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Storage Stability of Reduced-Sugar Preserved Mangoes Prepared with Acesulfame-K and/or Aspartame

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Abstract: Physical, chemical, microbiological and sensory properties of reduced-sugar preserved mangoes prepared by substituting 30% of the sugar used for concentration with equivalent sweetness of acesulfame-K, aspartame, and a mixture of acesulfame-K and aspartame (1:1) were determined throughout 6 weeks of storage at 4-5°C. The control and reduced-sugar formulations displayed some significative variation of physical and chemical properties during the storage period, except for reducing and non-reducing sugars content which showed an expressive alteration. Sensory results revealed significant differences ($p < 0.05$) for texture and flavor among control and reduced-sugar formulations after the fourth week of storage. All formulations tended to produce darken color and less crispy texture throughout 6 weeks of storage. The control and formulation with acesulfame-K were less acceptable than other formulations. The microbial counts of all formulations tended to increase with storage time; therefore, the microbiological safe was about 4 weeks of storage. According to the consumer preference, the reduced-sugar formulation containing acesulfame-K and aspartame (1:1) was considered as the most favourite, which provided the total caloric reduction about 24% in relation to 100g of the control preserved mango.

Key words: Preserved mango, acesulfame-K, aspartame, health food.

INTRODUCTION

The over-consumption of sugar may contribute to high risk of health problems regarding of diabetes, obesity, high blood glucose and hyperglycemia[11]. It also regards as a good source for growth of cariogenic microorganism in mouth such as *Streptococcus mutans* and *Lactobacillus plantarum*, thus causing problems with dental decay[7]. In order to avoid these problems, sugar substitutes; acesulfame-K and aspartame, are introduced because of their high sweetness (200 times of sucrose sweetness), low-pH and storage stability, prevention of tooth decay, non-cariogenic effect and safety for consumption[9, 10]. In high concentrations, acesulfame-K may produce a bitter of metallic residual flavor, while aspartame presents a flavor similar to that of sucrose with no unpleasant aftertaste. The acceptable daily intake (ADI) value of acesulfame-K is 15 mg/kg body weight, while that of aspartame is 50 mg/kg body weight[13]. It has been observed that the combination of acesulfame-K and aspartame presents a synergistic effect to maximize the sweetness power and profile of the products[6].

A preserved mango, one of processed mangoes, has been extensively consumed in many Asian countries. This product is obtained by concentrating mango slices with sugar until reaching the adequate concentration (40°Brix). However, the demand for this product is limited by the presence of high sugar content which has been subjected to health problems. Effort has been made in my previous study for use of acesulfame-K and aspartame to replace about 30% of sugar content in syrup used for concentrating the sweetness of products; and that, reduced-sugar preserved mangoes with aspartame and a combination of acesulfame-K and aspartame (1:1) were considered as acceptable products[1]. Therefore, this work aimed to determine changes of physical, sensory and microbial characteristics of reduced-sugar preserved mangoes with acesulfame-K and/or aspartame during the storage time at 4-5°C for 6 weeks. Also, the consumer preference for reduced-sugar products were investigated.

MATERIALS AND METHODS

Materials: Mangoes (*Mangifera indica* L.cv.Kaew) and brown sugar were purchased from a local supermarket. Food grade commercial sugar substitutes used were acesulfame-K and aspartame, which obtained from SIC LIMITED, Thailand as well as analytical grade

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calcium hydroxide, sodium chloride and citric acid were used.

Preparation of Preserved Mangoes: The mangoes were classified by using 3% brine solution to obtain mangoes with specific gravity in the range of 1.0-1.02. After manual operation of washing, peeling and slicing, sliced mangoes were soaked in 0.5% citric acid solution for 20 min, washed, soaked in 0.5% calcium hydroxide solution for 1 h, washed, and then let them in 10% sodium chloride solution for 24 h. The 1-kg of each mango slices were washed and packed in glass bottles, with the capacity of 1,000 mL, and then filled with 35°Brix syrup and let stand for 24 h. After that, the syrup was poured out, and filled with new 40°Brix syrup and let stand for 24 h. The preserved mangoes were packed in 100% polypropylene bags and kept at 4-5°C. The proportion of mango to brown sugar used was 1 kg:680 g.

The control preserved mango was prepared by using brown sugar as a sweetener, while reduced-sugar samples were prepared by substituting 30% of brown sugar with their equivalent in low-calorie sweetener, maintaining the original sweetness. The equivalent of acesulfame-K and aspartame (200 times of sucrose sweetness) was calculated at 5 g/kg of sugar. The storage time for control and reduced-sugar preserved mangoes was studied at refrigerated (4-5°C) for 0, 2, 4 and 6 weeks.

Physical and Chemical Analysis:

Proximate Analysis: The preserved mangoes were homogenized to make the sample for analysis. Moisture content, protein and lipid were determined according to AOAC procedures[3].

Total Sugars, Reducing Sugar and Non-reducing Sugar: These were determined by the method of AOAC[3].

pH: The mango (10g) was homogenized in 100 mL of distilled water. The pH of mangoes was measured by a pH-meter (model 320, Mettler-Toledo Ltd.,Essex, UK).

Color: The mango color was determined by using a Hunter Lab digital colorimeter (model D25M, Hunter Associates Laboratory, Reston, VA). The L* (lightness) was recorded for 5 samples per batch.

Texture: The Lloyd texture analyser (model LRX, Lloyd Instruments, Hampshire, UK) with 100 N load cell, and crosshead speed 250 mm/min was used for texture determination. Five samples were evaluated for peak force (N) using a cutting-test cell.

Water Activity: The mangoes were determined for water activity (Aw) by using an Aqua Lab device (model CX2, Decagon Device, Pullman, WA).

Caloric Value: The total caloric value was calculated from the results obtained in the chemical analysis for the energy component: total sugars, protien and lipid.

Sensory Evaluation: Ten undergraduate students at University of the Thai Chamber of Commerce (UTCC) were selected to be panelists based on participant interest and discriminative ability. Panelists were trained before initiation of the experiment by using different concentrations of sucrose and citric acid for absolute threshold, ordering and ranking. Sensory attributes for color, appearance, texture, sweetness, flavor and sourness were evaluated by using 13-cm unstructured line scale test. Besides this test, the consumer preference was conducted on a ranking test (1 = most preferred, 4 = least preferred) by using 100 untrained panelists. Panelists were not allowed to give equal acceptance ranks to samples. All testing sessions were held in UTCC sensory evaluation laboratory with partitioned booth. Unsalted cracker, apple juice and distilled water were provided to rinse the palate between samples[8].

Microbiological Analysis: Samples of 10g (week 0, 2, 4, and 6) were aseptically weighed and placed in a stomacher bag containing 90 mL of sterile 0.1% peptone (Difco) diluent and pumneled for 1 min with a Stomacher-400 (Tekmar Company, Cincinnati, OH). Aerobic plate count, yeast and mold were determined in this work. The serial (1:10) dilution of sample homogenates were spread plated onto Petrifilm® and incubated at 35°C for 48 h before aerobic counting and at 25°C for 5 days for yeast and mold determination.

Statistic Analysis: Data were evaluated by analysis of variance (ANOVA) using Statistical SPSS for Window version 11.0. When ANOVA showed a significant effect at a level of 5%, treatment means were compared using the Duncan's new multiple range test[4].

RESULTS AND DISCUSSION

Physical and Chemical Analysis: As shown in Table 1, there were significant differences ($p < 0.05$) for all physical and chemical properties, except for pH, acidity and water activity, among control and reduced-sugar preserved mangoes prepared with acesulfame-K, aspartame and a combination of both sugar substitutes (1:1) on each same time and over 6 weeks of storage. With respect to moisture content, there was no significant difference ($p > 0.05$) among all formulations on any time of storage. For protein and fat content, the formulations showed slight differences after the sixth week of storage.

The tendency for changes of the total sugars, reducing sugars and non-reducing sugars were evident. The control formulation exhibited the highest degradation of total sugars, which reflected on the highest alterations of reducing and non-reducing sugars during storage period. Each formulation tended to exhibit a significant increase ($p < 0.05$) of reducing sugars, due to the degradation of sucrose to glucose and fructose, with a consequent significant decrease ($p < 0.05$) in non-reducing sugars over the storage time[12]. It was observed that reduced-sugar formulations were significantly lower ($p < 0.05$) in total sugars, reducing and non-reducing sugars than those of the control formulation on each time of storage.

For color determination, the control formulation showed lower L*-value (lightness) on every each time of storage than reduced-sugar formulations, probably because of its high sugar content which participate in Maillard reaction, resulting in brown color to develop[12]. When considering texture determination, there was no significant difference ($p <0.05$) among all formulations.

Each formulation of preserved mangoes, when analysed during 6 weeks of storage with respect to physical and chemical properties, presented a slight variation in the results, except for reducing sugars which showed a significant increase ($p < 0.05$) with a consequent significant decrease ($p < 0.05$) in non-reducing sugars. Also, L*-values (lightness) decreased, this behavior is associated with non-enzymatic browning by Maillard reaction, which defines highly the perception of panelists (Table 2).

Sensory Evaluation: As shown in Table 2, the results obtained at time zero (0) and 2 weeks of storage exhibited no evidence of a significant difference ($p < 0.05$) in all sensory attributes among the 4 formulations. After the fourth week of storage, the control formulation presented lower ($p < 0.05$) scores for texture and flavor than reduced-sugar formulations, being considered as less crispy texture and slightly fermented flavor which affected panelists' acceptance, resulting in a decrease in sensory scores.

On the sixth week of storage, there were significant differences ($p < 0.05$) in color, texture and flavor between control and reduced-sugar formulations. It can be seen that the color score of control formulation was significantly lower ($p < 0.05$) than that of reduced-sugar formulations, indicating that darker color resulted from more sugar content involving in Maillard reaction was evident[2]. All reduced-sugar formulations presented higher scores for texture ($p < 0.05$) than that of the control, being considered as more crispy texture. For flavor attribute, the control showed significantly lower ($p < 0.05$) flavor scores than reduced-sugar formulations after the fourth week; moreover, both control and the formulation with acesulfame-K were the lowest preference after the sixth week. This could be possibly due to the much more sugar content in the control formulation, which participate in yeast fermentation, producing fermented flavor and unpleasant bitter metallic aftertaste of acesulfame-K[9]. However, the formulation with a mixture of acesulfame-K and aspartame (1:1) was acceptable similar to that with aspartame alone, implying that aspartame seemed to minimize the metallic aftertaste of acesulfame-K.

According to the sensory evaluation throughout 6 weeks of storage, each formulation exhibited significant differences ($p < 0.05$) for some sensory attributes such as color, texture and flavor, while other attributes exhibited no significant alterations ($p > 0.05$) during storage. The color of control formulation showed significantly change ($p < 0.05$) to darken color on the fourth week of storage, probably because of higher sugar content contributing to Maillard reaction, while reduced-sugar formulations exhibited similar changes after the sixth week of storage. This can be confirmed by the instrumental color determination (Table 1), showing a decrease in L*-values during storage. After the sixth week of storage, all formulations presented less crispy texture, indicating that hygroscopic effect of sugar involved the absorption of moisture from the atmosphere, making the product softer.

It was also evident that the control and the formulation with acesulfame-K showed lower scores for flavor than the others after the sixth week of storage. This result indicated a severe flavor alteration, which came from the yeast fermentation and a metallic flavor of acesulfame-K[9]. Aspartame has been noted to taste like sugar, have a clean, quickly perceptible sweet taste and does not have the unpleasant afterteste like acesulfame-K[6] ; therefore, the formulation with aspartame alone and a combination of acesulfame-K and aspartame (1:1) were considered more acceptable than the control and the formulation with acesulfame-K alone. Moreover, there were no significant differences ($p < 0.05$) for sweetness in all formulations throughout storage time, showing that both acesulfame-K and aspartame were stable.

Microbiological Analysis: The microbiological quality of preserved mangoes is shown in Fig. 1 shows that microbial counts in all formulations tended to increase during refrigerated storage. After the fourth week of storage, the total aerobic count determined in control

Table 1: Physical and chemical properties of control and reduced-sugar preserved mangoes during storage

Physical/Chemical properties	Storage time (weeks) 0: Co[1]	Ac[2]	As[3]	Ac+As[4]	2: Co	Ac	As	Ac+As
pH^{ns}	3.18	3.23	3.13	3.33	3.12	3.20	3.18	3.19
Acidity(%citric acid) ^{ns}	0.17^{Aa}	0.19^{Aa}	0.21^{Aa}	0.22^{Aa}	0.19^{Aa}	0.23^{Aa}	0.24^{Aa}	0.20^{Aa}
Moisture (%)	72.43^{Ab}	71.36^{Ab}	73.12^{Ab}	70.09^{Ab}	72.56^{Ab}	71.89^{Ab}	72.84^{Ab}	73.15^{Aa}
Protein (%)	0.81^{Aa}	0.64^{Bb}	0.73^{Aa}	0.78^{Aa}	0.75 ^{Ab}	0.79^{Aa}	0.81^{Aa}	0.69 ^{Ba}
Fat (%)	0.84 ^{Aa}	0.90 ^{Aa}	0.80 ^{Ba}	0.82 ^{Ba}	0.78 ^{Ab}	0.85 ^{Aa}	0.85 ^{Aa}	0.84 ^{Aa}
Total sugar (% glucose)	18.13 ^{Aa}	12.55 ^{Ba}	13.03 ^{Ba}	12.34 ^{Ba}	17.28 ^{Ab}	12.09 ^{Bb}	12.63 ^{Ba}	11.92 ^{Bb}
Reducing sugar (% glucose)	2.82 ^{Ac}	1.59 ^{Cd}	1.73 ^{BCd}	2.02 ^{Bc}	4.39 ^{Ab}	2.82 ^{Bc}	2.95 ^{Bc}	2.46 ^{Bc}
Nonreducing sugar (% sucrose)	15.31 ^{Aa}	14.14 ^{Ba}	11.30 ^{Ca}	10.32 ^{Ca}	12.89 ^{Ab}	9.27 ^{Bb}	9.68 ^{Bb}	9.46 ^{Bb}
Water activity(Aw) ^{ns}	0.96	0.97	0.97	0.97	0.96	0.97	0.97	0.97
Color as L*	31.44 ^{Ba}	32.64 ^{Aa}	33.50 ^{Aa}	33.25 ^{Aa}	31.95 ^{Bab}	31.83 ^{Aa}	32.80 ^{Aa}	32.65 ^{Aa}
Peak force (N)	6.91 ^{Ab}	6.64 ^{Ab}	6.77 ^{Ab}	6.70 ^{Ab}	6.74 ^{Aa}	7.11 ^{Ab}	7.24 ^{Ab}	6.64 ^{Ab}

Physical/Chemical properties	Storage time (weeks) 4: Co	Ac	As	Ac+As	6: Co	Ac	As	Ac+As
pH^{ns}	3.22	3.18	3.25	3.25	3.13	3.21	3.22	3.21
Acidity (%citric acid)	0.22^{Aa}	0.29^{Aa}	0.23^{Aa}	0.21^{Aa}	0.25^{Aa}	0.25^{Aa}	0.29^{Aa}	0.30^{Aa}
Moisture (%)	71.63^{Ab}	72.11^{Aa}	72.71^{Ab}	69.78^{Ab}	73.55^{Aa}	73.98^{Aa}	74.69^{Aa}	73.44^{Aa}
Protein (%)	0.72^{Ab}	0.79^{Aa}	0.77^{Aa}	0.71^{Aa}	0.85 ^{Aa}	0.61^{Cb}	0.70^{Ba}	0.74 ^{Ba}
Fat (%)	0.85 ^{Aa}	0.79 ^{Aa}	0.81 ^{Aa}	0.77 ^{Aa}	0.84 ^{Aa}	0.90 ^{Aa}	0.79 ^{Ba}	0.82 ^{Ba}
Total sugar (% glucose)	17.46 ^{Ab}	11.82 ^{Bb}	12.22 ^{Bb}	11.82 ^{Bb}	17.35 ^{Ab}	11.97 ^{Bb}	12.08 ^{Bb}	11.86 ^{Bb}
Reducing sugar (% glucose)	4.79 ^{Ab}	3.18 ^{Bb}	3.48 ^{Bb}	3.62 ^{Bb}	6.61 ^{Aa}	4.53 ^{Ca}	4.87 ^{BCa}	5.11 ^{Ba}
Nonreducing sugar (% sucrose)	12.67^{Ab}	8.64^{Bc}	8.74 ^{Bc}	8.20 ^{Bc}	10.74 ^{Ac}	7.44 ^{Bb}	7.21 ^{Bb}	6.75 ^{Cd}
Water activity(Aw) ^{ns}	0.95	0.97	0.97	0.97	0.97	0.98	0.99	0.99
Color as L*	28.02 ^{Bb}	29.50 ^{Ab}	28.80 ^{Bb}	31.42 ^{Ab}	27.15 ^{Bc}	27.70 ^{Bc}	28.05 ^{Bb}	30.74 ^{Ab}
Peak force (N)	7.00 ^{Aa}	7.15 ^{Aa}	7.32 ^{Aa}	7.15 ^{Aa}	7.18 ^{Aa}	7.24 ^{Aa}	7.27 ^{Aa}	7.25 ^{Aa}

^{A,B,C} Means in the same row with different capital letters are different ($p < 0.05$) among the different formulations at the same time of storage.
^{a,b,c,d} Means in the same line with different lower cases are different ($p < 0.05$) among the different times of storage for the same formulation.
ns = non-significant.
Control (Co) = 100% sugar used, and Ac, As and Ac+As are the 30% sugar replacement with acesulfame-K, aspartame and a combination of acesulfame-K and aspartame (1:1) for preserved mangoes, respectively.

and reduced-sugar formulations with acesulfame-K, aspartame and a combination of acesulfame-K and aspartame (1:1) were lower the standard level of 1 x 10^4 CFU/g; however, they were over the standard value on the sixth week. For yeast and mold counts, all values were below the standard level of 100 CFU/g[15]. It can be seen that the microbiological safe for reduced-sugar preserved mangoes was only 4 weeks, probably because of no preservative used in this work.

Consumer Preference: Fig. 2 presents the result of consumer preference on control and reduced sugar preserved mangoes. For the sum of orders, a value for 1 was considered as the most favorite and a value of 4 as the least favorite. The product with a mixture of acesulfame-K and aspartame (1:1) presented the least total rank, which meaned the most favorite. Panelists did not like the formulation with acesulfame-K alone, because of bitter metallic aftertaste[13]; therefore,

Table 2: Sensory scores of control and reduced-sugar preserved mangoes during storage

	Storage time (weeks)							
Attributes	0				2			
	Co[1]	Ac[2]	As[3]	Ac+As[4]	Co	Ac	As	Ac+As
Color	7.3 ^{Aa}	7.1 ^{Aa}	7.1 ^{Aa}	7.8 ^{Aa}	7.1 ^{Aa}	7.1 ^{Aa}	7.2 ^{Aa}	7.6 ^{Aa}
Appearance ^{ns}	7.2	7.2	7.2	7.4	7.2	7.1	7.2	7.3
Texture	7.9 ^{Aa}	7.1 ^{Aa}	7.6 ^{Aa}	7.8 ^{Aa}	7.5 ^{Aa}	7.2 ^{Aa}	7.1 ^{Aa}	7.1 ^{Ab}
Sweetness ^{ns}	7.3	6.8	6.6	6.9	7.3	7.1	6.8	6.7
Flavor	6.9 ^{Aa}	6.5 ^{Ab}	6.9 ^{Aa}	6.9 ^{Aa}	7.4 ^{Aa}	7.0 ^{Aa}	7.0 ^{Aa}	6.9 ^{Aa}
Sourness ^{ns}	5.6	6.1	5.5	6.0	5.9	5.8	5.9	6.1
	Storage time (weeks)							
Attributes	4				6			
	Co	Ac	As	Ac+As	Co	Ac	As	Ac+As
Color	6.1 ^{Ab}	6.8 ^{Aa}	6.9 ^{Aa}	7.1 ^{Aa}	5.8 ^{Bb}	6.2 ^{Ab}	6.3 ^{Ab}	6.6 ^{Ab}
Appearance ^{ns}	6.9	6.8	7.1	7.3	7.1	6.7	6.9	7.2
Texture	6.6 ^{Bb}	7.4 ^{Aa}	7.0 ^{Ab}	7.2 ^{Ab}	6.5 ^{Bb}	6.9 ^{Aa}	6.9 ^{Ab}	6.7 ^{Ab}
Sweetness ^{ns}	6.9	7.2	6.8	6.9	7.1	6.8	6.6	6.9
Flavor	6.0 ^{Bb}	6.5 ^{Ab}	6.7 ^{Aa}	7.1 ^{Aa}	4.2 ^{Bc}	4.4 ^{Bc}	5.4 ^{Ab}	5.5 ^{Ab}
Sourness ^{ns}	5.9	5.7	6.1	5.9	5.8	5.2	5.9	5.9

^{A,B} Means in the same row with different capital letters are different ($p < 0.05$) among the different formulations at the same time of storage. ^{a,b,c} Means in the same line with different lower cases are different ($p < 0.05$) among the different times of storage for the same formulation. ns = non-significant.

*Control (Co) = 100% sugar used, and Ac, As and Ac+As are the 30% sugar replacement with acesulfame-K, aspartame and a combination of acesulfame-K and aspartame (1:1) for preserved mangoes, respectively.

**Based on a 13–cm unstructured line scale test : Color (0 = dark, 10 = pale), appearance (0 = poor, 10 = good), texture (0 = crisp, 10 = tough), sweetness /flavor/sourness (0 = weak, 10 = strong).

Table 3: Chemical composition and caloric content of reduced-sugar preserved mangoes

Chemical composition	Co	Ac	As	Ac + As
Total sugars	17.35 ^{a}	11.97 ^{b}	12.08 ^{b}	11.86 ^{b}
Protein	0.85 ^{a}	0.61 ^{b}	0.70 ^{b}	0.74 ^{ab}
Fat	0.36 ^{b}	0.90 ^{a}	0.79 ^{a}	0.82 ^{a}
Caloric value (Kcal/100g)	76.04	58.42	58.23	57.78

^{a,b} Means in the same row different superscripts are different ($p < 0.05$).

Control (Co) = 100% sugar used, and Ac, As and Ac+As are the 30% sugar replacement with acesulfame-K, aspartame and a combination of acesulfame-K and aspartame (1:1) for preserved mangoes, respectively.

aspartame combined with acesulfame-K presented only a slight advantage over acesulfame-K alone for use in preserved mangoes.

Nutritional Evaluation: As sugar content decreased, energy content declined (Table 3). This result supported findings of Mendonca et al.[8] who reported calorie reduction positively correlated with sugar reduction. In this study, all reduced-sugar preserved magoes were considered nutritious because the composition of about 100g would provide approximately less than 30.4-31.6% of sugar and the total caloric value reduction was about 23.2-24% in relation to 100g of the control preserved mango.

Conclusion: The control and 30% reduced-sugar preserved mangoes made with acesulfame-K, aspartame and a mixture of acesulfame-K and aspartame (1:1) showed a slight variation on physicochemical and sensory properties during 6 weeks of storage at 4-5°C, although showing a partial degradation of sugars which related to darken color. The panelists indicated acceptable qualities of the formulations after the fourth week of storage. The combination of acesulfame-K and aspartame (1:1) provided the best preferable 30% reduced-sugar preserved mango, which exhibited about 24% of total caloric reduction as compared with the control.

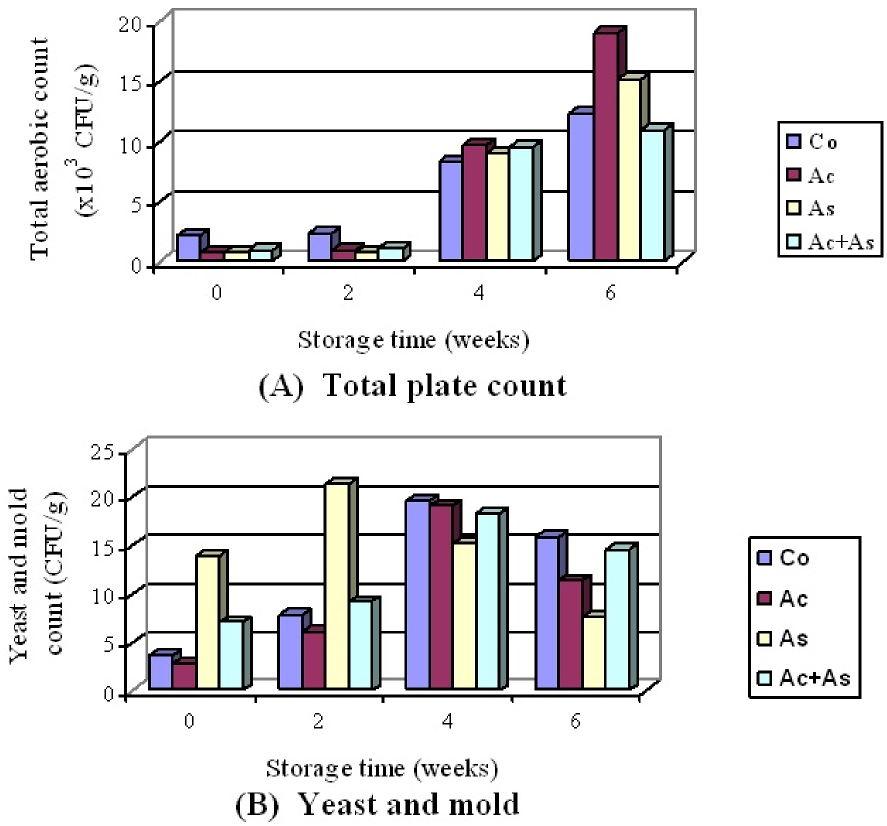

Fig. 1: Microbiological counts in reduced-sugar preserved mangoes during storage time at 4-5°C for 6 weeks: Control (Co) = 100% sugar used, and Ac, As and Ac+As are the 30% sugar replacement with acesulfame-K, aspartame and a combination of acesulfame-K and aspartame (1:1) for preserved mangoes, respectively.

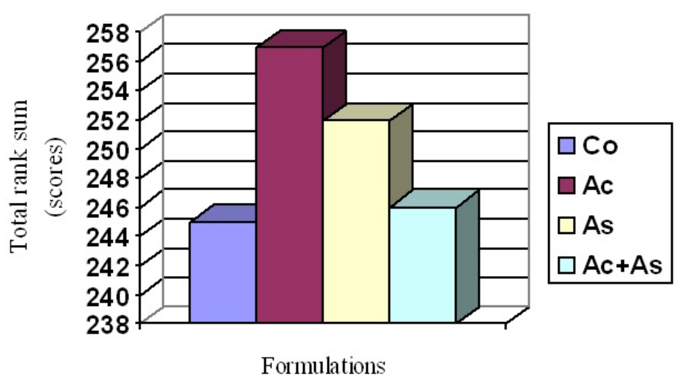

Fig. 2: Consumer preference of reduced-sugar preserved mangoes. Control (Co) = 100% sugar used, and Ac, As and Ac+As are the 30% sugar replacement with acesulfame-K, aspartame and a combination of acesulfame-K and aspartame (1:1) for preserved mangoes, respectively.

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