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Full Length Research Paper

Colour behaviour on mango (*Mangifera indica*) slices self stabilized in glass jars by hurdle technology during storage

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The effect of the syrup composition on behaviour colour of self stabilized mango slices in glass jars by hurdle technology during 180 days of storage was studied through 2^{6-2} fractional factorial design. *L (lightness), *a** (redness and greenness), and *b** (yellowness and blueness) values were measured with a colorimeter and then hue angle (*H**) and chroma (*C**) calculated, each 30 days. At the end of storage period, the pH and ascorbic acid influenced significantly ($p < 0.05$) the *b** and *C** values, while potassium sorbate the *L**, *b** and *H** values, and sodium bisulphite the *a** and *H** values. These results could help to select the better syrup formulation for the self stabilization of mango slices in glass jars by hurdle technology in terms of colour quality.**

Key words: Mango, colour, hurdle technology, self stabilization.

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the important tropical fruits. This fruit is relished for its succulence, exotic flavor and delicious taste. Mango is a rich source of carotenoids and provides high vitamin A content (Pott et al., 2003). According to the FAO (2007), more than 26.5 millions of metric tons of mango were produced in worldwide, being México the 4th most important producer after India, China and Thailand, but the major exporter country in the world providing about 29.7% of the exportation volume. Most mangos are consumed fresh, but some non fibrous pulpy mango varieties are used for processing. However, substantial quantities of mangoes are wasted because of poor post-harvest management and lack or appropriate facilities in developing countries. Therefore, the development and application of inexpensive preservation techniques to produce high quality and acceptance products of mango could be beneficial, allowing a better utilization of the fruit. In this respect, hurdle technology which is characterized by an intelligent combination of some soft treatments or hurdles (Leistner, 1992, 1994, 1995; Leistner and Gorris, 1995), has demonstrated to be a useful and economic method in the production of processed fruit, if the process conditions to guarantee the microbial quality and appearance of the products during storage are appropriately selected (Alzamora et al., 1995; Tapia de Daza et al., 1996).

The classical method of hurdle technology applied to minimally processed fruits consists of fruit blanching followed by an activity water depression step in a tank, which contains syrup prepared generally with sucrose, citric acid (pH 3.0 to 4.1), potassium sorbate or sodium benzoate, and sodium bisulphite. The tank containing the fruit and syrup is held at constant room temperature during the equilibration time of 3 to 5 days. After equilibration or stabilization, the fruit slices are drained and packaged in glass jars or plastic high-density polyethylene bags, leaving only enough syrup to cover them (Alzamora et al., 1993; Alzamora et al., 1995; Tapia de Daza et al., 1996). These minimal processes have proved to be energetically efficient and very simple to carry out, resulting fresh-like products of long shelf-life and high sensory quality, especially for texture (Aguilera and

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Table 1. Syrup composition to package the mango slices.

Syrup	Sucrose (g/kg)	Sodium chloride (g/kg)	pH (adjusted with citric acid)	Potassium sorbate (g/kg)	Ascorbic acid (g/kg)	Sodium bisulphite (g/kg)
1	300	1.50	3.60	0.75	0.50	0.45
2	250	1.50	3.60	0.75	0.00	0.45
3	300	1.50	3.40	0.50	0.00	0.45
4	250	0.00	3.60	0.75	0.50	0.25
5	300	0.00	3.40	0.75	0.50	0.45
6	300	1.50	3.60	0.50	0.50	0.25
7	300	0.00	3.60	0.75	0.00	0.25
8	300	1.50	3.40	0.75	0.00	0.25
9	250	0.00	3.60	0.50	0.50	0.45
10	300	0.00	3.60	0.50	0.00	0.45
11	250	0.00	3.40	0.50	0.00	0.25
12	250	1.50	3.60	0.50	0.00	0.25
13	250	0.00	3.40	0.75	0.00	0.45
14	300	0.00	3.40	0.50	0.50	0.25
15	250	1.50	3.40	0.75	0.50	0.25
16	250	1.50	3.40	0.50	0.50	0.45

Chirife, 1994; Liestner, 1995), which is often problematic for canned fruit. However, the process previously described is highly time consuming and costly. Therefore the self stabilization of the fruit in the container is desirable to get a continuous process.

On the other hand, the colour contributes greatly to the attractive appearance of the fruits. The majority of the changes related to the alteration of colour in processed fruits are associated with enzymatic and not enzymatic reactions, as well as the degradation of pigments (Cornwell and Wrolstad, 1981; Jayaraman et al., 1999; Soliva-Fortuney et al., 2002). These reactions produce undesirable odour, flavor changes and lowering of the nutritive value (Toribio and Lozano, 1986). Therefore the objective colour determination by instrumental measurements is important not only for the description of colour change but also as source of useful information for quality control of food products (Garza et al., 1999; Mazkan, 2001).

The purpose of this research was to evaluate the effect of the syrup composition on colour behaviour on mango slices self stabilized in glass jars by hurdle technology during storage.

MATERIALS AND METHODS

Mangoes

Kent mangoes were obtained from a commercial grower in Navarrete municipality of San Blas, Nayarit, México (21°22'30'' North latitude, 105°07'30'' West longitude), and transported to the Centro de Tecnología de Alimentos of the Universidad Autónoma de Nayarit, at ambient temperature (25°C). The mangoes were picked mature green in anticipation of the processing date and were allowed to ripen for 4 days at room temperature (25°C). Mangoes were washed with water, peeled with a knife, the flesh removed from the seed, and then cut into slices in shape of slabs of 7 x 5 x 1 cm. The mango slices were blanched at 80°C for 10 min with a ratio fruit: water of 1:4.

Formulation and preparation of syrups

Formulations of syrups were obtained by means of a 2^{6-2} fractional factorial design (Montgomery, 2002), having as factors sucrose, salt (sodium chloride), pH (adjusted with citric acid), potassium sorbate, ascorbic acid, and sodium bisulphite. The high level of each food additive of the syrup formulations was established in agreement with the dose used generally in processing of fruits by hurdle technology (Alzamora et al., 1995) and the international legislation in the matter (FAO/WHO, 2006). All the ingredients for the preparation of syrups were food grade (Almacén de Drogas La Paz, S.A., de C.V., Guadalajara, Jalisco, México). The syrups were prepared as follows: firstly the water temperature was raised at 80ºC, and then appropriate amounts of sucrose, sodium chloride, potassium sorbate, ascorbic acid, and sodium bisulphite were added to it, and the pH was immediately measured adjusting it with citric acid to the corresponding level. Finally, the syrup temperature was raised at 90ºC and it was ready to be used as covering liquid for the packaging of mango slices in glass jars. Table 1 shows the composition of each syrup used for the packaging of mango slices.

Mango slices packaging

For the packaging of mango slices, glass jars of 500 ml with a metallic lid covered with a polymeric film resilient to high acidity were used. In each glass jar was deposited seven mango slices, which were equivalents to the 60% weight capacity of the container, and the remainder 40% was filled with the covering liquid, added at 90ºC. Then, immediately the glass jar was enclosed. When the glass jars were at room temperature, then they were placed in cardboards for later analysis. The storage of the cardboards with self stabilized mango slices in glass jars was at room temperature (25°C).

Table 2. Analysis of variance of the syrup components for the colour parameters of the mango slices self stabilized in glass jars by hurdle technology at 180 storage days.

Main effects	[a]F-ratio				
	L*	*a**	*b**	C*	H*
Sucrose	0.15^{NS}	0.05^{NS}	0.54^{NS}	0.51^{NS}	0.24^{NS}
Sodium chloride	1.05^{NS}	1.46^{NS}	0.54^{NS}	0.52^{NS}	1.70^{NS}
pH	0.65^{NS}	3.16^{NS}	6.01^{S}	5.78^{S}	2.96^{NS}
Potassium sorbate	17.25^{S}	2.40^{NS}	34.63^{S}	35.24^{S}	1.07^{NS}
Ascorbic acid	0.94^{NS}	0.78^{NS}	12.17^{S}	12.09^{S}	0.75^{NS}
Sodium bisulphite	3.03^{NS}	77.74^{S}	1.71^{NS}	1.48^{NS}	76.10^{S}

*L** = lightness, *a** = redness and greenness, *b** = yellowness and blueness, *C** = chroma, *H** = hue angle.
[a]Numerical values are the F-ratio of the variance explained by a factor compared with the unexplained variance.
^{S}p <0.05, ^{NS}=non significant.

Colour analysis

The colour of the mango slices was measured with a Minolta colorimeter CR-300 (Minolta Corp., Ramsey, NJ, U.S.A.). The colorimeter was calibrated with a white standard. The colour measurement was each 30 days during the storage period of 180 days. Seven slices from each glass jar were used for colour measurement. One side of each slice was placed flush against the light source and based on the Commission Internationale de l'Eclairage (CIE) *L** (lightness), *a** (redness and greenness) and *b** (yellowness and blueness) values were measured (CIELAB colour scale). Hue angle (*H**) was calculated as $\tan^{-1}(b^*/a^*)$ and chroma (*C**) as $(a^{*2}+b^{*2})^{1/2}$.

Statistical analysis

Analysis of variance and the least significant difference (LSD) test for comparison of means were performed using the software Statgraphics Plus Version 4.0 Plus (Manugistics, Inc.,Rockville, Md., U.S.A.). Significance of differences was defined at p <0.05.

RESULTS

Table 2 shows the analysis of variance of the syrup components on colour parameters of mango slices self stabilized in glass jars by hurdle technology at 180 days of storage. According to these results, the sucrose and salt did not have a significant (p <0.05) effect on any of the colour parameters studied, while the pH (adjusted with citric acid), potassium sorbate, ascorbic acid, and sodium bisulphite had a significant (p <0.05) effect on at least one of the colour parameters evaluated.

The effect of sucrose, salt, pH, potassium sorbate, ascorbic acid, and sodium bisulphite of the syrups on *L** from the self stabilized mango slices in glass jars by hurdle technology during storage, are shown in Figure 1. When *L** decrease, this behaviour is associated with the browning, which defines highly the perception that the consumers have of the quality of processed fruits, principally of fruits packaged in transparent containers, because the people have the chance to evaluate this characteristic before the acquisition of the product. According to Figure 1, the *L** values on mango slices increased significantly (p <0.05) during the firsts 30 days of storage, independently of the high or low level of each syrup component. In general, after 30 days of storage, the *L** values on the mango slices began to drop by effect of each level and syrup ingredient up to 180 days of storage, getting approximately the *L** initial value, except for potassium sorbate; the low level of potassium sorbate (0.5 g/kg) in the syrups produced a higher value of *L** compared with the high level of such substance.

The behaviour of *a** by effect of the levels of the syrup ingredients on self stabilized mango slices during 180 days of storage is shown in Figure 2. All the syrup ingredients, with their respective levels, had a irregular behaviour in *a** during the storage period, with increases and decreases, but at 180 days the high level of sodium bisulphite (0.45 g/kg) produced a yellow colour clearer than the observed on the mango slices at low level of such substance (0.25 g/kg).

In general, the behaviour of *b** by effect of each syrups ingredient, independently of their level, showed a decrease at the end of the storage period (Figure 3). The initial and end values of *b**, in the storage period (180 days), were 58.0 and 45.6 (Figure 3d), respectively, decreasing 12.4 units in the scale of this colour parameter at the low level of potassium sorbate (0.5 g/kg). On the other hand, the high levels of pH (3.6) and ascorbic acid (0.5 g/kg) had a significant (p <0.05) decrease lower of *b** than their low levels, respectively.

The mean *H** values of mango slices in syrups with 0.25 g/kg of sodium bisulphite during the storage period of 180 days decreased by 1.44°, while those in syrups with 0.45 g/kg of sodium bisulphite increased by 2.2° (Figure 4).

The higher decrease of the *C** values was detected on the mango slices in syrups with 0.75 g/kg of potassium sorbate (from 57.9 to 45.6), while the presence of ascorbic acid (0.5 g/kg) and a pH value of 3.6 in the syrups produced a minor variation of *C** from 57.6 to 49.3

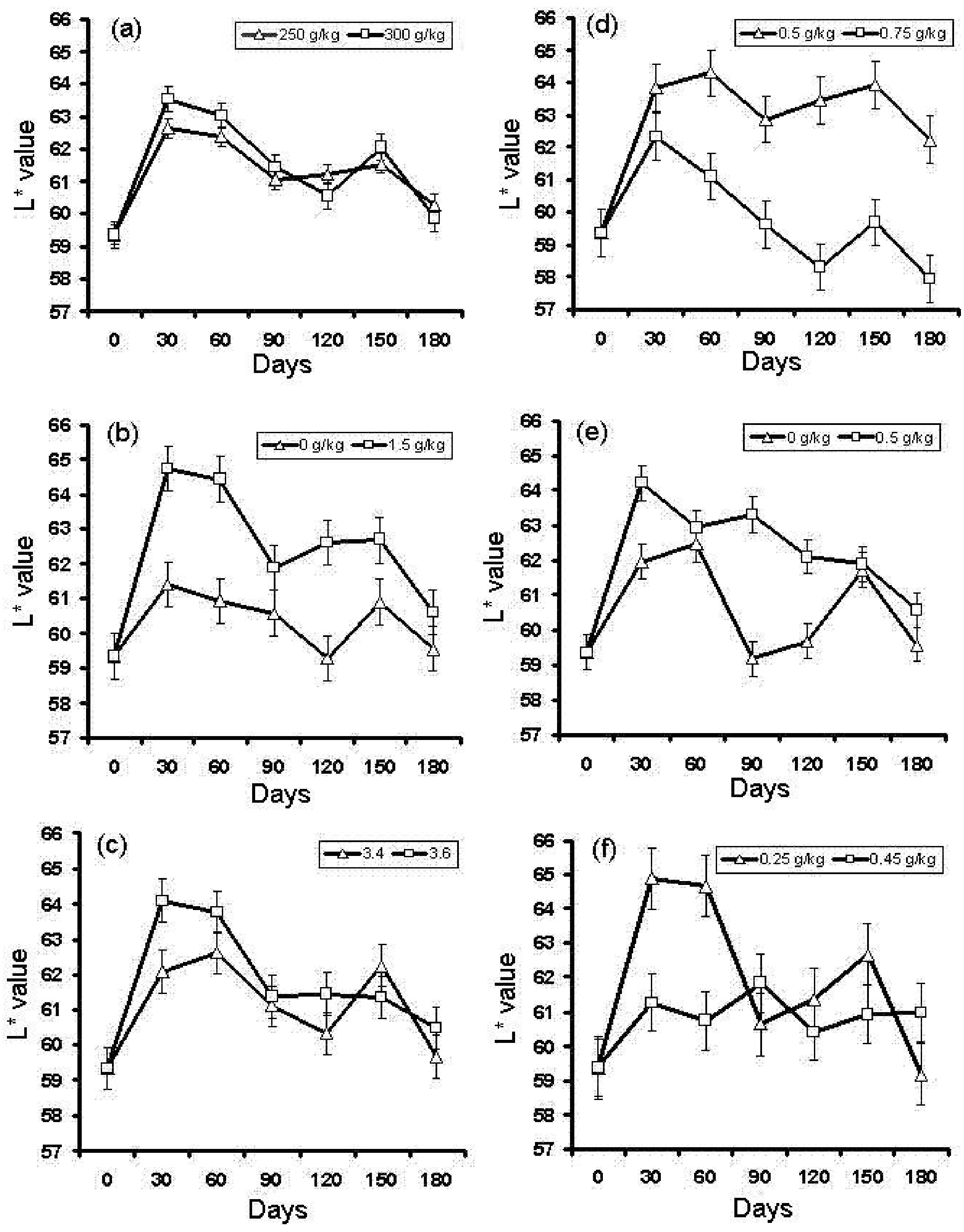

Figure 1. Behaviour of *L** on the mango segments self stabilized in glass jars by hurdle technology with effect of sucrose (a), sodium chloride (b), pH (c), potassium sorbate (d), ascorbic acid (e), and sodium bisulphite (f).

and 57.6 to 48.9, respectively (Figure 5).

DISCUSSION

The main problem of appearance during storage of processed yellow fruit by hurdle technology, which affects greatly the quality of the products, is the degradation of the carotenoids. However, it is possible that other natural or added substances contained in the processed fruit will suffer degradation with the consequent damage of the desirable characteristic of colour during storage. The beneficial action of sulfites as antioxidants in the stabilization of carotenoids is due to the removal of the

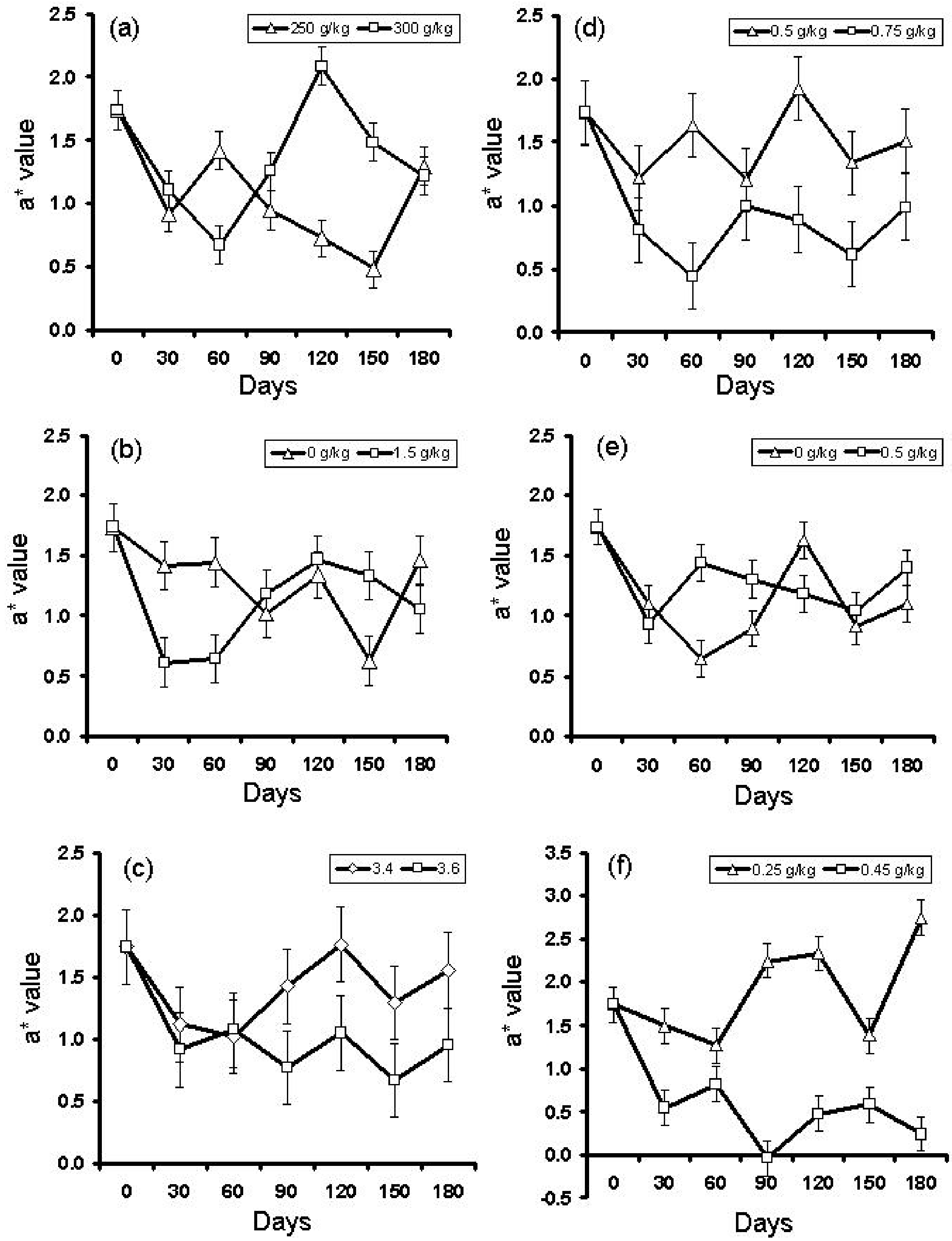

Figure 2. Behaviour of *a** on the mango segments self stabilized in glass jars by hurdle technology with effect of sucrose (a), sodium chloride (b), pH (c), potassium sorbate (d), ascorbic acid (e), and sodium bisulphite (f).

oxygen in packaged food (Sapers, 1993). On the other hand, the sulfites are functional food additives useful in the pretreatment of dried vegetables, principally for the protection of colour (Latapi and Barret, 2006; Kinsgly et al., 2007). In this study, the syrups with a high level of sodium bisulphite (0.45 g/kg) determined *a** values smaller and *H** values bigger on mango slices, near to zero and 90° at 180 days of storage, respectively, producing a

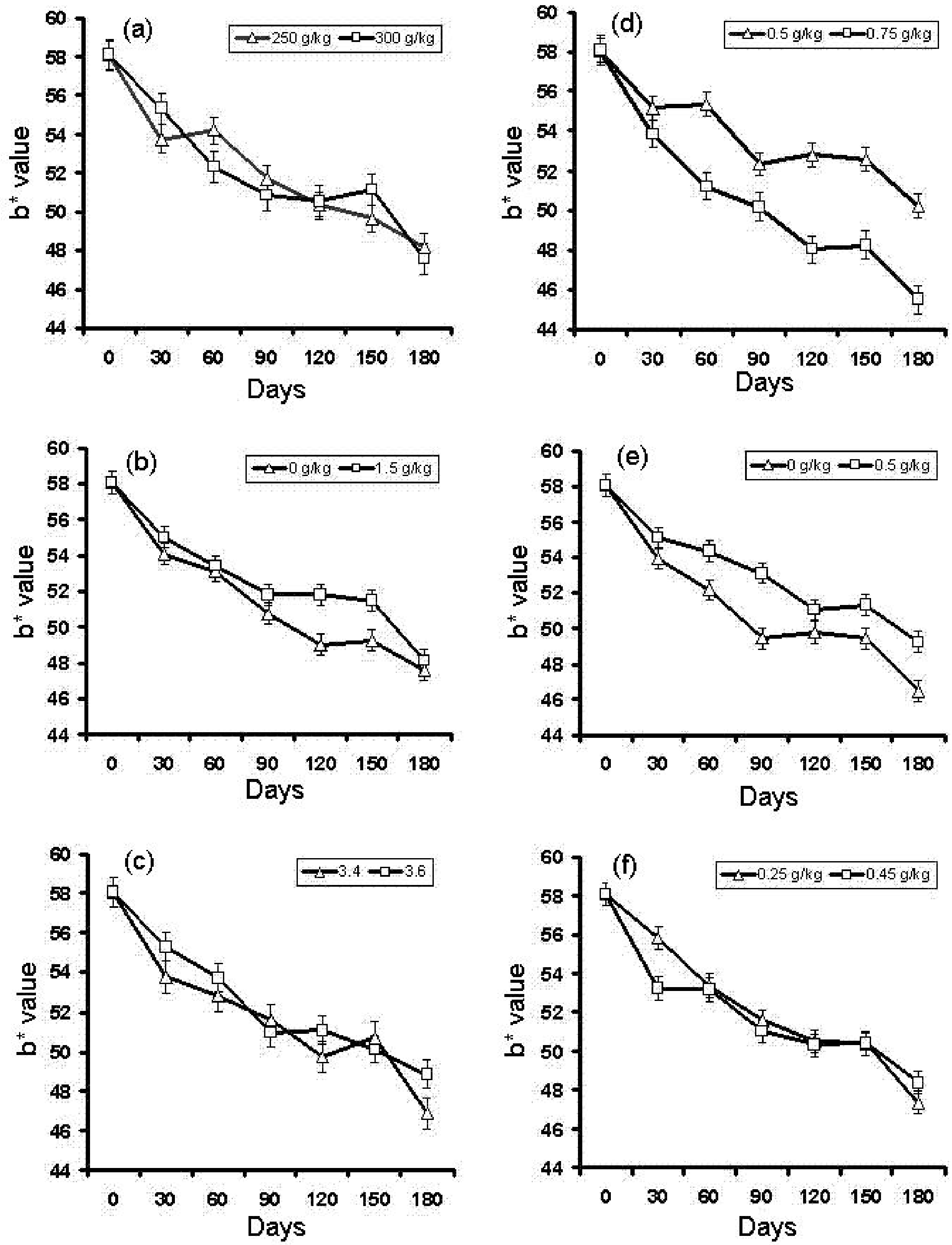

Figure 3. Behaviour of *b** on the mango segments self stabilized in glass jars by hurdle technology with effect of sucrose (a), sodium chloride (b), pH (c), potassium sorbate (d), ascorbic acid (e), and sodium bisulphite (f).

yellow colour clearer than the yellow colour of the mango slices in syrups with a low level of sodium bisulphite (0.25 g/kg). An appropriate dose of sulfites in processed fruit by hurdle technology prevents the chemical and/or physical depletion of this antioxidant during storage, which assures an acceptable appearance of the product in terms of colour (López-Malo et al., 1994). Jarayaman et al. (1999) reported low oxidation of carotenoids in products of high humidity from mango and papaya, which were stabilized by hurdle technology. As the sodium bisulphite, the ascorbic acid can be added also in processed fruit to fulfill an antioxidant function (Sawamura et al., 2000;

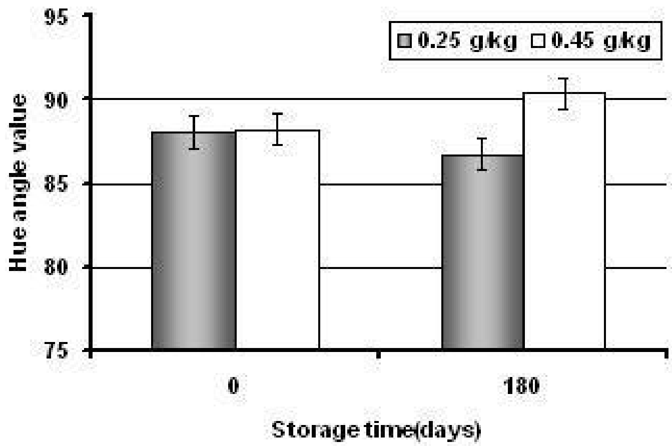

Figure 4. Hue angle values of mango slices self stabilized in glass jars by hurdle technology with effect of sodium bisulphite.

Guerrero-Beltrán et al., 2006). In this work the presence of ascorbic acid (0.5 g/kg) and a pH value of 3.6 in syrups increased the *b** and *C** values on the mango slices at the end of the storage, in contrast with the mango slices in syrups without ascorbic acid. This increase of the *b** value was desirable because the yellow colour on the mango slices was located, onside the colour space, as a yellow clearer in comparison with the yellow colour of the mango slices packaged in syrups without ascorbic acid. A value bigger of *C** on the mango slices was desirable because the purity or saturation of the colour also was bigger. With respect to the potassium sorbate in syrups and its effect on the colour characteristic on packaged mango slices, at the end of storage, the high dose of such preservative (0.75 g/kg) generated values lower of *L**, *b** and *C** than the values of the same parameters in syrups with low dose (0.5 g/kg). Sorbic acid and its potassium salt, commonly named sorbates, are added to a wide range of foods because they have a very effective inhibitory action on microbial growth (Hsiao and Siever, 1999). However, sorbates suffer an oxidative degradation in aqueous solutions that depends on pH, water activity, presence of other additives and conditions of storage and processing (Gerschenson and Campos, 1995; Campos and Gerschenson 1996). It is well known that this degradation is accompanied by an increase in the concentration of carbonylic compounds, mainly acetaldehyde and β-carboxyacrolein, which polymerize rapidly to brown pigments (Arya and Thakur, 1988). In this research, the low dose of potassium sorbate (0.5 g/kg) in the syrups for packaging of mango slices showed values higher of *L**, *a** and *C**, which indicated a browning grade lower that the mango slices packaged in syrups with the high dose of potassium sorbate (0.75 g/kg). This above behaviour was reported by Vidysagar and Arya (1984) for mango squash where the addition of 0.1% sorbic acid did not affect the rate of browning, while 0.2% caused a slight increase in the rate of browning.

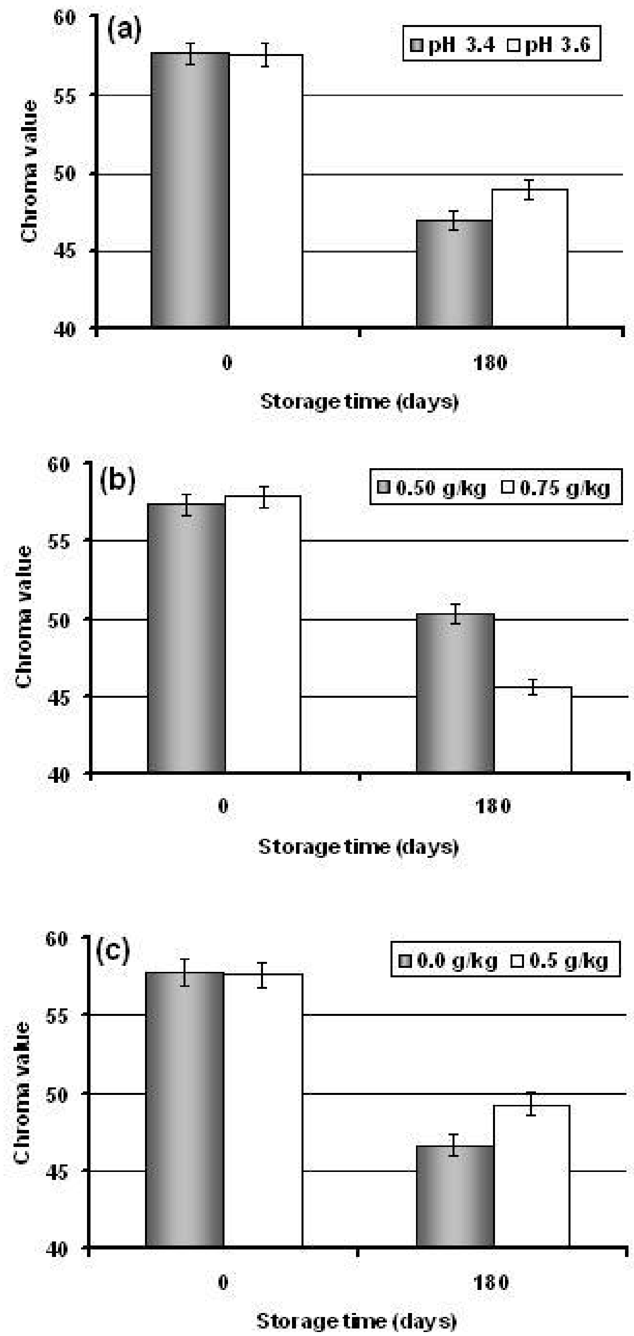

Figure 5. Chroma values of mango slices self stabilized in glass jars by hurdle technology with effect of (a) pH, (b) potassium sorbate, and (c) ascorbic acid.

In conclusion, this study demonstrated that the appropriate formulation of syrup was important in the stability of the colour on the mango slices self stabilized in glass jars by hurdle technology during storage, which is deduced from the small changes observed in the studied colour parameters. In general, these small changes did not showed alterations visually perceptible on the yellow colour of the fruit.

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