerrado. The double hybrid AG-1051 were planted. After the cobs were harvested, they were submitted to three treatments, each treatment with three repetitions and each repetition contained 4 cobs. The analyzes carried out were: fresh weight loss, instrumental coloring, titratable acidity content, ascorbic acid content and soluble solids. The results were submitted to the 5% Tukey test and regression. The treatment with polyethylene stood out for the loss of fresh mass, color of the maize cobs as for the levels of titratable acidity, presenting the best results and, for the same parameters, the maize cobs of the treatment with straw showed the lowest results, showing that the conservation straw cobs is the least suitable treatment. As for the content of ascorbic acid and soluble solids, the results showed no statistical difference for any of the treatments showing that they kept the contents unchanged during storage.

Keywords: *Zea mays* L., postharvest quality, modified atmosphere

1. Introduction

Maize has economic importance due to its scope of use, that goes since the animal feeding until the high technology industry, where dry or green grain is used. After soy, maize is the Brazil most produced grain, cause according Santos, Sediyama, Santos, Salgado, and Vidiga (2011) reports, the Brazil edaphoclimatic conditions are favorable to maize production, in special the harvest green maize. This can be consumed as curau, juice, roasted, cooked or still as an ingredient in the cake, cookie, ice cream, pamonha and other foods making (Pereira Filho, Cruz, & Gama, 2002).

The use of appropriate and efficient storage technics are essential practices that influence directly in shelf life of the food. The green maize storage in appropriated packaging is marketed as minimally processed product, although its common find green maize storage in improper packages, fact that influences directly in the postharvest quality (Mamede, Chitarra, Fonseca, Soares, & Pereira Filho, 2014).

The green maize cobs are harvest with the immature grains with degree of humidity between 70 and 80%. However, the metabolism continues active after the harvest, this factor turns the green maize highly perishable and if it isn't storage correctly, can loss the commercial characteristics in few hours (Vale, Fritsche-Neto, & Lima, 2011).

Due to the fact that the maize metabolism keeps active even after the harvest, become necessary measures like cooling and use of suitable packages, which has the role of delaying the cobs senescence, protecting from unfavorable conditions, as attack of microorganisms, besides preventing gas exchange and water loss, factors that also reduce the metabolic activity extending maize service life (Pereira Filho et al., 2002), through the modified atmosphere created by the changes in the concentration of gases inside the packages (Braz et al., 2006).

Thereby, aimed with this research evaluate three packages for the green maize post-harvest conservation at room temperature in the conditions of the Brazilian cerrado.

2. Material and Methods

2.1 Experimental Area

The experiment was conducted in the experimental area of Jataí Federal University. There referred experimental area has climatic classification as tropical savanna (Aw), with rainy season from October to April and dry season from May to September. The medium temperature annual oscillates between 21 °C and 23 °C and the annual rainfall average is the 1700 mm.

2.2 Conducting the Experiment

First of all, with the aid of a regulated seeder with 0.45 m, were open grooves in an area of 371 m². Then, the manual sowing of the hybrid AG 1051 was carried out, obeying the 0.3 m spacing between plants in November 2018. The border planting was carried out with the hybrid 2B810 PW following the same spacing of the mounting of the experiment, but with the use of a pneumatic seeder.

After planting, cover fertilization was performed with simple superphosphate, potassium chloride and urea, according to the recommendation for maize culture. Fertilization and planting were carried out manually.

Periodic spraying with herbicides and insecticides was carried out whenever the need was identified. The harvest of the green cross was made in February 2019, 93 days after plantation, in the moment that the grains were in the milky phase, known as "green crop point". The cobs were packed in bags after the harvest, and then were taken to Agronomic Research Nucleus, where they were selected for size, shape, color and injuries. With straw, the cobs were between 20 and 25 cm long, without straw, the values varied between 14 to 19 cm.

A completely randomized design was used, with parcels subdivided over time, with parcels in package [treatment 1: low density polyethylene bags—LDPE with dimensions of 30.5 × 40.5 cm and thickness of 0.02 mm, which were tied; treatment 2: polyvinyl chloride—PVC with dimensions of 28 × 26 cm and thickness of 0.013 mm, were the maize cobs were placed on Styrofoam trays B3 (with dimensions of 18.5 × 23.5 cm, thickness of 16 mm and weight of 5.12 g) and then wrapped with PVC and treatment 3: strawed cobs arranged on Styrofoam tray B3, with nothing covering them] and in the subplots the sampling intervals, with three repetitions and four cobs for repetition, totaling 12 cobs per experiment parcel in each evaluation day.

After the application of the treatments, the packages were placed on benches and were evaluated on days 0; 2; 4 and 5 after storage, at room temperature, without any kind of environmental control, while they were viable for commercialization.

2.3 Evaluated Characteristics

2.3.1 Fresh Weight Loss

Fresh weight loss is determined by gravimetry, considering the difference between the initial weight of the cobs and that obtained in each sampling, carried out though weighing's during all the evaluation days and the results expressed in %.

2.3.2 Coloring

The instrumental coloring of the cobs is given by the coordinates L*, b*, C* and h°, determined with the aid of a digital colorimeter, which measures the reflected light, using a system of cartesian coordinates L*, a* and b*. The coordinate L* refers to the luminosity varying from black to white; the b* coordinate indicates the color variation from blue to yellow, C (chroma) which measures saturation where the value highlights the distance from the luminosity axis and starts at zero in the center and Angle hue (h°) measures the predominance of intensity of the predominant color in the cobs (Kong, Murdoch, Vogels, Sekulovski, & Heynderickx, 2019).

2.3.3 Soluble Solids Content

The content of soluble solids was evaluated in a digital refractometer and the results expressed in °Brix. Titratable acidity was obtained by titrating green maize grains in 0.1 N NaOH, using phenolphthalein as an indicator and the results expressed in citric acid g/100 mL of pulp (Instituto Adolfo Lutz [IAL], 2008).

2.3.4 Ascorbic Acid Content

The ascorbic acid content was evaluated by titrating 2 ml of pulp until a slightly pink color was obtained for 10 seconds with Tillmans reagent [2.6 dichlorophenolindophenol (sodium salt) 0.1%], in which the results were expressed in mg of ascorbic acid/100 g of juice (IAL, 2008).

2.4 Statistic Data

The data obtained were subjected to the normality and homogeneity error test, and subsequently to the F test of analysis of variance. The means were compared by the Tukey test, adopting the level of 5% of probability of error ($p \leq 0.05$). For the characteristics of fresh weight loss and color coordinates, the data were submitted to regression analysis. The models adjusted by regression were chosen based on the significance of the regression coefficients at the level of 5% probability by the Student's "t" test, on the coefficient of determination and on the potential to explain the biological phenomenon. Regardless of whether the interaction between packaging and days is significant or not, it was decided to split it, given the interest in the study. The statistical program Rbio (Bhering, 2017) was used for the analyzes.

3. Results

It can be seen that the greatest loss of fresh weight occurred in the treatment with straw, showing high reductions (Figure 1). This may be a consequence of perspiration, which is the main factor that leads to loss of mass in fruits and vegetables (Mamede et al., 2014). This factor may be the result of a difference in water vapor pressure that led to greater mass losses due to transpiration (Braz et al., 2006), since the straws do not form a controlled atmosphere as do the LDPE and PVC treatments.

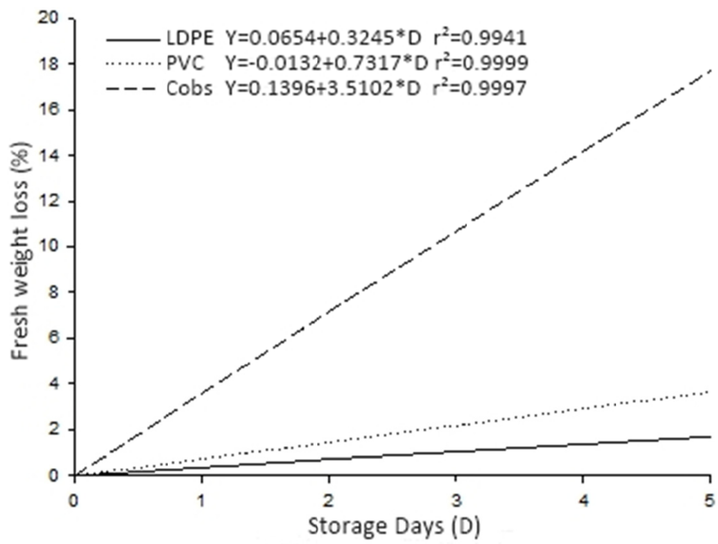

Figure 1. Estimate for fresh weight loss (%) of green maize in different packages during storage, as a function of time (D). Jataí, Goiás, Brazil (2019).

The coordinates L*, b*, C* and h° for green maize in the different packages showed a quadratic adjustment (Figure 2).

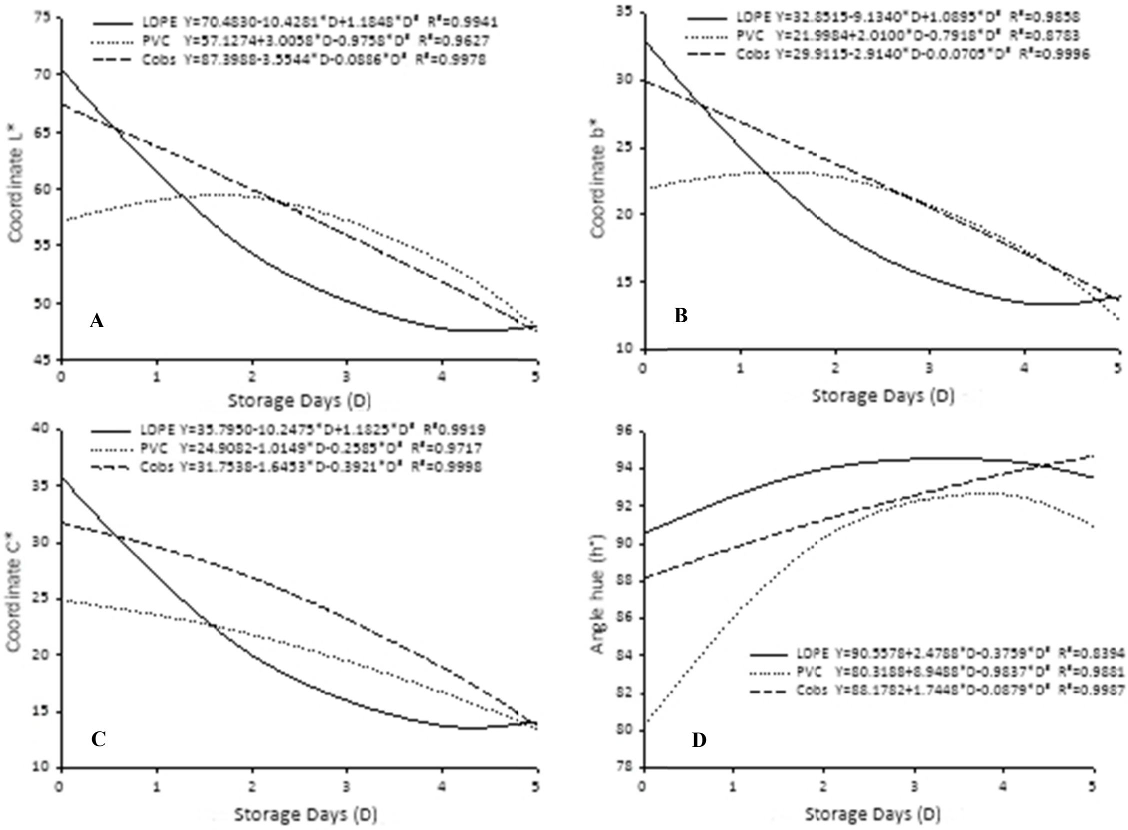

Figure 2. Estimate for coloring of green maize in different packages, A: coordinate L, B: coordinate b *, C: coordinate C and D: Angle hue for coloring maize cobs, during storage, as a function of time (D). Jataí, Goiás, Brazil (2019).

The L* coordinate refers to luminosity, ranging from black (0) to white (100). Regarding the means for the L* coordinate found in this work, values between 48.21 and 64.85 were obtained, with the lowest value corresponding to the last day and the maximum value to the first day of evaluation (Figure 2A). It was observed that there were decreases in the values of the L* coordinate during the storage period, that is, the cobs lost their luster, however this loss was imperceptible in visual terms, thus not compromising the commercialization of the ears for the different packaging used.

As for the average data referring to the b* coordinate, on the first day 34.45, 21.30 and 29.93 were observed for green maize in LDPE, PVC and straw packaging, respectively, which was reduced during the evaluation period in a quadratic way (Figure 2B). This coordinate indicates the color variation between blue (-100) and yellow (+70).

The graph shows the average maximum value of C* between packages of 30.54 on the first day, on the last day the minimum value of 14.30 was observed (Figure 2C).

It is observed that the angle h° presented values between 80.09 and 94.06, with values between 91 and 94 being more constant, showing the accentuated yellow color of green maize (Figure 2D).

Still with respect to the coordinates shown in the graphs (Figure 2), the coefficient of determination R^2 reveals the interaction between the coordinate values and the evaluation days, the closer to 1, better is the degree of explanation of the variation in the coordinate values. In the present work, the high R^2 value for all coordinates indicates a great interaction between the values decreasing linearly with the storage period.

Titratable acidity is related to the cobs' respiratory activity, when breathing occurs there is synthesis and accumulation of organic acids and the increase in these acids indicates an increase in titratable acidity. The gradual reduction in the titratable acidity levels indicates the efficiency of the treatments in reducing the respiratory rate (Mamede et al., 2014).

For titratable acidity, the average values found in this study varied between 0.95 and 2.12%. Treatments with PVC and polyethylene stood out, showing efficiency of the treatment in reducing the titratable acidity content (Figure 3), and on day four, the treatment with PVC began to show flaws in efficiency at the same aspect. Therefore, the treatment with polyethylene stood out in relation to maintaining the titratable acidity content as it decreased over the days and continued to stand out statistically.

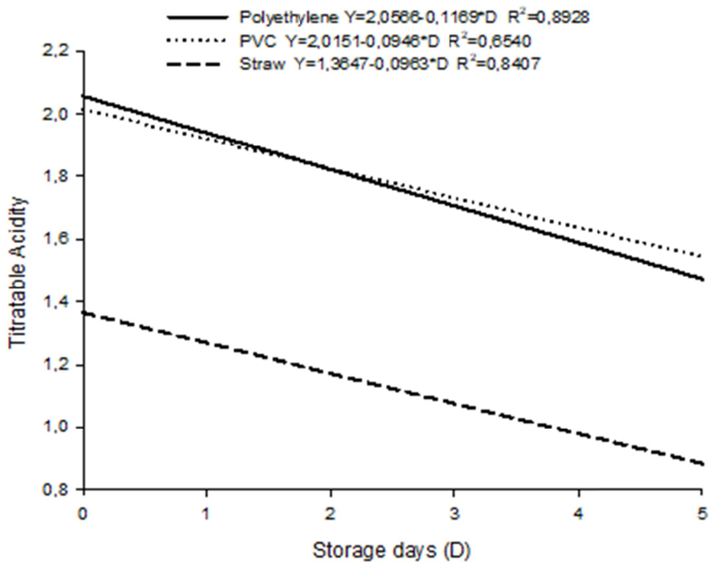

Figure 3. Adjusted data of titratable acidity of green maize in different packages during storage, as a function of time (D). Jataí, Goiás, Brazil (2019)

Ascorbic acid is an antioxidant that plays an important role in the post-harvest of foods, once it prevents browning (Préstamo & Manzano, 1993). As for the data regarding the ascorbic acid content, these revealed that there was no statistical difference between the treatments on the evaluation days, showing that the treatments obtained efficiency in the conservation of ascorbic acid, with no significant reductions (Table 1).

Table 1. Average values of titratable acidity, soluble solids content and ascorbic acid content for each treatment (polyethylene, PVC and straw) on each evaluation day. Jataí, Goiás, Brazil (2019)

Day	**0**	**2**	**4**	**5**
Acid Ascorbic Content				
Polyethylene	25.83a	27.29a	23.90a	28.46a
PVC	25.19a	24.01a	24.35a	25.40a
Straw	28.67a	31.06a	21.36a	22.40a
CV (%)	6.21	12.61	12.23	11.03
Soluble Solids Content				
Polyethylene	5.07a	5.30a	5.37a	6.13a
PVC	5.80a	5.13a	4.90a	6.20a
Straw	4.67a	4.30a	4.40a	4.10a
CV (%)	16.82	12.57	9.55	23.12

Note. CV: coefficient of variation of each treatment in each analysis.

Soluble solids are related to the sugar content of foods, these are responsible for the sweet taste and soft texture of green maize. In addition to palatable factors, sugars are a quick source of energy (Sousa, 2013). In the results found in this work in relation to soluble solids, values were found between 4.30 and 5.80 °Brix (Table 1), with the lowest results being attributed to treatment with straw, the medians with polyethylene and the highest with PVC. However, there was no significant difference between the results found here, showing that the treatments did not influence the loss of sugar from the cobs over the evaluation days (Table 1). There was a small increase in the levels of soluble solids on the last day of storage, for treatments with PVC and polyethylene (6.20 and 6.13 °Brix, respectively), which is probably due to the water loss that occurred (Figure 1).

4. Discussion

Mass loss is an important feature when working with postharvest conservation of green maize, as it is associated with the quality of life during storage and may be associated with water loss caused by metabolic reactions such as sweating and breathing (Mamede et al., 2014).

According to Braz et al. (2006), for fresh vegetables the maximum fresh weight loss must be 10%. However, losses between 3% and 6% are already capable of causing significant loss of quality (Saores, Guimarães, Silva, Durigan, & Silva, 2017). In the treatments with LDPE, PVC and straw, losses of approximately 2%, 4% and 18% were observed, respectively, for the last day of evaluation, demonstrating that the treatments with polyethylene and PVC are below the limit of 10%, being that, in the treatment in which the LDPE was used, the loss of mass did not influence the loss of quality of the green maize, presenting the lowest values of loss of fresh mass during the whole experimental period when compared to the other packages.

Thus, it is observed that the treatment with LDPE stood out among the others and the treatment with PVC showed acceptable results for the standards of vegetables. This is probably due to the fact that the plastic film creates an environment of modified atmosphere that considerably decreases the rate of metabolic reactions keeping the environment inside the tray moist, reducing the loss of water that leads to lower loss of fresh mass (Braz et al., 2006; Sousa, 2013).

In work with minimally processed green maize in a controlled atmosphere, values up to 90.2 were found (Mamede, Fonseca, Soares, Pereira Filho, & Godoy, 2015), indicating that the green maize in this study maintained the brightness of the cobs during the evaluation period for all packages tested with higher values.

The yellow color in green maize, as well as its intensity, may reveal the content of carotenoids present in the cobs. A high content of carotenoids is a very desirable characteristic since it is directly related to the nutritional quality of maize (Mamede et al., 2014). According to Mamede et al. (2015), the carotenoid content is directly related to the b* coordinate value, the same authors observed a maximum b* value of 30.36 in green maize with controlled atmosphere on the day 11 of evaluation under refrigeration.

For the present work, mean values of b* were observed on the 5th evaluation day of 14.99, 14.12 and 13.53 for green maize in LDPE, PVC and straw packages, respectively. Indicating that the modified LDPE and PVC packaging were efficient in maintaining the yellow color of the green maize even under ambient temperature conditions, because when comparing the data with Mamede et al. (2015), the authors used a controlled atmosphere and a temperature of 5 °C.

The C* coordinate is the chromaticity representing the color saturation and, thus, quantifies the intensity of the coloring element so that brighter colors have high saturation, while neutral colors, low saturation (Ferreira & Spricigo, 2017).

Soares et al. (2017) found values of Angle hue between 80.7 and 81.4 in post-harvest work with intercropped green maize. The average values for the Angle hue found in this work indicate that the green maize produced in the conditions of the cerrado of Goiás has a more intense yellow color. Once, this angle represents the qualitative of the color, thus, each of the angles 0°, 90°, 180° and 270° represent a color, and the angle of 90° represents the yellow color (Ferreira & Spricigo, 2017).

In work with baby maize production, Von Pinho, Carvalho, Rodrigues, and Pereira (2003) observed values of titratable acidity between 1.50 and 3.50%, indicating that even in the first days, the cops evaluated in the present study had lower levels of titratable acidity, demonstrating the efficiency of the treatments used. Organic acids are present inside the cells in a free form or associated with salts, esters, and glycosides. During the storage, the organic acids can be used as substrates on the respiratory process or be converted into sugars (Souza et al., 2019), which is why on this work there was a decrease in titratable acidity, especially on the treatments with LDPE and PVC since the increase on temperature provided by the packages leads to the increase of metabolic activity (Arruda, Fischer, Jeronimo, Zanette, & Silva, 2011).

The levels of ascorbic acid observed in this work were higher than those found by Von Pinho et al. (2003) and the content of 16.4 mg/100 g described by Franco (2003) as ideal for the production of green maize. This may be a consequence of factors that influence the cobs' ascorbic acid content, such as edaphoclimatic conditions, post-harvest care, among others (Von Pinho et al., 2003).

The levels of soluble solids found in the present study are close to the values found in a similar study, in which the highest content was 5.82 °Brix, a value similar to that found on the first day in the PVC treatment (5.80 °Brix). In comparison with the works found on minimally processed maize and sweet maize, in which the levels vary between 10 and 15 °Brix (Perfeito et al., 2017; Mamede et al., 2015), values higher than those found in the present work.

5. Conclusions

The use of polyethylene packaging was the most efficient in the postharvest conservation of green maize, providing less loss of fresh mass, retaining the yellowish color of the cobs grains and presenting the smallest decreases in the titratable acidity levels.

The use of cobs in the straw for post-harvest conservation of green maize is impracticable.

All packaging used maintained the levels of vitamin C and soluble solids.

Acknowledgements

The authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and National Council for Scientific and Technological Development (CNPq) for the financial support.

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