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FRUIT JUICES AS AN ALTERNATIVE TECHNIQUE FOR CONSERVATION OF FRESH-CUT BANANA[1]

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ABSTRACT - Browning discoloration after cutting is detrimental for the quality of a number of fruits and vegetables, such as banana, apple, pear, potato, and some roots such as cassava, yam, and others. Browning and softening compromise banana after cut shelf-life in a few hours under cold storage. Therefore, anti-browning compounds have been applied to slices before packing. Some commonly used substances are calcium chloride, ascorbic acid, cysteine and citric acid, in immersed inchemical mixtures. Recent studies have demonstrated the possibility of preserving fresh-cut banana immersed in sweetened fruit juice for relatively longer periods, favoring commercialization. This type of conservation, although widely used in Brazil for fruit salads, consists of a more complex system in a physiological basis, requiring adjustment of the solution parameters, such as sugar concentration, pH and acidity, considering the viability and freshness of the plant tissue. In this short review, we discuss some experimental data and present a new method for preserving fresh-cut banana. Reduction of enzymatic activity, either in temporary dipping treatment or permanent immersion of banana slices is regarded as a key factor for maintaining its quality during cold storage.

Keywords: banana; browning; antioxidant; passion fruit syrup; polyphenoloxidase.

TÉCNICAS ALTERNATIVAS UTILIZANDO SUCO DE FRUTA NA CONSERVAÇÃO DE BANANA MINIMAMENTE PROCESSADA

RESUMO - O escurecimento após o corte é deletério à qualidade de várias frutas e hortaliças, tais como banana, maçã, pera, batata, e algumas raízes como mandioca, inhame, dentre outras. O escurecimento e o amaciamento comprometem a vida de prateleira de banana cortada em poucas horas sob conservação refrigerada. Deste modo, substâncias anti-escurecimento são aplicadas nas fatias antes de serem embaladas. Algumas substâncias mais utilizadas são: cloreto de cálcio, ácido ascórbico, cisteína e ácido cítrico, imersas em misturas químicas. Estudos recentes tem demonstrado a possibilidade de conservação de banana minimamente processada imersa em caldas de frutas por períodos relativamente maiores, favorecendo a comercialização. Este tipo de conservação, embora seja muito utilizado no Brasil para saladas de frutas, constitui-se em um sistema complexo sob o ponto de vista fisiológico, exigindo uma série de ajustes na solução, tais como a concentração de açúcar, pH e acidez, considerando-se a manutenção da vitalidade e frescor do tecido vegetal. Nesta pequena revisão são discutidos alguns dados experimentais, e é apresentado um novo método para a preservação de banana minimamente processada. A redução da atividade enzimática, tanto no tratamento de imersão temporária quanto na imersão permanente de fatias de banana é considerada um fator chave para manter sua qualidade durante a conservação refrigerada.

Palavras-chave: banana; escurecimento; antioxidante; calda de maracujá; polifenoloxidase.

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INTRODUCTION

The growing market for minimally processed products is beyond the convenience of having them ready to eat. It is mostly related to the increasing awareness of consumers about health benefits associated with the consumption of fresh fruits, vegetables and mixed salads. In this regard, studies have demonstrated that a diet rich in fruits and vegetables has been related to several benefits, including prevention of chronic diseases such as cancer, arthritis and atherosclerosis.

Banana is a fruit rich in vitamin C, α-tocopherol, β-carotene, and polyphenolic antioxidant compounds such as dopamine and gallocatechin, compounds that protect the body against the damaging effects of free radicals. Banana consumption could help in the prevention and treatment of diseases related to oxidative stress, such as atherosclerosis.

In Brazil, there are several banana cultivars, all of them showing pronounced differences in relation to quality attributes such as size, color, flavor and texture. For minimal processing, it is mandatory to select the fruit in the appropriate maturity stage in order to maintain its quality after cutting. Banana maturity stage is usually chosen according to the peel color, and it will vary depending on the cultivar. Following a scale proposed by Von Loesecke (1950), and by the banana industry, researchers have used stage 4 (more yellow than green) for Cavendish (VILAS-BOAS; KADER, 2006; BICO et al. 2009), stage 5 (yellow with green tips) for 'Silver' (DINIZ, 2009; VILAS BOAS et al., 2009) and stage 6, (full yellow) for 'Apple' bananas (MELO et al., 2009).

The various operations required to obtain fresh-cut products, such as selection, peeling, slicing and rinsing and/or sanitizing are considered stress factors imposed to fruit tissues which affect not only the sensory aspect but also potentially reduce the health benefits of fresh fruits and vegetables. All the operations promote the increase in oxidation processes initiated by handling procedures and intensified by peeling and slicing. The oxidative damage in the tissue is mostly catalyzed by enzymes such as polyphenol oxidase, causing oxidation of antioxidant phenolic compounds and visual browning of the cut surfaces.

Fresh-cut banana, without any post-cutting treatment, presents browning and marked firmness loss within 6 hours (VILAS BOAS et al., 2009). Thus, in the operations for fresh-cut banana preparation, immersion of slices in a mixture of anti-browning chemical substances such as calcium chloride, ascorbic acid, cysteine and/or citric acid is mandatory, in order to maintain the quality of the productin cold storage for up to 4 days. Furthermore, banana dipping solutions could potentially make it a vehicle of antioxidants for human consumption, also increasing its antioxidant potential in the plant tissue (MELO, 2010).

In Brazilian fruit market, there are fruit salads in which the product is immersed in juices, usually from orange, passion fruit and pineapple. Differently from the widespread anti-browning immersion treatments, which occur in a short-term period, from seconds to 1 or 2 minutes, the immersion in sucrose solution is permanent throughout conservation. This technique could contribute as an alternative to anti-browning dipping for banana, since it can also inhibit enzymatic browning reactions (DINIZ, 2009), and it is a natural, innocuous and a low-cost alternative. However, such treatment requires tests for adjustments of the compounds in the juice in order to avoid further quality losses (DINIZ, 2009). Currently few studies are made on this regard.

In this paper, we discuss some research works that show promising results related to the use of anti-browning substances, as well as solutions containing sugar and passion fruit juice in maintaining quality of fresh-cut banana.

Anti-browning substances in minimally processed products

Minimally processed fruits and vegetables undergo enzymatic browning and softening, and microbial contamination, which reduces their shelf-life compared with the similar intact (SOLIVA-FORTUNY; MARTIN-BELLOSO, 2003).

Nutritional changes caused by fresh-cut operations in fruits and vegetables are closely related to phenolic metabolism in response to injury, which can alter the antioxidant activity, thereby affecting its functional value (SALTVEIT, 2000; REYES et al, 2007). Moreover, injuries related to minimal processing can induces several kinds of stress, such as oxidative stress, measured directly by quantifying the accumulation of reactive oxygen species, lipid peroxidation products, or indirectly, from changes in the components or enzymes of antioxidant defense systems such as catalase and superoxide dismutase (TOIVONEN, 2004; FREIRE, 2014).

Banana is the most commercialized fruit in the world, and a potent antioxidant, once it has reasonable concentrations of vitamin C and high content of phenolic compounds (LIM et al., 2007). Some studies conducted in bioassays have shown the prominent antioxidant capacity of compounds present in the pulp and peel of banana (KANAZAWA; SAKAKIBARA, 2000; SOMEYA et al, 2008.). However, sliced banana is very sensitive to physiological browning, which has excluded its use in minimally processed salads (MOLINE et al., 1999). Browning is primarily due to the polyphenol oxidase (PPO) enzyme that catalyzes the hydroxylation of o-diphenols monophenols, and their oxidation toquinones, leading to the formation of brown pigments (ZAWISTOWSKI et al., 1991).

Once the optimum pH for the activity of PPO

in banana is around 6.5 (YANG et al., 2000), the enzyme activity in minimally processed banana could be highly inhibited by immersion in anti-browning mixtures, which have very low pH, since they contain large amounts of various organic acids (Sapers, 1993).

The immersion in mixtures of antioxidants has been a successful method for reducing browning and softening and prolonging the shelf life of various fresh-cut fruits such as kiwis (CARVALHO; LIMA, 2002), apples (LEE et al., 2003), pears (GORNY et al, 2002) and bananas (MOLINE ET AL., 1999; Melo& VILAS BOAS, 2006; VILAS BOAS; KADER, 2006). A chemical solution containing ascorbic acid, calcium chloride and cysteine was more effective than the application of these compounds separately in maintain the quality and extend the shelf life of fresh-cut 'Apple' banana for 4 days (MELO; VILAS BOAS, 2006). Bico et al. (2009), evaluated dipping treatment containing ascorbic acid (1% w/v) + calcium chloride (1% w/v) + L-cysteine (0.75% w/v), and observed lower reduction of color saturation in sliced Cavendish banana, expressed as a lower decrease of Chroma.

The inhibition of PPO activity or color formation caused by polyphenol polymerization is the main objective of the application of chemical compounds in fresh-cut products. Ascorbic acid is a "universal" antioxidant, reducing o-quinones back to o-diphenols, after the reaction of PPO, or maintaining the pool of α-tocopherolof cell membranes in the reduced form, protecting them against lipid peroxidation (SHEWFELT; PURVIS, 1995; LURIE, 2003).

Citric acid is a highly effective chelator which inhibits the enzymatic browning by reducing the availability of Cu^{2+} at the site of action of PPO (DZIEZAK, 1986), and it is also an acidulant, decreasing pH and inhibiting the enzyme activity.

Cysteine can delay the enzymatic browning by reducing o-quinone, similarly to other antioxidants (RICHARD et al., 1991), and react with primary PPO oxidation products, generating colorless quinone-cysteine conjugates that act as enzyme inhibitors. Moreover, according to Richard-Forget et al. 1992, undesirable pinkish-red formation occurs when the proportion of cysteine in the mixture is not sufficient to proportionally react with phenolic compounds released from the cut tissues, at a cysteine/ phenol ratio lower than 1,.

For the dipping treatment of ‘apple’ banana, concentrations below 1% w/v in the mixture are not recommended, and the lower the concentration, the higher the red color formation (MELO; VILAS BOAS, 2006). In the other hand, excessive cysteine concentrations are not consistent with good sensory properties or economically viable for industrial purposes. The development of red color in banana slices is observed to occur near the vascular bundles (Figure 1). Moline et al. (1999), also reported a more intense browning formation in the vascular region, and attribute this observation to the higher phenolic content in vascular bundles and xylem vessels.

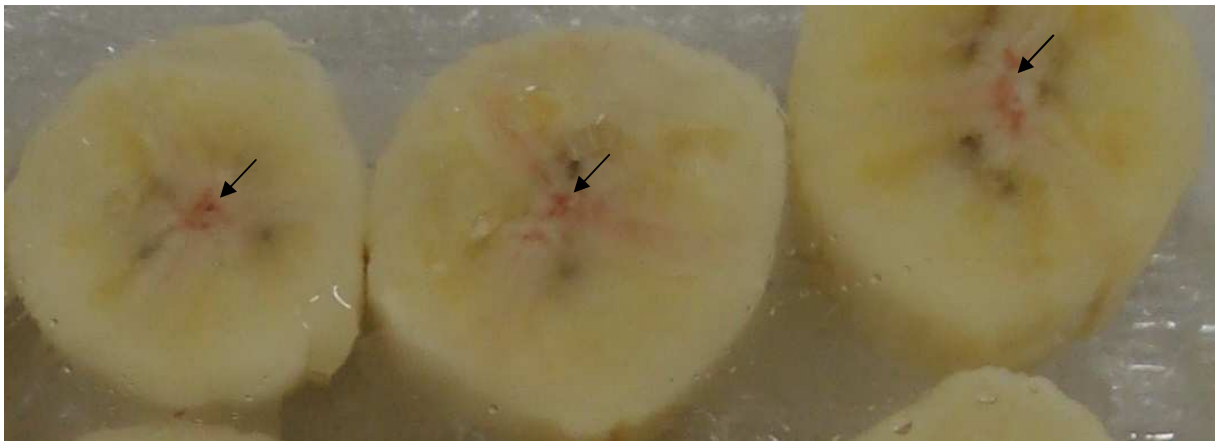

Figure 1. ‘Silver’ banana immersed in solution of ascorbic acid + $CaCl_2$ + L-cysteine hydrochloride (1% w/ v) inside a tray covered by PVC film after 3 days of storage at 5 ^{o}C. The arrows show the pinkish-red color formation concentrated near vascular tissues.

The low pH presents a key role in maintaining color of treated fresh-cut banana. Cysteine in concentrations lower than 0.5% has its role compromised at neutral pH, favoring the formation of pinkish-red pigments in fresh-cut banana (VILAS BOAS; KADER, 2006). Silver bananas immersed in the mixture of 1% w/v calcium chloride, ascorbic acid and cysteine at pH 2.0 presented lower values for coordinate a*, indicating less reddening, and lower total color difference (ΔL) comparative to the same mixture at pH 7.0 (MELO, 2010). Divergent results have been observed regarding the efficiency of the anti-browning solutions in different pH for the control of enzymatic browning in fruits after processing. In fresh-cut apples (SAPERS; MILLER, 1998) and pears (GORNY et al, 2002), the treatment under neu-

tral conditions was more efficient than the immersion in acidic pH; Vilas Boas and Kader (2006), however, observed that the immersion in acidic chemical mixtures provided higher firmness values and reduced browning in 'Grand Nain' banana.

The low pH of the solutions of immersion inhibits the activity of PPO and browning, can potentially cause injuries in membranes (TOIVONEN, 2004) as well as induce the activity of enzymes related to hydrolysis of cell wall material (KNEE, 1982). Thus, it is believed that improving the efficiency of anti-browning agents, lowering the pH of the dipping solution, seems to be an inducer of color stability in fresh-cut banana. In this way, lower instrumental color difference is observed when fresh-cut banana slices are maintained in sucrose solution at pH 3.5 (DINIZ, 2009).

Fresh-cut tissue softening, characterized by loss of textural quality is a another main concern for fresh-cut banana, resulting in impairment of sensory attributes and significantly shortening its shelf life (MELO; VILAS BOAS, 2007). It has been shown that presence of calcium ions in dipping solutions is essential for maintaining firmness in fresh-cut banana of the cultivars 'Apple' (MELO; VILAS BOAS, 2007) and Cavendish group (VILAS BOAS; KADER, 2006).

Calcium is assumed to play a rolein the majority of cementing properties of the cell walls, by connecting dimethyl esterified pectin to produce cross-linked polymer networks in the middle lamella (POOVAIAH, 1986; TOIVONEN; BRUMMEL, 2008), and maintaining cell wall structure. This arrangement improves cell-to-cell adhesion, thereby increasing mechanical strength, and delaying the normal degradation of intercellular connections in ripening fruit (TOIVONEN; BRUMMEL, 2008).

Fruit tissue softening is related to the activity of pectolytic enzymes such as polygalacturonase (PG) and pectin methyl esterase (PME), synergistically acting on pectins. Calcium crosslinks in galacturonic acid residues, forming calcium pectate in the middle lamellae, is probably responsible for higher firmness in fresh-cut banana immersed in $CaCl_2$ solutions.

Fresh-cut banana immersed in passion fruit pulp and sucrose

The conservation of fresh fruits by immersion is usually seen in mixed salads, which are most commonly sold in supermarkets, hotels, cafeterias, and also in airport catering services. This technology is applied in fruit salads containing banana, pineapple, melon, orange, and others, immersed in solutionswhich can be made of pineapple, orange, passion fruit, and other juices. In general, banana is the most important component of this kind of mixed salad. However, studies on the effect of these compounds considering the physiology of the fruits tissues are still very preliminary.

Diniz (2009), has presented a study comprising the viability of the tissues of fresh-cut banana immersed in sweetened passion fruit suspension. It was considered as a system in order to be compared with the conventional modified atmosphere for the conservation of banana fruit slices. This system, containing only one type of fruit is simple in comparison with mixed salads, however complex when considered the influence of the solution and the possible interactions between fruit tissues and the surrounding environment. In order to preserve sensory properties related to fruit quality such as flavor and texture, the system requires a fine adjustment of the concentrations of sucrose in the solution, control of the acidity and pH of the fruit pulp, by standardizing fruit maturity, and studying the best proportion of fruit pulp/ sucrose media (Figure 2).

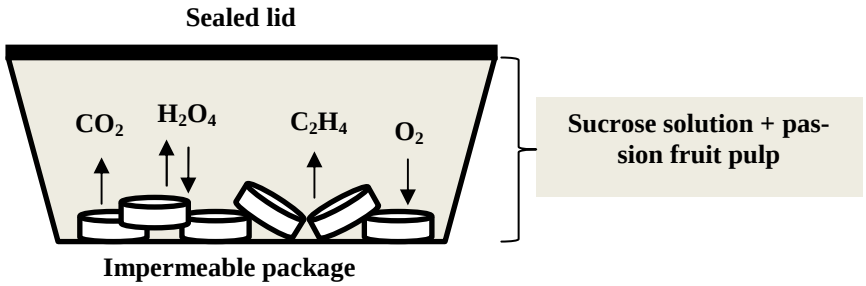

Figure 2. A system containing sucrose solution and suspension of passion fruit pulp (juice) for conservation of fresh-cut banana.(Adapted from KADER and SALTVEIT, 2003).

Taking into consideration that there is an initial difference in soluble solids between the banana and the solution/suspension, water exchange and variations in soluble solids in the components of the whole system will occur during storage, and it is shown in Figure 3. The equilibrium between banana tissue and solution was reached at an initial concentration of sucrose of 15%. It is believed that sucrose plays an important role maintaining the osmotic balance in the system, and a faster stabilization in soluble solids content could maintain product quality and increase the storage time.

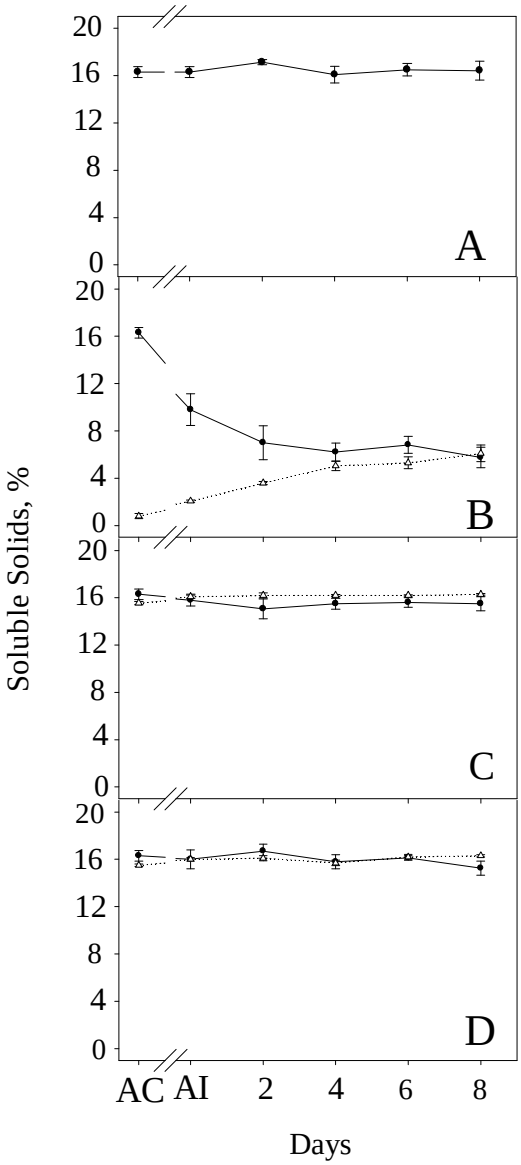

Figure 3. Soluble solids in banana slices (-●-) and the respective solutions/suspensions(-Δ-). Immediately after cutting (AC). Immersed for 2h (AI). Sliced non-immersed banana (A), and immersed for eight days at 5 °C in: suspension of passion fruit pulp (B), 15% sucrose solution (C) or suspension of passion fruit pulp containing 15% sucrose (D). Vertical bars represent standard deviation.

Changes in the instrumentally measured color difference and brightness are also noticeable between non-immersed banana slices and those immersed in sucrose solution (Figure 4). In banana slices immersed in suspension of passion fruit pulp with and without sucrose, color changes are minimal (Figure 4).

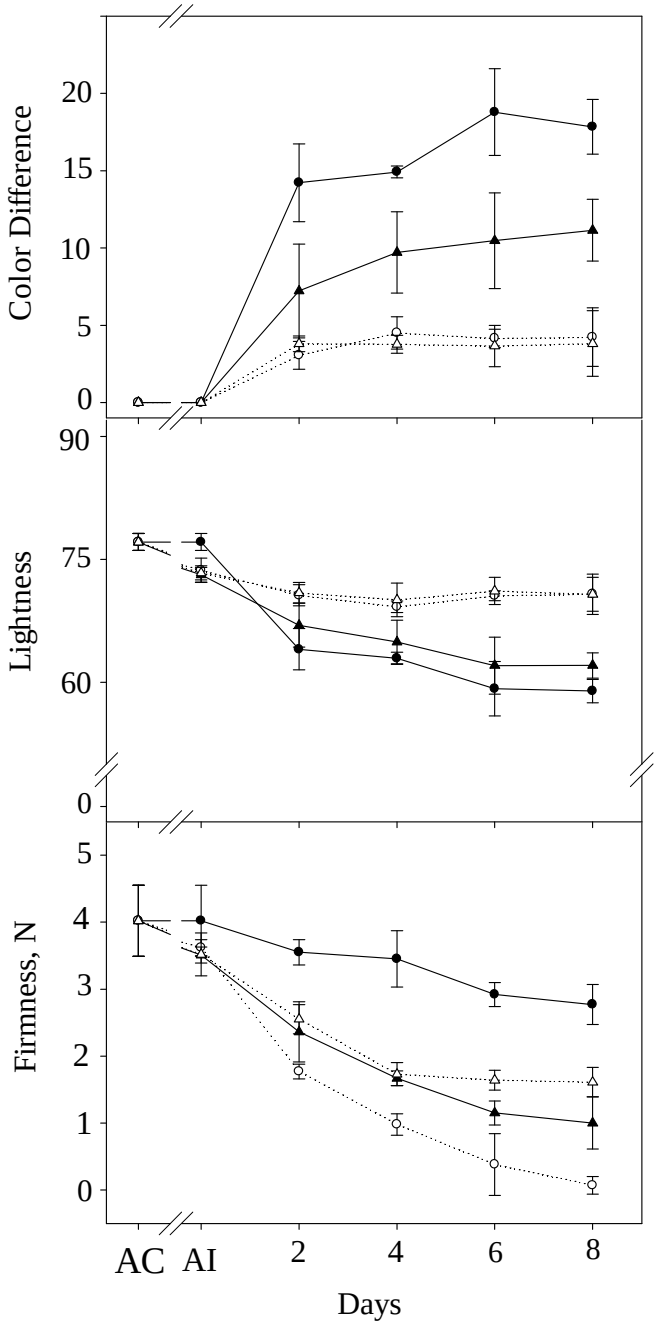

Figure 4. Color difference, lightness and firmness of banana slices immediately after cutting (AC), immersed for 2h (AI) and immersed for eight days at 5 °C in 15% sucrose solution (▲), in suspension of passion fruit pulp (○) and suspension of passion fruit pulp containing 15% sucrose (Δ). Non-immersed banana slices (●). Vertical bars represent the standard deviation.

The increase in color difference is related to a reduction in lightness (L) of the product surface. The lower the L value the darker the evaluated surface (MUNSELL, 1912). Reduction of L value in non-immersed banana slices during storage was also observed by other authors, even when treated with anti-browning substances (VILAS-BOAS; KADER, 2006).

Browning was drastically reduced in banana slices immersed in the combination containing passion fruit pulp. The lower pH values of solutions containing passion fruit pulp, around 3.5, and the reduced O_2 diffusion in aqueous mediumare the main factors to reduce the enzymatic browning caused by PPO.

The immersion treatments have determined loss of firmness in relation to non-immersed banana slices (Figure 4). In slices immersed in suspension of passion fruit pulp with no sugar added, firmness is significantly lower (Figure 4), which is associated to

a water flux into the banana slices, as a function of the water potential difference (Figure 3). Firmness of banana slices which were immersed in solution of sucrose or sucrose in combination solution/passion fruit pulp was intermediate and similar during storage.

Examining tissue failure under tensile stress, Harker et al., (1997) showed that banana presents a 'splitting pattern', meaning that cells are preferentially separated along the middle lamellae, instead of occurring cell wall rupture. In other tissues such as apples and pears, the tissue failure is more related to cell wall breakdown. For banana immersion in hypotonic solution of passion fruit pulp with no sugar added, cell wall separation without rupture has probably occurred, being exacerbated by the movement of water to the fruit tissue.

Despite the positive effects on the product quality, the sucrose added to the solutions for banana conservation must be moderated, considering its undesirable use for a crescent number of consumers looking for healthier products in a diet with less sugar intake.

CONCLUSIONS

Banana, although highly perishable and susceptible to enzymatic browning and softening, has a prolonged shelf-life when subjected to chemical treatments containing calcium and antioxidant maintaining its color and texture. These chemicals are usually applied for a few minutes and the pieces are drained after dipping, maintaining fresh appearance up to 4 days inside MA packaging for marketing purposes.

Other proposed technique, the storage in sweetened fruit juice solutions, is a promising low cost technology in which the slices are maintained immersed throughout all the storage period. It is a poorly studied method, although widely used commercially. It is believed that more research on this topic will bring important results, given that it complies with the growing search for a healthy diet.

In any case, the low pH of the medium and mainly the reduction of enzymatic activity still seem to be still a key factor on main taining fresh-cut banana with marketable quality.

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