

Effect of partial replacement of sucrose with the artificial sweetener sucralose on the physico-chemical, sensory, microbial characteristics, and final cost saving of orange nectar

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Abstract: This study is aimed to produce economical and high quality orange nectar by partial replacement of sucrose with an equivalent sweetness from the safe artificial sweetener sucralose. Using different ratios from sucrose and sucralose at concentrations equivalent to sucrose sweetness in the final orange nectar affect significantly ($p < 0.05$) the total soluble solids (Brix) and viscosity (cp) but does not affect other physico-chemical properties or microbial counts in all treatments compared to the control nectar (10% sucrose). The control orange nectar Brix was 14.3°Brix, while in T₁ (7.5% sucrose: 0.005% sucralose), T₂ (5.0% sucrose: 0.01% sucralose) and T₃ (2.5% sucrose: 0.015% sucralose) nectars the Brix was decreased to 11.3, 8.5 and 5.5° Brix, respectively. Viscosities of nectars were reduced from 6.6 cp in control to 6.0, 5.3 and 3.2 in T₁, T₂ and T₃, respectively. The average ratings given by panelists for the sweetness, odor and taste of T₁ nectar were more accepted (higher ratings) than T₂ and T₃. No differences were found in T₂ and T₃ taste, but the odor and sweetness of T₂ nectar was given higher ratings than T₃. The use of 86 kg (75%) of sucrose from the original amount (115 kg sucrose) usually used in production of one ton of orange nectar and 0.05 kg from sucralose (T₁) was found to be the best combination in reduction of orange nectars production cost without drastic changes in sensory and physico-chemical characteristics, and consistent with Jordanian standards for orange nectars.

Keywords: Orange nectar, sucralose, splenda, physico-chemical tests, sweetener

Introduction

Sucrose from sugar cane or sugar beets has been a part of the human diet for centuries and its sweet taste is a natural preference by humans (Grotz, and Munro, 2007). Sucrose has many important properties other than sweetener in food industry such as preservatives, enhancing and bringing out the characteristics of other flavoring ingredients, provides bulk and colloidal osmotic pressure in food, and influences the physical properties of food. However, sucrose has posed significant technological problems in certain applications like the hydrolysis in acidic systems which may resulted in changing the sweetness and flavor characteristics of the product, and it must be dissolved in water before use in many applications (Hallfrisch, 1983).

In many studies different alternative sugars have been used in food industries due to the growing concern about people's intake of sugar and nutritionist recommendation to reduce the intake of sucrose (Ludwig *et al.*, 2001; Parpinello *et al.*, 2001; Schulze *et al.*, 2004; Sun and Empie, 2007; Rodbotten *et al.*, 2009). Glucose syrups and high fructose corn syrups (HFCS) proved themselves as alternative to sucrose in liquid applications because they are stable in acidic

foods and beverages (Saenz *et al.*, 1998; Fulgoni, 2008), but due to their high initial prices and shipping costs (syrups provided in barrels) makes their uses infeasible. Recently, most of food industries are using sugar blends from sucrose, glucose, fructose, sorbitol and artificial sweeteners to reduce both sugar and caloric content (Nabros, 2002; Meyer, 2002; Cardoso and Bolini, 2007; Rodbotten *et al.*, 2009). Although, artificial sweeteners were used wholly or partly in different food industries, but due to safety issues, objectionable aftertaste and their need to additional ingredients to match one or more of other attributes of sucrose, make complete replacement of sucrose with alternative sweeteners in juice industry associated with some of the technological and legislative problems. Thus, combining artificial sweeteners (partial) with sucrose may prove the best combination in keeping quality, cost reduction and low caloric juice production.

Sucralose is a non-nutritive sweetener produced by substitution of three atoms of chlorine for three hydroxyl groups in sucrose (Jenner, 1989). Studies show that sucralose is safe, poorly absorbed, intensely sweet (600 times sweeter than sucrose), does not have the bitter aftertaste, highly stable at elevated temperatures and has excellent stability in acidic

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products (Jenner, 1989; Horne *et al.*, 2002; kuhn *et al.*, 2004; Grotz, and Munro, 2007) which make it an ideal sweetener for both beverage manufacturers and consumers.

In Jordan, orange juices and nectars are the most preferred and consumed fruit juices. The ideal concentration of soluble solids considered by the consumers is 14% and for legislation authority (Jordanian standards and metrology) is not less than 11° Brix for juices or nectars. The aim of this study was to produce high quality orange nectar using different combinations from sucrose and sucralose in order to reduce the final production cost without affecting the physico-chemical characteristics and meet the Jordanian standards for the produce. The produce is expected to be of high economical and nutritional values.

Materials and Methods

Orange nectar processing

Orange nectar is prepared by dissolving sucrose (115 kg) in clean drinking water (850 liters) with citric acid (2 kg), pectin (350 g), vitamin c (100 g), β -carotene (10-20 g) and orange flavors (syrup). The orange juice concentrated base (45 kg of 60%) was hydrated and mixed with sugar syrup following the manufacturer's recommendations (Figure 1) for production of one ton of orange nectar (25% natural juice). The final total solids were measured at this step to assure brix value (14° Brix). Finally, the mixture is pasteurized at 90°C for 3 min, homogenized and filled aseptically hot in 250 ml glass bottles.

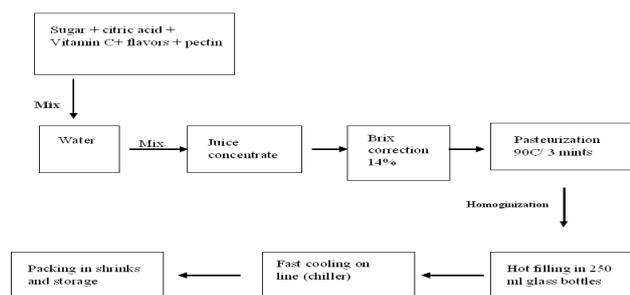


Figure 1. Processing scheme of orange nectar

Formulation of sugar substitute

Orange nectar samples were prepared in juice company (Allotus company, Amman, Jordan) following the procedure used by the manufacturer from unsweetened concentrated juice. The samples were sweetened with different ratios from sucrose and sucralose to give the sweetness that is considered ideal by the manufacturer (14°Brix). SPLENDA® type sucralose artificial sweetener was used in this study as sucrose substitute. This sucralose is 600

times sweeter than sucrose. The relative amounts of sucralose needed for orange nectar production were determined to create the same degree of sucrose sweetness in the final nectars. Four different sugars blend from sucrose and sucralose (sucrose: sucralose) were used for adding sweetness to orange nectars composed as follows: 10.0%: 0 (control), 7.5%: 0.005% (T₁), 5.0: 0.01% (T₂) and 2.5%: 0.015% (T₃).

Methods of analysis

Total soluble solids content (Brix) was measured with Abbe refractometer at 20°C. Acidity was determined by titration with 0.1 N NaOH and expressed as percent of citric acid using phenolphthalein as the indicator. The pH was measured with a Fisher pH meter (Model 210, Fisher). The viscosity (cps) was determined in a Brookfield viscometer (20°C, spindle No 1 at 50 rpm). For the microbial counts, samples were serially diluted, plated in total count agar (Plate count Agar, Merck, Germany) for total counts, and in acidified potato dextrose agar (Potato Dextrose Agar, Merck, Germany) for mold and yeast counts. Plates were incubated at 30°C for 48 h for total count and 5 days for molds and yeast. All the analytical measurements were done in triplicate.

Sensory analysis

The relative sweetness (sucrose like sweetness), taste (flavour related to fruity acid) and odor (fresh and fruity orange odor) of different sugar formulations in orange nectars were determined by rating the preferred sample from 1-10 in comparison with the normally produced orange nectar (control). Water was used for cleansing palates. The panel was composed of ten untrained persons working in the factory and familiar with the company produced juices and nectars. The samples were presented in a transparent glass at room temperature (20°C).

Statistical analysis

Data in triplicate were analyzed using statistical analysis system, SAS program (SAS Institute Inc., Cary, NC, USA). Significant differences among means of treatments were determined using LSD test. Differences at $P < 0.05$ were considered to be significant.

Results and Discussion

Effect of different treatments on the physico-chemical and microbial characteristics of orange nectars

The effects of using different ratios of sucrose and sucralose on the physical and chemical properties of

Table 1. Effect of different ratio from sucrose and sucralose on the physico-chemical and microbial characteristics of orange nectars

Characteristic	Control	T ₁	T ₂	T ₃
pH	3.36 ± 0.05 ^a	3.36 ± 0.04 ^a	3.38 ± 0.04 ^a	3.37 ± 0.04 ^a
Titration acidity (%)	0.42 ± 0.03 ^a	0.35 ± 0.02 ^b	0.38 ± 0.02 ^{ab}	0.39 ± 0.02 ^{ab}
°Brix	14.3 ± 0.2 ^a	11.3 ± 0.1 ^b	8.5 ± 0.2 ^c	5.5 ± 0.2 ^d
Viscosity (cp)	6.6 ± 0.1 ^a	6.0 ± 0.2 ^b	5.3 ± 0.2 ^c	3.2 ± 0.2 ^d
Molds and yeast (cfu/ml)	< 1 cfu/ml	< 1 cfu/ml	< 1 cfu/ml	< 1 cfu/ml
Total Plate Counts (cfu/ml)	< 1 cfu/ml	< 1 cfu/ml	< 1 cfu/ml	< 1 cfu/ml

^a Values are the means of triplicate measurements. Values in the same row followed by different letters are significantly different (P < 0.05).

the produced orange nectars are shown in Table 1. All measurements carried out directly after processing. There were no significant differences in pH and microbial counts between treated samples and control. In spite of significant differences in the titration acidity measurements it can be considered negligible since all treatments (except T₁) measurements are not different from control, and T₁ is not significantly different from other treatments. Significant differences were detected in Brix degree and viscosity of samples according to the treatment.

The control juice Brix was 14.3°Brix (14.3%), while in T₁, T₂ and T₃ was decreased to 11.3, 8.5 and 5.5% respectively. The replacement of large proportion of sucrose with low amount of sucralose results in the reduction of nectars Brix in all treatments and this reduction is proportional to the amount of sucrose replaced by sucralose. Jordanian standards specify 11 Brix as the minimum degree for natural juices or nectars production, thus only the control and T₁ nectars were fallen within this specifications.

The viscosities of different nectar treatments were significantly different from control. The decrease in the viscosity was increased by increasing the replaced amount of sucrose with sucralose across all treatments. The replacement of large proportion of sucrose with low amount of sucralose produced a decrease in the viscosity of nectars and this reduction in viscosity is proportional to the decreases in the produced nectars water activities. Benitez *et al.* (2008) showed that specific viscosity of a colloidal dispersion of solids in syrups is increased by increasing particle-sugar interactions and by lowering the water activity of syrups.

Effects of different treatments on microbial flora of orange nectars

Citrus juices are the most susceptible to yeast spoilage, owing to their low pH and high contents of sugars and vitamins (Kimball, 1999; Rivas *et al.*, 2006). The microbial spoilage of juice products may lead to off-flavors, odors, turbidity and gas production (Jay and Anderson, 2001). The effect of sucrose partial substitution with sucralose on the total plate counts and yeast and mold flora in the produced orange nectars after pasteurization is shown in Table 1. The population levels of both aerobic bacteria, and

yeast and mold were below the detection limit in all treatments (<1 cfu/ml) directly after pasteurization and hot filling of nectars. There are many studies showing that pasteurization alone is not efficient in inactivation of microbial flora of juices under different storage conditions (Ayhan *et al.*, 2001; Min *et al.*, 2003; Mehmood *et al.*, 2008). This study showed that hot filling of the pasteurized nectars and acidic medium are efficient in the elimination of tested microbe's growth directly after processing. However, the growth of juice flora may occur during storage due to the decrease in juices pH (Mehmood *et al.*, 2008).

Effects of different treatments on sensory analysis

Figure 2 shows the average ratings given by the judges for different sensory characteristics of orange nectars.

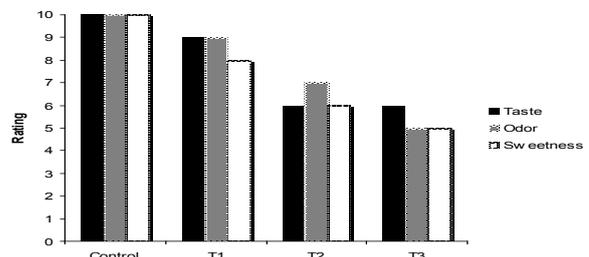


Figure 2. Results of the sensorial analysis comparing taste, odor and sweetness of treated samples with the untreated nectar control

Control nectar made from sucrose was found to be the most acceptable by securing highest score during sensory evaluation. The odor, sweetness and taste of T₁ sample was more accepted (higher ratings) than T₂ and T₃. No differences were found in T₂ and T₃ taste, but odor of T₂ sample was given higher ratings than T₃. The degree of sweetness in all treated samples was decreased by increasing the partial substitution of sucrose, this may due to the slightly bitter taste detected due to the replacing of sucrose with sucralose in different treatments. Treatments with lower sucrose contents were perceived as most bitter (T₃) and the least bitter samples were high in sucrose content. This finding is in agreement with studies reported by Rodbotten *et al.* (2009) and Kerutzmann *et al.* (2008). They have shown that high sucrose content may cover the sensory perception of bitterness. Orange nectars sensory scores in this study suggest that nectars with

Table 2. Relative amounts of sucrose and sucralose needed for the production of one ton of orange nectars and their relative costs

	100% sucrose (control)	T ₁ 75%:50g	T ₂ 50%:100g	T ₃ 25%:150g
Amount of sugar used for production of one ton of orange nectar (kg)	115	86	58	29
Cost of sucralose used for production of one ton orange nectars (US \$) ^a	0.0	7.5	15.0	22.5
Total cost of sugar with or without partial replacement of sucralose used (US \$)	115.0	93.8	72.5	51.3
Total cost of one ton sugar with or without partial replacement of sucralose (US \$)	1000.0	812.5	625.0	437.5
Cost saving from using sucralose as partial replacement in 1 ton of sucrose (US \$)	0	187.5	374.5	562.5
Cost saving (US \$) in one month (average uses of sugar is 2 tons / day) at Allotus company	0	11250.0	22470.0	33750.0

^aCost of one ton sucrose is 1000 US \$ and cost of 1kg sucralose (SPLENDA® type) is 150 US \$ at the time of carrying out this study.

the higher sucrose content can enhance sweetness, taste and odor and these attributes were getting lower rating by increasing the partial substitution of sucrose with sucralose in the studied orange nectars.

Relative cost of different sugar treatments in orange nectar production

Table 2 gives estimates of the relative cost of sweetness provided from using sucrose alone and from different ratios from sucrose and sucralose for production of one ton of orange nectars. The results suggest that the partial replacement of 25% of sucrose with sucralose to give an equivalent sweetness for orange nectar can reduce the cost of final nectar by around 11250.0 US \$/ month if only 2 tons of sucrose are used daily and the processed orange nectar meets the Jordanian specifications and comparable to the control nectar produced from sucrose only in all quality indicators.

Conclusions

This research has resulted in the establishment of the best ratios from sucrose and artificial sweetener sucralose for commercial production of safe, high quality and low cost orange nectars that meet Jordanian specifications and market demand. There was no real difference in some of the physico-chemical characteristics (pH, titrable acidity) of partially replaced sucrose in T₁ nectar and untreated orange nectars. The sensory and microbial qualities remained almost unchanged and acceptable for control and T₁ nectars.

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