

# Post-Harvest Conservation of Baby Corn Under Controlled Atmosphere and Refrigeration

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## Abstract

The baby corn has been gaining ground in the market and arousing interest of producers. However, there is a barrier in its production chain due to the lack of scientific knowledge in the harvest and post-harvest strategies. Therefore, the objective of this study was to evaluate the changes in the physicochemical characteristics of the baby corn stored at different temperatures and under controlled atmosphere. The studies were performed at UNIMONTES with the 'AG 1051' baby corn spikelets. Two tests were performed, one considering the spikelets in the straw and the other with the husked spikelets. The tests were carried out under CRD, in a  $2 \times 2 \times 6$  factorial scheme, that is two storage temperatures (16 and 25 °C), two controlled atmosphere conditions (with and without PVC plastic wrap) and six evaluation periods (0, 3, 6, 9, 12 and 15 days after harvest) with four replications. The quality characteristics of the spikelets were analyzed in the post-harvest. The post-harvest quality preservation of baby corn in the straw and the husked ones was affected by temperature, controlled atmosphere and evaluation period. The best storage condition to maintain the main quality characteristics of the spikelets at post-harvest was observed at the temperature of 16 °C with controlled atmosphere use. For the spikelets preserved with the presence of straw, the maximum storage time for maintenance of post-harvest characteristics was four days, and for spikelets stored without straw, the maximum storage time was two days and 12 hours, both at refrigerated temperature (16 °C) and under controlled atmosphere.

**Keywords:** storage, quality, *Zea mays*

## 1. Introduction

Baby corn is the corn spikelet (*Zea mays* L.), harvested in the early stage of development, prior to fertilization (Rattanachai & Kanlayanarat, 2015). Considered a refined product, with crispy texture, slightly sweet flavor and delicate appearance, can be found *in natura* or in the form of canned acidified food (Lima, Melo, Oliveira, Tolentino, & Branco, 2015). Due to its diversified uses, this vegetable has gained ground in the market and has aroused producer's interest (Asaduzzaman et al., 2014). However, their production is limited due to the lack of scientific knowledge in the phytotechnical adjustments and the harvest and post-harvest strategies (Rodrigues, Silva, & Mori, 2004).

The baby corn cycle is considered short, ranging around 45 to 70 days (Brandão, 2015). Its harvest extends for several days after its beginning, which generates different harvested volumes. Thus, in order to obtain the required volume for transport to the agroindustries, it is occasionally necessary to store the spikelets harvested previously.

However, this vegetable presents a short post-harvest life, due to its active metabolism, and the shelf life of the product varies inversely with the respiration rate, causing reduction in water content, weight loss, changes in aroma, flavor and darkening of spikelets, making them undesirable regarding quality and appearance of the product (Bakry, El-Shorbagy, El-Desuki, El-Behairy, & Ibrahim, 2015; Saltveit, 2016).

Aiming to develop the best strategy of storage of these horticultural crops, studies are necessary to guarantee the best yield and less waste of them. Some treatments, associated to refrigeration and controlled atmosphere storage, have shown good results in delaying senescence and prolonging life during storage (Vani, Rajasekhar, & Reddy, 2013).

Thus, the present study had as objective to evaluate the changes in physicochemical characteristics of the baby corn, under conditions of storage at different temperatures and under the use of the controlled atmosphere.

## 2. Materials and Methods

The study was conducted at the State University of Montes Claros (Unimontes), Campus Janaúba-MG, in 2016. The analyzes were carried out at the Technology Laboratory for the Processing of Vegetable Origin Products of Unimontes. Baby corn spikelets of AG 1051 cultivar were used, marketed by the company Agroceres. The baby corn cultivation was carried out in the experimental area of Plant Science located in the same University, at the coordinates 15°47'18" South latitude and 43°18'18" West longitude, with an altitude of 515 meters.

The research consisted of two concomitant experiments, in the experiment I was carried out the physicochemical quality assessment of the conserved baby corn spikelets in the straw, and the experiment II was carried out in a similar way, but with husked spikelets storage.

The treatments were distributed under a completely randomized design (CRD), in a  $2 \times 2 \times 6$  factorial scheme, and four replications for both experiments. The treatments consisted of two storage temperatures, 16 °C (refrigerated) and 25 °C (room temperature), in two conditions, being, controlled atmosphere with PVC plastic wrap, presenting 20 µm thickness and self-adhesive and without cover, evaluated in six different periods of post-harvest comprising 0, 3, 6, 9, 12 and 15 days after harvest.

Harvesting of spikelets was performed in the morning. The samples were placed in plastic boxes and sent to the laboratory, where they were washed under running tap water and sanitized with a sodium hypochlorite solution containing 100 mg L<sup>-1</sup> for 15 minutes and then placed on paper towels to dry at room temperature. For experiment I were selected spikelets inside the straw, standardizing their size and diameter, to compose the treatments. In experiment II, the spikelets were husked and those that met the requirements of 8 to 12 cm in length (commercial standard) were selected, then washed and sanitized once more with a sodium hypochlorite solution of 20 mg L<sup>-1</sup> for 15 minutes, after this procedure, the samples were placed on paper towel until the total drying at room temperature.

In both experiments, the following physicochemical characteristics, related to the quality of baby corn post-harvest, were evaluated for each time period considered: Fresh Matter Loss (FML); Titratable Acidity (TA); Hydrogen-ion potential (pH); Soluble Solids (SS); and the ratio of soluble solids and titratable acidity (SS/TA) of spikelets.

The FML was measured in electronic balance accurate to 0.001 g, and the results expressed as a percentage. A TA was determined by neutralization titration, which consists of diluting 10 mL of spikelet juice, triturated with the aid of a Mallory Robot® UP 150w mixer in 90 mL of distilled water, using 0.1 % phenolphthalein solution as indicator and titration with 0.1 N NaOH solution. The obtained results were expressed as percent of malic acid. To determine the pH was used a mPA210 pH meter from Ms Tecnopon®, calibrated using pH 4 and 7 buffer solutions. The SS were determined by refractometry using HI 96801 digital refractometer by HANNA® mark and the results expressed in °Brix. The SS/TA ratio was determined by the quotient between soluble solids and titratable acidity (Instituto Adolfo Lutz, 1985).

The variables were submitted to the normality test of Lilliefors and the Bartlett test to verify the normality of the data and homogeneity of the variances, respectively. After confirming these assumptions, the variables were submitted to an analysis of variance ( $p < 0.05$ ) to verify the existence of interactions between the factors studied in both experiments. In the affirmative of the interactions, the qualitative factors (temperature and packaging) were compared by the F test ( $p < 0.05$ ) while the quantitative factor (storage times) were studied by regression. The regression models were adjusted according to their significance ( $p < 0.05$ ) and to the explanatory power of the biological effect in it. Statistical analyzes were performed with the aid of statistical software GENES (Cruz, 2016).

## 3. Results and Discussion

The experimental coefficient of variation (CV%) allows comparisons between variables of different natures and provides an idea of the accuracy of the data. At first it is considered that the lower the CV%, the more homogeneous the data and the greater the experimental precision. In field experiments when the CV% is lower than 10% is considered low, between 20 to 30% medium and when over 30% considered high (Pimentel-Gomes, 2000). In general, it is observed in this study that the experimental precision, evaluated by CV%, was considered low for the variable pH, indicating high precision and classified as average for FML, TA, SS e SS/TA, which is a good precision in both experimental tests (I and II) (Tables 1 and 3), judging correct the inferences raised in the experiment.

### 3.1 Experiment I

It was observed lower fresh matter loss when the spikelets were kept at a lower temperature (16 °C) and stored with PVC plastic wrap package (Table 1), verifying that at 15 days after harvest, there is greater conservation of spikelets when stored in this condition (Table 2).

According to Soares, Guimarães, Silva, Durigan, and Silva (2018), packaging reduces the loss of corn mass during the days of storage, providing a better product appearance. Losses in the order of 3% to 6% are sufficient to cause

Table 1. Physicochemical parameters of baby corn conserved with straw (Experiment I), considering different temperatures, storage forms and post-harvest days. Janaúba-MG, Unimontes, 2019

Temperature (°C)	Package (PVC plastic wrap)	Periods (days)						CV (%)
		0	3	6	9	12	15	
<i>Fresh matter loss</i>								
16	w <sup>1</sup>	0 aA	3.7 bB	9.6 bB	13.9 bB	19.0 bB	24.6 bB	13.27
	w/o <sup>2</sup>	0 aA	16.6 bA	33.1 bA	39.8 bA	45.7 bA	90.7 aA	
25	w	0 aA	11.4 aB	22.2 aB	31.5 aB	40.6 aB	49.4 aB	
	w/o	0 aA	29.4 aA	43.0 aA	50.5 aA	56.8 aA	62.7 bA	
<i>Titrateable acidity</i>								
16	w	0.19 aA	0.19 aA	0.16 bB	0.15 bB	0.26 bA	0.19 bB	17.62
	w/o	0.21 aA	0.21 bA	0.27 aA	0.23 bA	0.30 bA	0.34 bA	
25	w	0.19 aA	0.19 aB	0.31 aA	0.32 aA	0.32 aB	0.36 aB	
	w/o	0.19 aA	0.28 aA	0.25 aA	0.31 aA	0.41 aA	0.46 aA	
<i>Hydrogen-ion potential</i>								
16	w	5.67 aA	5.72 aA	5.84 aA	6.24 aA	5.81 aA	6.06 bA	4.22
	w/o	5.67 aA	5.68 aA	5.55 aA	6.01 aA	5.81 aA	5.75 aA	
25	w	5.67 aA	5.71 aA	5.58 aA	5.97 aA	5.85 aA	6.43 aA	
	w/o	5.67 aA	5.58 aA	5.49 aA	5.89 aA	6.13 aA	6.06 aB	
<i>Soluble solids</i>								
16	w	8.32 aB	7.93 aA	8.90 aB	6.48 aB	7.23 aB	6.80 aB	17.72
	w/o	10.82 aA	10.30 aA	11.48 aA	14.57 aA	11.93 aA	12.87 aA	
25	w	8.69 aA	8.28 aA	10.63 aA	8.65 aA	7.75 aB	6.23 aA	
	w/o	8.73 aA	10.13 aA	11.83 aA	10.76 bA	10.55 aA	8.55 bA	
<i>Ratio of soluble solids and titrateable acidity</i>								
16	w	3.04 aA	2.89 aA	3.89 aA	3.02 aA	1.95 aB	2.45 aA	19.33
	w/o	3.52 aA	3.35 aA	2.93 aB	3.72 aA	2.68 aA	2.54 aA	
25	w	3.04 aA	2.88 aA	2.34 bB	1.85 bA	1.75 aA	1.16 bA	
	w/o	3.06 aA	2.45 bA	3.24 aA	2.36 bA	1.82 bA	1.27 bA	

Note. \* Means followed by different lowercase letters, presented in the column, differ from each other by the F test ( $p < 0.05$ ) as a function of the temperature factor interaction within the packaging factors and storage times.

Means followed by different upper case letters, presented in the column, differ from each other by the F test ( $p < 0.05$ ) as a function of the interaction of the packaging factor within the temperature factors and storage times.

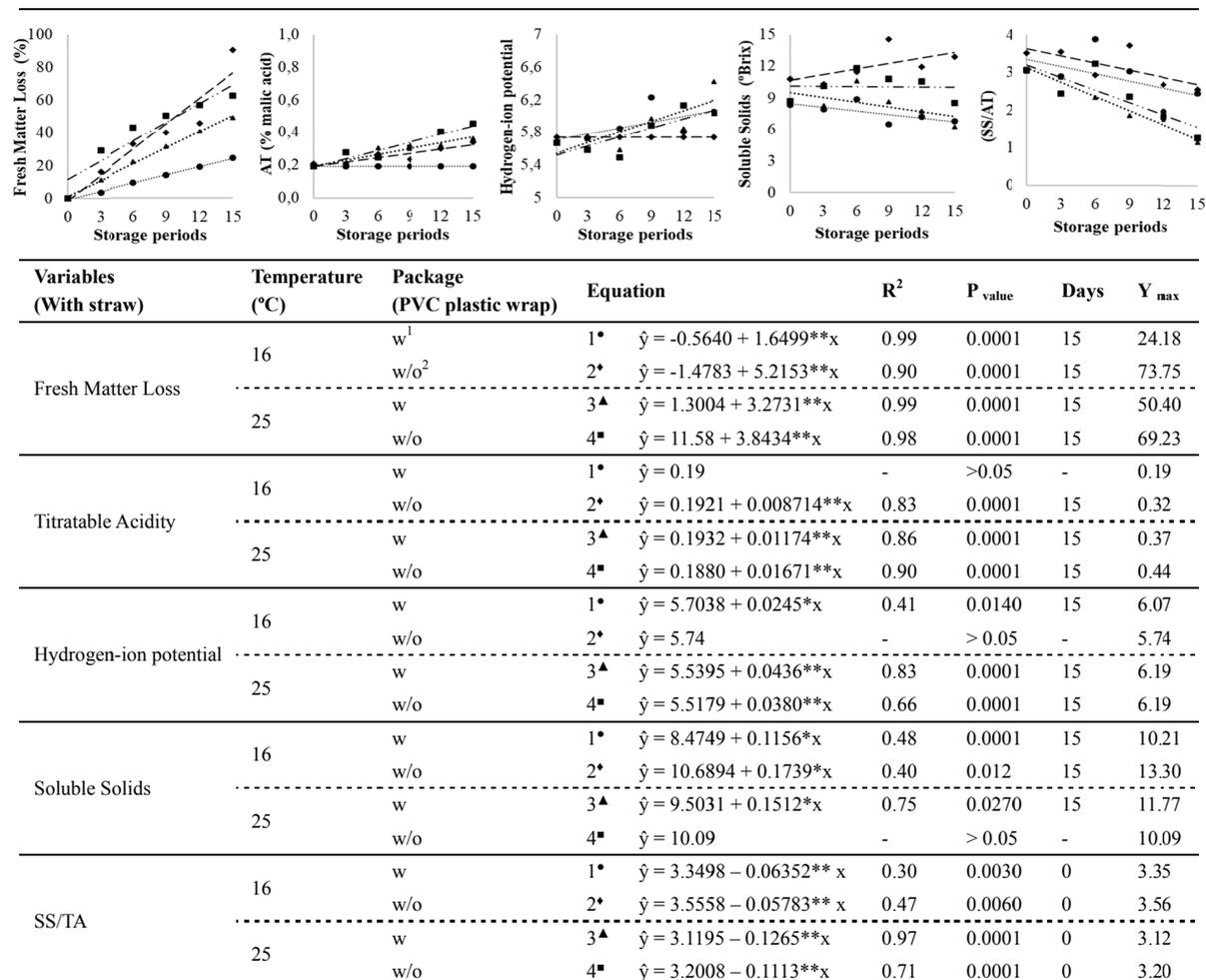
<sup>1</sup> With; <sup>2</sup> Without.

a significant decline in quality (Mamede et al., 2009). Considering these assertions, it is possible to affirm that the treatments without the PVC plastic wrap protection do not meet this criterion from four days of storage, even submitted to the cooling (16 °C).

Inside baby corn there is a high moisture content, causing an intense metabolic activity, as stated by Santos and Oliveira (2012). This can lead to large post-harvest losses, such as high dehydration and physicochemical changes, restricting the period of commercialization. In sweetcorn the use of refrigeration and controlled atmosphere are shown to be promising technologies, with positive reports evidenced by Mamede, Fonseca, Soares, Pereira Filho, and Godoy (2015) and Soares et al. (2018), also in the present study, for baby corn, these technologies reduced dehydration and maintained the post-harvest characteristics of the products.

From the third day, the packaged spikelets preserved at the lowest temperature (16 °C), obtained the lowest values of titratable acidity (Table 1). The spikelets acidity increased along the days of storage, with a linear and positive increase over the temperatures and packages, except for those under temperature of 16 °C with packaging, that no differences were observed regarding storage days (Table 2).

Table 2. Equations for the variables considered in the experiment I of baby corn conserved with straw in different times of post-harvest. Janaúba-MG, Unimontes 2019



Note. <sup>1</sup> With; <sup>2</sup> Without.

Low values TA, due to storage of products under controlled atmosphere and at low temperatures, are attributed a reduction of organic acids amounts acids due to deceleration in the respiratory process and metabolic activity of the spikelets (M. I. F. Chitarra & A. B. Chitarra, 2005). Besides the degradation process, the decrease of the moisture contents favors the concentration of acidity, explaining the fact that the spikelets stored at higher temperatures (25 °C) and unpackged presented the highest values of acidity (Table 1). However, even with a higher acidity (which is responsible for the flavor of the spikelets), it is not only attributed to organic acids, but also to a beginning of acid fermentation by microorganisms during storage (Sena et al., 2016). Considerable factor since these were in direct contact with the environment.

At the 15th day of storage, the lowest pH values were observed when the spikelets were stored at 16 °C and stored without the package (Table 1). The hydrogenionic potential of spikelets increased in function of days of storage. The highest pH increase occurred at 25 °C with the use of package, and the lowest increment and pH observed at 15 days of storage occurred at the temperature of 16 °C with the use of the package (Table 2).

The pH of the food is an important variable, since it allows the determination of possible changes caused by the action of microorganisms, as well as indicates its parameters of acidity and flavor (M. I. F. Chitarra & A. B.

Chitarra, 2005). The pH results obtained in this study agree with Lima et al. (2015) that evaluated the quality of six varieties of organic baby corn, 'Pipoca', 'Super doce', 'Doce cristal', 'Eldorado', 'Cate-tinho' and 'Branco', confirming that the baby corn is an acid food, regardless of the studied varieties, without altering in great magnitude the level of acidity.

During the storage process of the spikelets, it was possible to notice that the conditions with higher temperature and without package favored the increase of the organic acids and the pH; contributed with a possible microbiological activity in the spikelets, although this action has not been evaluated (Table 1). At the lowest temperature (16 °C) with presence of package it is observed the maintenance of the spikelets acidity levels found on the harvest day.

A concentration in the SS contents of the baby corn spikelets is observed after the post-harvest days. The spikelets submitted to the temperature of 16 °C without package obtained the highest increase and final soluble solids content (Table 2). The same behavior was observed in the fresh matter loss, pointing out a possible ratio between these variables. If this occurs, the lower the moisture content, the greater the concentration of soluble solids in the spikelets, indicating in grams, the solids that are dissolved in the juice or in the pulp, may increase with maturation by means of synthetic processes or by the degradation of the polysaccharide (M. I. F. Chitarra & A. B. Chitarra, 2005). Perfeito et al. (2017), observed for sweet corn, soluble solids values ranging from 15.0 to 17.0 °Brix, while Lima et al. (2015) working with baby corn, detected values ranging from 3.0 to 6.0 °Brix, and the results observed in the present study are lower than those found with sweetcorn and higher than the results obtained to baby corn by the authors (Table 1). In the evaluation of the SS/TA ratio, the samples stored at 25 °C without package were lower, evidencing a greater imbalance between the contents of sugars and acids of this vegetable (Table 1).

A decrease in SS/TA can be observed as days of storage increase, where the highest reduction is associated with the temperature of 25 °C, with greater accentuation with the use of package to store the spikelets (Table 2). The reduction of this ratio observed during storage days is indicative of quality losses. This change is affected by the physical and metabolic degradation of the spikelets and constitutes an important parameter to define the best alternative for storage (Menezes et al., 2017).

### 3.2 Experiment II

The spikelets stored at 25 °C had the highest fresh matter losses, and the treatment without package had significant losses at both temperatures (Table 3). In all treatments there was an increase of FML. However, lower losses were observed in conserved baby corn at the temperature of 16 °C with the use of the package (Table 4). In accordance with Mamede et al. (2009) in which the fresh matter losses for spikelets may not exceed 6%, the condition that provided the longest storage time was under controlled atmosphere and refrigeration of 16 °C, providing a maximum time of 2.5 days.

The lower loss of matter caused by the use of the controlled atmosphere can be explained by the low concentration of O<sub>2</sub>, along with the increase of CO<sub>2</sub> concentration in the vegetables conserved in package, causing the reduction of the respiratory rate and consequently decreasing the matter loss (Soliva-Fortuny & Martín-Beloso, 2003). Araújo, Campos, and Gomes (2014) studying sweetcorn, accomplished that the use of the modified atmosphere associated with refrigeration helps to maintain the quality and improve the appearance of sweetcorn.

From the 3rd day of storage, the packaged baby corn exhibited lower acidity at the two temperatures studied (Table 3). As for FML, there was an increase in TA over the stored days, and the highest acidity values were observed at 25 °C without the use of the package (Table 4). Spikelets stored without package has an increase in their respiratory activity, undergoing influences of dehydration, that is, occurs greater synthesis and accumulation of organic acids and, consequently, increases the titratable acidity (Oliveira et al., 2017).

pH differences between treatments were observed only from the 9th day of evaluation, in which was detected in the packaged spikelets a lower pH at a temperature 16 °C when compared to the samples at 25 °C in the same condition (Table 3). Treatment with unpacked spigots at 25 °C obtained the lowest pH at 2.2 days of storage, while in the treatment with unpacked spikelets at 16 °C, the lowest pH value was observed only at 8.9 days after storage (Table 4). According to Miranda, Marques, Passos, and Oliveira (2017), the decrease in pH indicates the increase of spikelets acid fermentation, leading to deterioration of the product and senescence. The lowest pH, in shorter storage time, was observed in the spikelets conserved at 25 °C compared to those maintained at 16 °C. Thus, a lower temperature induces a delay in pH elevation, consequently contributing to the better post-harvest quality and shelf life of this horticultural.

Table 3. Physicochemical parameters of conserved baby corn without straw (Experiment II), considering different temperatures, storage forms and post-harvest days. Janaúba-MG, Unimontes, 2019

Temperature (°C)	Package (PVC plastic wrap)	Periods (days)						CV (%)
		0	3	6	9	12	15	
<i>Fresh matter loss</i>								
16	w <sup>1</sup>	0 aA	6.1 bB	16.1 bB	23.1 bB	30.8 bB	39.3 bB	10.70
	w/o <sup>2</sup>	0 aA	50.9 aA	36.8 bA	51.3 bA	64.3 bA	72.6 aA	
25	w	0 aA	16.8 aB	31.6 aB	44.3 aB	56.8 aB	67.3 aB	
	w/o	0 aA	29.8 bA	49.2 aA	62.9 aA	71.7 aA	77.0 aA	
<i>Titrateable acidity</i>								
16	w	0.22 aA	0.22 aA	0.28 bB	0.28 aB	0.30 bB	0.26 bB	13.30
	w/o	0.27 aA	0.27 aA	0.40 aA	0.41 bA	0.57 aA	0.58 bA	
25	w	0.19 aA	0.25 aB	0.36 aB	0.34 aB	0.55 aA	0.58 aB	
	w/o	0.19 bA	0.33 aA	0.46 aA	0.58 aA	0.56 aA	0.72 aA	
<i>Hydrogen-ion potential</i>								
16	w	5.67 aA	5.61 aA	5.59 aA	5.76 bA	5.62 bA	5.98 bA	3.05
	w/o	5.67 aA	5.62 aA	5.48 aA	5.62 aA	5.68 bA	6.16 aA	
25	w	5.67 aA	5.44 aA	5.52 aA	6.12 aA	5.91 aB	6.22 aA	
	w/o	5.67 aA	5.44 aA	5.54 aA	5.61 aB	6.38 aA	6.04 aA	
<i>Soluble solids</i>								
16	w	9.08 aB	8.65 aB	10.63 aA	8.80 bB	8.83 bB	8.00 aB	10.57
	w/o	11.58 aA	11.03 aA	12.27 bA	14.18 bA	15.78 bA	16.25 bA	
25	w	8.71 aA	9.60 aB	9.70 aB	13.13 aB	12.45 aB	6.16 aB	
	w/o	8.68 bA	12.03 aA	15.5 aA	21.05 aA	23.64 aA	25.10 aA	
<i>Ratio of soluble solids and titrateable acidity</i>								
16	w	2.81 aA	2.68 aA	2.56 aA	2.50 aA	2.00 aA	2.07 aA	16.60
	w/o	2.94 aA	2.79 aA	2.12 aA	2.38 aA	1.86 bA	1.90 aA	
25	w	3.03 aA	2.75 aA	1.87 bA	2.65 aA	1.56 aB	0.97 bB	
	w/o	3.05 aA	2.41 aA	2.28 aA	2.45 aA	2.62 aA	2.34 aA	

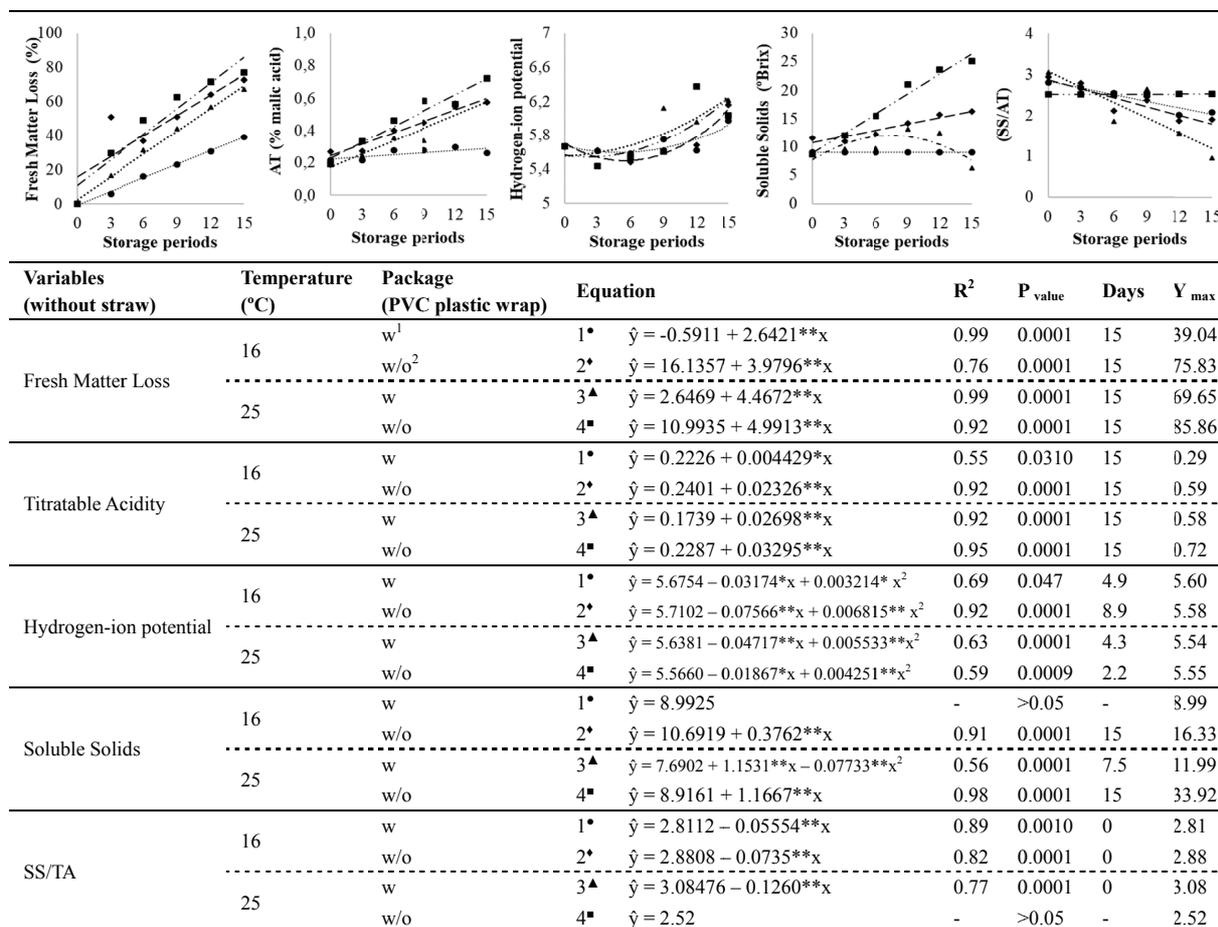
Note. \* Means followed by different lowercase letters, presented in the column, differ from each other by the F test ( $p < 0.05$ ) as a function of the temperature factor interaction within the packaging factors and storage times.

Means followed by different upper case letters, presented in the column, differ from each other by the F test ( $p < 0.05$ ) as a function of the interaction of the packaging factor within the temperature factors and storage times.

<sup>1</sup> With; <sup>2</sup> Without.

From the 6th day of storage, the soluble solids contents were higher for the treatments kept at 25 °C, and the lowest contents were observed in the packaged spikelets, under a temperature of 16 °C (Table 3). It is observed the higher solids contents in the husked spikelets without plastic wrap cover, which have positive linear increase along the storage period, being this increase in the contents more noticeable in the temperature of 25 °C (Table 4). The interaction between the variables Soluble Solids with Fresh Matter Loss, largely explains the obtained results. Spikelets, along storage days, tend to lose moisture and to concentrate SS, such ratio is higher in unpacked spikelets, preserved at higher temperatures (25 °C) and without natural cover (straws). The soluble solids content determines the concentration of the organic acids and other sugars dissolved in the solution within the food, presenting an important indicator of their quality and flavor. In addition, it largely determines consumer acceptance of the product (Silva, Martins, Nascimento, Moraes, & Santos, 2018).

Table 4. Equations for the variables considered in the experiment II of baby corn conserved without straw in different post-harvest seasons. Janaúba-MG, Unimontes, 2019



Note. <sup>1</sup> With; <sup>2</sup> Without.

The ratio between soluble solids and titratable acidity in the stored spikelets without straw decreased as a function of the increase in storage days, except for samples at 25 °C without the presence of plastic wrap packaging, which did not fit the statistical model (Table 4).

The packaging and lower temperatures provided better values of SS/TA because these storage conditions promote a reduction of moisture loss. Thus, the maintenance of post-harvest quality of the spikelets is preserved and the ratio between soluble solids and acidity are more stable, leading to a higher flavor of the baby corn. The decrease in SS/TA over the storage days can be attributed to changes in soluble solids contents and acidity of the spikelets, because even increasing the values observed in these isolated variables, their imbalance leads to a decrease in the flavor, being an important characteristic, linking this variable with the smooth and pleasant taste of them (Ferreira et al., 2010).

**4. Conclusions**

The best storage condition for the spikelets with straw and husked ones, aiming at maintaining the main characteristics of quality in the post-harvest, are obtained at the temperature of 16 °C and with the use of the controlled atmosphere, through the packaging with the PVC plastic wrap.

For spikelets preserved by the presence of straw, the maximum storage time for maintenance of characteristics in the post-harvest was four days, and for spikelets stored without straw, the maximum storage time was two days and 12 hours, both at refrigerated temperature (16 °C) and under controlled atmosphere.

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