

Minimally processed cabbage stability under different treatments

ABSTRACT

The present work aims to evaluate the efficiency of postharvest conservation treatments on the stability of minimally processed cabbage kept under refrigerated conditions. Cabbage heads from cv. Golden Acre purchased locally in Altamira, PA. After processing, the samples were exposed to the following treatments: bleaching for 1 and 3 minutes, 1% citric acid solution and 3% acetic acid solution at 1 and 3% plus a lot which represented the control treatment. The samples (100 g) were packed in tray polystyrene beads, coated with PVC plastic film and stored for eight days under refrigeration conditions (10 °C). At two days intervals the samples of each treatment were analyzed physicochemical and sensorially on the loss of fresh mass, soluble solids content, titratable acidity, pH and darkening index. The statistical analysis showed a significant effect on the interaction of the days storage factors and treatments for all the evaluated characteristics. The exposure of the samples to bleaching for 3 minutes and to citric and acetic acids in the concentration of 3% is efficient in prolonging the useful life without compromising the quality characteristics. Practicality and low cost favors the use of bleaching as a postharvest technology for the conservation of minimally processed cabbage.

KEYWORDS: *Brassica oleracea* L var. *carpitata*; bleaching; chemical additives; principal component analysis.

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INTRODUCTION

The minimum processing of vegetables is an excellent option to provide practical products and quality for consumption on a daily basis, as they meet the expectations of consumers regarding quality in its broadest sense, and above all aspects related to the appearance of the product (SILVA *et al.*, 2009, SHANKY, 2013).

In Brazil, it is the most consumed brassicacia (SOARES *et al.*, 2009; GIOPPPO *et al.*, 2012), which is one of the most important botanical varieties in the world (*Brassica oleracea* var. capitata).

According to Pasha *et al.* (2014), among the minimally processed products available on the market, the cabbage stands out due to its high consumption and good value aggregation. The structure of the cabbage submitted to the minimum processing should be firm, with no presence of cracks and spots on its leaves, because, despite having a resistant appearance, the cabbage suffers from tissue injury with ease (LIMA *et al.*, 2010).

Tissue injuries induce physiological and biochemical responses that accelerate senescence, decreasing the quality of minimally processed products (FERREIRA *et al.*, 2014). Thus, the use of post-harvest treatments that do not alter the sensorial characteristics and reduce the damages caused the mechanical injury resulting from the processing is fundamental for the extension of the useful life (PEREIRA *et al.*, 2010).

Bleaching is considered a low-cost method (BATISTA; BORGES, 2013). It is an effective technique to remove air from the interior of foods, reduce microbial contamination, improve texture and enhance coloration of products (GONÇALVES *et al.*, 2010), as well as inhibit ethylene synthesis and the action of enzymes that degrade the cell wall (SILVEIRA *et al.*, 2011).

The use of acidifying agents such as citric acid and acetic acid acts to maintain the pH of the medium below the optimum, thus inhibiting the action of catalytic enzymes such as peroxidation (POD) and polyphenoloxidase (PPO) causing browning, especially in foods (SILVA *et al.*, 2007). In this paper, we present the results obtained in this paper.

This work is justified by the need to generate more stability to minimally processed cabbage, increasing its shelf life sufficiently for the distribution, commercialization and consumption of the product. Thus, the present work aims to evaluate the efficiency of different postharvest conservation treatments aiming at maintaining the quality and stability of minimally processed cabbage stored under refrigeration.

MATERIALS AND METHODS

Golden Acre cabbage (*Brassica oleracea* L. var. capitata) were purchased at the local trade in Altamira, PA and transported in thermal boxes to the Product Technology Laboratory of the Federal University of Pará, Campus Altamira, PA.

In the laboratory the heads were selected, discarding the external leaves that presented mal formation or any indication of mechanical damage or attack by

pests or diseases. Subsequently, the heads were sanitized in a solution containing 200 mg.L⁻¹ sodium hypochlorite and dried under benches at room temperature.

The minimum processing consisted in manual cutting of the heads and slicing into strips with the help of a stainless steel knife, then the samples were submitted to the following treatments:

- Bleaching at 1 minute and 3 minutes: It consisted of immersing the cabbage strips in warm water (80 °C) for 1 minute and 3 minutes.
- 1% and 3% citric acid solution: the commercial sodium salt formula, 10 ml (for 1%) and 30 ml (for 2%), diluted in 1 liter of distilled water and immersed in the solution for 3 minutes.
- 1 and 3% acetic acid solution: the commercial vinegar formula 10 g/ml (for 1%) and 30 g / ml (for 3%) diluted in 1 liter of distilled water and immersed in the solution for 3 minutes.
- Control: the samples were directly conditioned under refrigeration.

After application of the treatments, 100 g of the processed product was packed in polystyrene styrofoam trays coated with 14 micron PVC plastic film and stored for 8 days under refrigeration (10 ± 2 °C and 85 ± 5% RH), simulating the gondolas in supermarkets.

A completely randomized experimental design was used in a 7x5 factorial design (seven treatments and five storage times: 0, 2, 4, 6 and 8 days), with 3 replicates for each treatment. The physical-chemical and sensorial evaluations were determined every two days on the following variables:

Fresh weight loss: determined using a digital scale (0,1 g precision), the difference between the initial weight and that determined on the day of the evaluation being calculated as the percentages (%).

Soluble solids content was measured using refractometry using 10 g of the pulp macerated in a digital refractometer and the results expressed in ° Brix, as described by AOAC (2012).

The titratable acidity content was determined by the titration method with 0.1 M NaOH solution and 1% phenolphthalein as indicator, and the results expressed as% citric acid according to AOAC (2012).

The pH was measured with the help of a digital phameter through the maceration of 10 g of the sample in a beaker and diluted with 50 mL of distilled water according to the methodology described by AOAC (2012).

The post-harvest physiological deterioration evaluated the darkening index, being determined subjectively with the help of 7 trained evaluators who assigned scores from 1 to 5 on the samples, where: 1 = no injury (no injury); 2 = mildly injured (surface with up to 25% of injury); 3 = moderately injured (surface between 26 and 50% of injury); 4 = extremely injured (surface between 51 and 75% of injury); 5 = completely injured (surface with more than 76% of injury).

The results were submitted to analysis of variance and the means compared to each other by the F test at 5% of significance through the statistical program ASSISTAT 7.7 beta versions. For the multivariate analysis, data of all variables were self-staggered using the Excel program (2010) and submitted to the main component analysis (PCA) through the STATISTIC 7.0 Software.

RESULTS AND DISCUSSION

The values presented in Table 1, refer to the F test for each evaluated variable. In general, it can be observed that there was a significant effect for all the variables analyzed in the interaction between the treatments x days factors at the level of 1 and 5%.

Table 1- Summary of the analysis of variance by the F test on the variables: fresh mass loss (FMP), total soluble solids (TSS), titratable acidity (ATT), hydrogeonic potential (pH) and physiological post (DFP).

Sources of variation	Analysis table					
	GL	PMF	SST	ATT	pH	DFP
Treatments	4	117,74**	145,17**	106,64**	391,78**	105,78**
Days	6	68,38**	19,09**	278,30**	364,08**	10,55**
Int. Treatments x Days	24	16,14**	13,79**	26,97**	32,90**	1,79*
Treatments	34	106,03**	30,18**	193,52**	554,74**	15,59**
Residue	70	0,001	0,01	0,002	0,004	0,23
CV (%)		2,97	2,63	2,15	0,35	6,11

NOTE: ** significant at the 1% probability level ($p < 0.01$); * significant at the 5% probability level ($0.01 < p < 0.05$). GL: Degrees of liberty

According to Figure 1, it is observed that the loss of fresh mass (%) occurred in all treatments with storage time. In general, the most significant losses at the end of eight days were observed in the control treatment (3,19%), since the treatments used proved to be efficient in reducing water loss, especially when exposed to a lower bleaching temperature (2,34%) and treated with the highest concentration of citric acid (2,23%) and acetic acid (2,57%). Similar to the results presented in Figure 1a, Huber *et al.* (2016) determined in crude extracts of the brown beans, results of DPPH between 2.96 to 14.04 mg TEAC. g⁻¹ extract and in the ABTS assays, between 13.70 and 29.51 mg TEAC.g⁻¹ extract.

According to Banerjee *et al.* (2016), wilting may occur in most vegetables if mass losses of 5% or more occur. In this work the loss of fresh mass did not exceed 4% after 8 days of storage.

It is suggested that the temperature control, the packing of the samples in the packaging that reduced the gas exchange with the external medium and, mainly, the application of the treatments contributed to this lower loss of water during the storage time.

Similar results were obtained by Moreno *et al.* (2016), which during refrigerated storage (8 °C) of the minimally processed cabbage, observed an average percentage of 3.85%.

There was variation in soluble solids content with storage time in all treatments (Figure 2). Similarly, Ferreira, Silva and Pascoal (2014) also observed oscillation in soluble solids contents during storage of minimally processed white cabbage.

In general, the accumulation observed in the initial days is due to the loss of water accumulating the sugars in the samples, suggesting a sweeter flavor. The reduction is due to the advance in the oxidative processes that accelerate the respiratory metabolism where the sugars are started to be consumed as an energy substrate (CHITARRA; CHITARRA, 2005; SANTOS *et al.*, 2008).

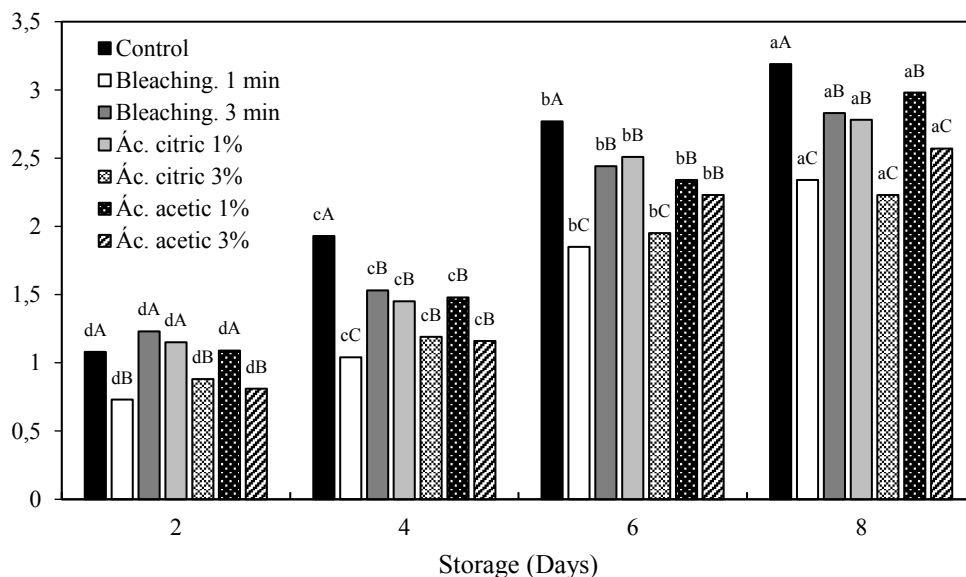


Figure 1- Evolution of fresh mass loss (%) in minimally processed cabbage submitted to different treatments and stored under refrigeration ($10 \pm 2 \text{ }^\circ\text{C}$ and $85 \pm 5\% \text{ RH}$) for 8 days. Lower case letters (days of storage) and upper case letters (treatments), do not differ among themselves by the Tukey test at the 5% probability level.

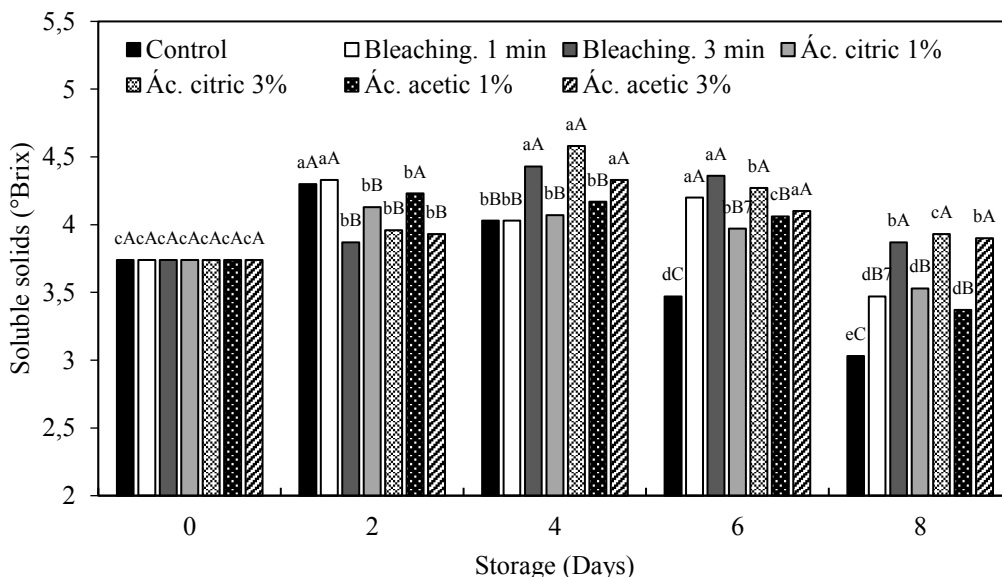


Figure 2- Soluble solids content (°Brix) in minimally processed cabbage, submitted to different treatments and stored under refrigeration ($10 \pm 2 \text{ }^\circ\text{C}$ and $85 \pm 5\% \text{ U.R}$) for 8 days. Lower case letters (storage days) and upper case letters (treatments) do not differ from each other by the Tukey test at the 5% probability level.

Thus, the immersion of the samples under treatment with bleaching for 3 minutes and in citric acid and acetic acid in the concentration of 3%, are shown to be efficient in controlling the respiratory metabolism due to the greater accumulation of soluble solids during 8 days of storage. The preservation of the soluble solids content was also observed in lychees (ANJOS *et al.*, 2014) and in minimally processed pears (VILAS BOAS *et al.*, 2015), when exposed to higher bleaching time and higher citric acid concentration. Andrade *et al.* (2016), observed lower variation and degradation of soluble solids consumption in the pulp of processed table manioc, corroborating with the observed in this work.

Figure 3 shows that the acidity content showed a small increase after two days in the samples exposed to bleaching for 3 minutes and when immersed in the solutions of citric acid and acetic acid, in addition to a smaller reduction in the mean values for eight days of storage, not differing between them and being statistically superior to the other treatments.

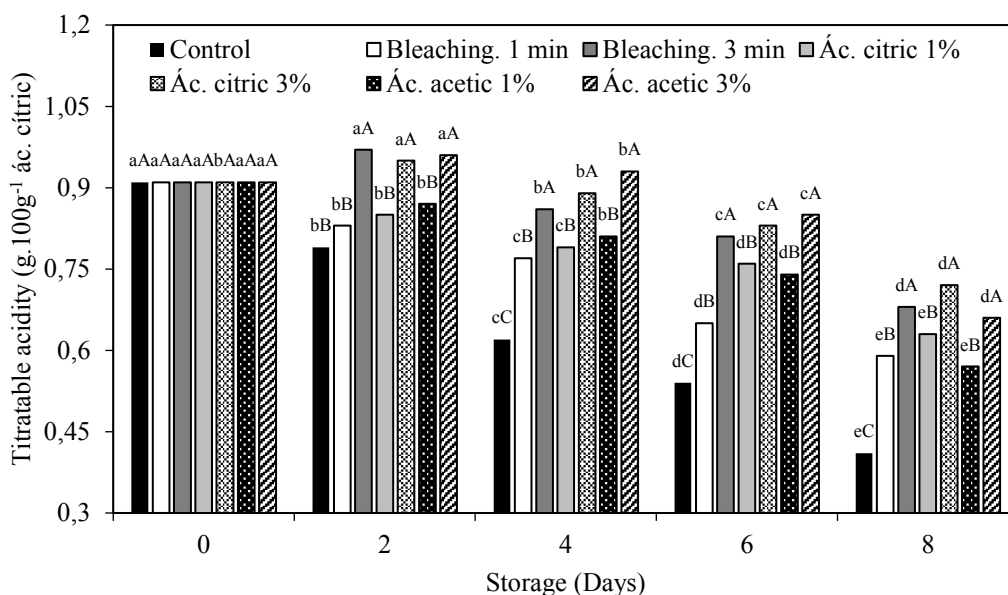


Figure 3- Titratable acidity (% citric acid) in minimally processed cabbage, submitted to different treatments and stored under refrigeration (10 ± 2 °C and $85 \pm 5\%$ of U.R) for 8 days. Lower case letters (storage days) and upper case letters (treatments) do not differ from each other by the Tukey test at the 5% probability level.

The reduction of acidity is associated to the consumption of acids as an energetic substrate for respiration (CHITARRA; CHITARRA, 2005), thus, the samples exposed to the lowest bleaching time and the concentration of citric and acetic acids were not efficient in minimizing the consumption of organic acids, especially those of the control treatment representing the greatest reduction of acidity over the refrigerated storage time (Figure 3).

Acidity reduction was also observed in minimally processed cabbages (GAJEWSKI *et al.*, 2015, MORENO *et al.*, 2016), which attributed to processing the intense respiratory activity of the samples as the physiological aspect related to the decrease of organic acids during storage .

The pH is an important analysis in post-harvest physiology because at low levels the cellular content is more acidic, inhibiting the microbial development (AOAC, 2012). In this work, it was observed that there was an increase in pH with

the storage time, however, the samples exposed for 3 minutes to bleaching and 3% of citric and acetic acid were able to keep the values low for eight days, differing from other treatments (Figure 4).

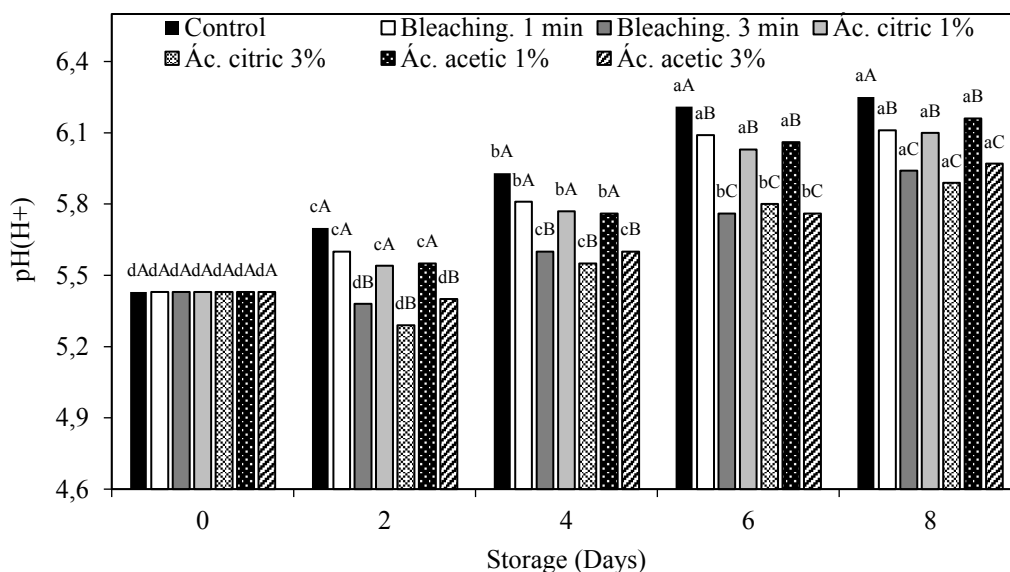


Figure 4- pH (H+) in minimally processed cabbage, submitted to different treatments and stored under refrigeration (10 ± 2 °C and $85 \pm 5\%$ of U.R) for 8 days. Lower case letters (storage days) and upper case letters (treatments) do not differ from each other by the Tukey test at the 5% probability level.

The mean pH value increased from 5,43 at day zero to 6,28 at the end of eight days of storage. Samples from the control treatment showed the largest significant increase in relation to the other treatments (Figure 4).

Gómez-López *et al.* (2007) reported an increase in pH from 5,7 to 6,4 in minimally processed cabbage after 14 days of storage at 7 °C. Salata *et al.* (2014), working with minimally processed cabbage under different chemical additives, observed an increase from 5,93 to 6,68 over eight days of refrigerated storage, well above that determined in this work.

This increase may be related to the tissue response in trying to control the reduction of the acidity generated by the carbon dioxide in the breathing process, thus raising the cellular content to the basic medium (FANTUZZI *et al.*, 2004; RINALDI *et al.*, 2009).

Post-harvest physiological deterioration correlates the darkening index of the samples. Analyzing Figure 5, it was observed that darkening occurred as the storage time progressed, regardless of the treatment applied. Rinaldi *et al.* (2009) also observed an increase in enzymatic darkening in samples of freshly minced cabbage and stored at 5 °C, regardless of the packaging used.

In general, the samples from the control treatment had a higher incidence with a mean score of 4 (surface area between 51 and 75% injured) at the end of eight days. Among the treatments, it was observed that the longer exposure time to bleaching and to citric and acetic acids delayed the development of darkening in the samples whose average grade for the same storage time was 2,55, that is, 25% of injury (Figure 5).

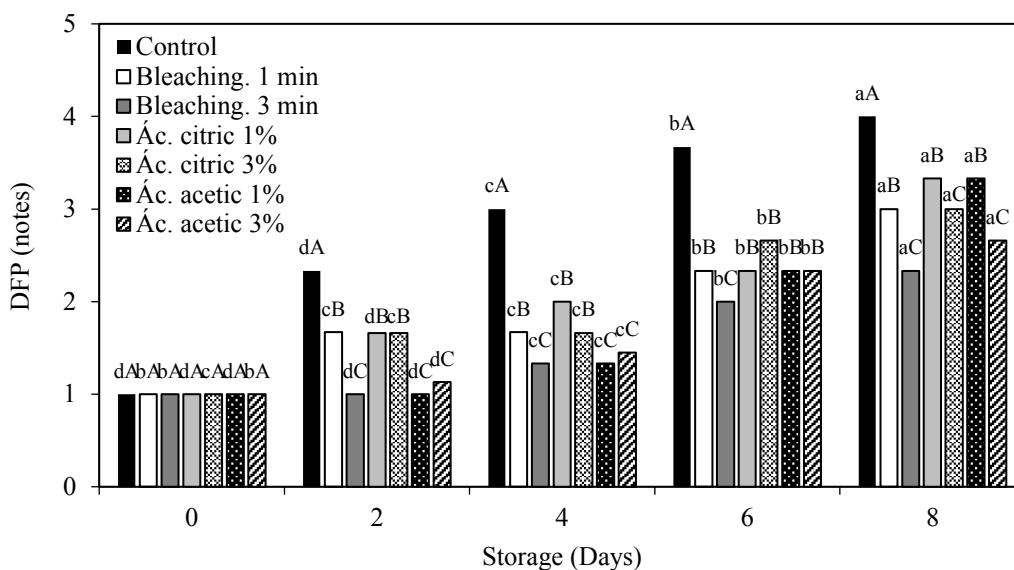


Figure 5- Post-harvest physiological deterioration - DFP (notes) in minimally processed cabbage treated with different storage methods throughout storage time. Lowercase letters (storage time) and upper case (conservation treatments).

This positive effect was already expected, since bleaching is a thermal process capable of inactivating enzymes that cause browning (GONÇALVES *et al.*, 2010). However, the acidifying agents (citric and acetic acid) are able to keep the pH low, thus inhibiting the formation of substrates for the enzymes peroxidase (POD) and polyphenoloxidase (PPO), which cause enzymatic browning (SILVA; ROSA; VILAS BOAS, 2009; SOUZA; LEÃO, 2012).

The reduction of browning was also observed by Souza and Leão (2012) in processed banana, apple and potato samples when treated with acetic acid. Andrade *et al.* (2016) observed that the incidence of darkening in minimally processed table cassava was lower when they were subjected to bleaching and immersion in citric acid.

The main component analysis (Figure 6) correlates the analyzed variables, the storage time and the applied treatments, where the total variability of the data is explained by 93,63%, and CP1 corresponds to the highest variation of the data (74, 69%) and CP2 explains 18,94%. According to Araújo *et al.* (2010), percentages above 70% of the total data variation show an excellent correlation between the factors.

Regarding the treatments, a positive correlation was observed between whitening for 3 minutes and exposure to citric and acetic acids at 3% as a function of the angle formed between their vectors. In practice, these treatments proved to be efficient in preserving the quality of the cabbage samples during storage. In turn, the control treatment presents a projection opposite to the applied treatments, corroborating with the greater loss of quality of the samples (Figure 6).

Regarding the analyzed variables, there is a strong correlation between pH, DFP and PMF. It is suggested that the loss of water from the samples with storage time induced a series of metabolic transformations such as ethylene synthesis, increased respiratory rate and intense enzymatic activity through the increase in

pH favoring the production of substrates for the enzymes causing the darkening, and thus raising DFP scores (Figure 6).

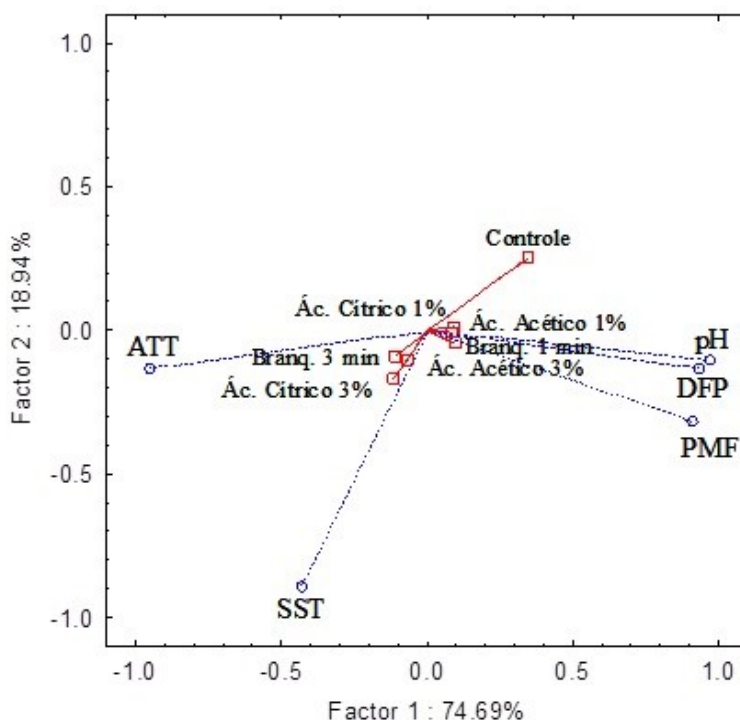


Figure 6- Analysis of main components on the applied treatments and the physical-chemical and sensorial characteristics in minimally processed cabbage throughout the storage time. ATT = total titratable acidity; SST = total soluble solids; DFP = post-harvest physiological deterioration; PMF = loss of fresh mass.

The angle of the vectors and the projection of soluble solids and titratable acidity show a low correlation between them. This fact is due to the synthesis of these compounds during storage, where the acids (ATT) tend to be degraded first, while sugar biosynthesis (SST) occurs, suggesting a sweeter flavor.

CONCLUSIONS

The results of this research show that it is possible to extend the shelf life of minimally processed cabbage when exposed to previous treatments such as bleaching for 3 minutes and to citric and acetic acids at a concentration of 3% for a longer period of time.

Because of the accessibility to the treatment and its efficiency in the control of the darkening it is recommended the practice of bleaching as a post-harvest technology in the conservation of minimally processed cabbage.

Estabilidade de repolho minimamente processado sob diferentes tratamentos

RESUMO

O presente trabalho tem por objetivo avaliar a eficiência de tratamentos de conservação pós-colheita na estabilidade do repolho minimamente processado mantido em condições de refrigeração. Utilizaram-se cabeças de repolho do cv. Golden Acre adquiridos no comércio local de Altamira, PA. Após o processamento, as amostras foram expostas aos seguintes tratamentos: branqueamento por 1 e 3 minutos, solução de ácido cítrico a 1 e 3% solução de ácido acético a 1 e 3 % além de um lote que representou o tratamento controle. As amostras (100 g) foram acondicionadas em bandejas de isopor de poliestireno, revestidas com filme plástico de PVC e armazenadas por oito dias sob condições de refrigeração (10 °C). Em intervalos de dois dias as amostras de cada tratamento foram analisadas físico-química e sensorialmente sobre a perda de massa fresca, teor de sólidos solúveis, acidez titulável, pH e deterioramento fisiológico pós-colheita. A análise estatística mostrou efeito significativo ($p < 0,05$) na interação dos fatores dias de armazenamento e tratamentos para todas as características avaliadas. A exposição das amostras ao branqueamento por 3 minutos e aos ácidos cítrico e acético na concentração de 3% mostra-se eficiente em prolongar a vida útil sem comprometer as características de qualidade. A praticidade e o baixo custo favorecem a utilização do branqueamento como tecnologia pós-colheita para a conservação do repolho minimamente processado.

PALAVRAS-CHAVE: *Brassica oleracea* L. var. *capitata*; branqueamento; aditivos químicos; análise de componentes principais.

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Recebido: 05 jun. 2018.

Aprovado: 24 mai. 2019.

DOI: 10.3895/rebrapa.v9n3.8384

Como citar:

SOUZA, S. S. et al. Minimally processed cabbage stability under different treatments. **Brazilian Journal of Food Research**, Campo Mourão, v. 9, n. 3, p. 125-137, jul./set. 2018. Disponível em: <https://periodicos.utfpr.edu.br/rebrapa>

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