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Production and Evaluation of Low-Calorie Pomegranate Juice with Sucralose

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LIMITING the consumption of high-calorie foods and juices of many consumers in different ages to avoid many diseases such as diabetes, obesity, tooth decay, heart diseases, and arteriosclerosis, is an important issue and challenge for nutritionists and the food industry. Therefore, the aim of this study was to produce a low-calorie pomegranate juice by replacing sucrose with sucralose at different levels. Five low-calorie pomegranate juice formulae were prepared mainly from pomegranate pulp then sweetened using sucrose and replaced with sucralose (Su) (25, 50, 75, and 100%) and evaluated for the physicochemical and sensory properties of the resultant juice during storage period for 6 months at ambient temperature. The obtained results showed that the increase in the replacing levels of the sucralose led to a decrease in the total carbohydrate content and total calories. The results concluded that the use of sucralose as a replacement for sucrose at a level of 50% recorded a high score of sensory evaluation in terms of taste and general acceptance, compared with all the other treatments after 6 months of storage at room temperature. Sensory characteristics indicated that the low calories pomegranate juice had good color, taste, mouth-feel during storage periods.

Keywords: Pomegranate, Low calorie juice, Sucralose.

Introduction

Pomegranate fruits have innumerable health benefits and its implication in disease cure has been widely recognized since ancient time. Pomegranate (*Punica granatum* L.), a South East Asian native, is one of Egypt's most popular fruits. The Punicaceae family includes pomegranate. Because of its high nutritive value, antioxidant potential, bioactive compounds, and consumer palatability, it is referred to as a "super-fruit.". The edible part of the fruit contained a considerable amount of acids, sugars, vitamins, polysaccharides, polyphenols and important minerals (Dhumal et al., 2015). Pomegranate juice contains polyphenols, anthocyanins, vitamins C and E, lipoic acid, and punicalagin, a bioactive constituent that accounts for more than half of the juice's antioxidant activity. Pomegranate juice intake reduced LDL aggregation and retention while also increasing serum paraoxonase activity (Vroegrijk et al., 2011). Daily consumption of pomegranate juice lowered blood pressure in hypertensive subjects, delayed the atherosclerotic process and increased the total antioxidant status of blood. Pomegranate juice has a remarkable ability to decrease oxidative stress by 40–80% and to increase the antioxidant enzymes-paraoxonases by 50–100% (Aviram et al., 2004). Moreover, cholesterol homeostasis is improved by a decrease in LDL total cholesterol levels especially in diabetics (Jurenka, 2008). The fruit of the pomegranate has been used for centuries to treat inflammation, cancer, diabetes, hypertension, infertility, and a variety of other ailments. Because of its high potential, it is now being used in the medical and nutrition industries. Pomegranate polyphenols have anti-proliferative properties and function as solid bases.

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Low-calorie sweeteners (LCS) including aspartame, acesulfame K, saccharin, sucralose, and steviol glycosides are highly sweet compounds of almost no calories that can be used to substitute sugar in food and beverages. When used in place of higher energy ingredients, LCS do not raise appetite and have no discernible impact on satiety. They also help to reduce energy. When used as part of a therapeutic weight loss program, LCS may increase weight loss in real-life situations and can have a beneficial impact on post-prandial glucose and insulin in healthy people and people with diabetes. When used in foods, drinks, toothpaste, and drugs, LCS has dental benefits as long as the other constituents are non-cariogenic and non-erosive (Gibson et al., 2014). 1,6-dichloro-1,6-dideoxy-β-D-fructofuranosyl-4-chloro-4-deoxy-α-D galactopyranoside is the chemical name for Sucralose. Sucralose is a non-nutritive artificial sweetener that is 600 times sweeter than sucrose and, among other things, is very stable at high temperatures (Al-Dabbas & Al-Qudsi, 2012).

Sucralose is approved by the FDA, in 1999, to be utilized in foods, beverages, pharmaceutical products, diets and vitamin supplements (Rodero et al., 2009). Sucralose has no effect on the utilization and absorption of glucose, carbohydrate metabolism, or insulin secretion. As a result, it is a healthy drug that can be consumed by diabetics and does not induce insulin secretion or lower plasma glucose levels. Sucralose is therefore not acidogenic or cariogenic, according to clinical reports (Mandel & Grotz, 2002).

Various unfavorable quality changes occur such as loss of nutritional value, ascorbic acid degradation and reduction of polyphenolic compounds, and undesirable color changes resulting from enzymatic and non-enzymatic browning during processing and storage of fruit juices (Terefe et al., 2014; Moazzem et al., 2019).

The aim of this study was to produce low-calorie pomegranate juice by sucralose as a replacement to sucrose and evaluate the resultant pomegranate juice for some physical-chemical and sensory quality attributes during storage for 6 months on ambient temperature.

Materials and Methods

Materials

Pomegranate (*Punica granatum* L.) fruits namely: Manfalouty were obtained from Manfalut City, Assiut Governorate, Egypt. Sucralose was obtained from (Fine print company) imported by Rebat Company for Food Stuffs Trade, Egypt. Citric acid monohydrate (E330) was obtained from Weifang Insayn industry (Shandong City, china), Xanthan gum was obtained from CP Kelco Germany GmbH, 23755 Grossenbrode, Germany.

Methods

Preparation of formulated low calorie pomegranate juice.

Pomegranate fruits were washed with clean running water to remove dust particles and to reduce the microbial load on the surface of the fruits. Pomegranate fruits were cut into pieces by hand and arils were separated. The juice was extracted from these arils by passing them through a juicer (Braun type: 4290). Muslin cloth was used to filter the extracted juice. Table 1. indicates the five pomegranate juice formulations that were used in this study.

TABLE 1. Formula of low calorie pomegranate juice.

Ingredients (g)	**Level of substitution (%)**				
	T1	**T2**	**T3**	**T4**	T5
	0%	**25%**	**50%**	**75%**	**100%**
Pomegranate pulp	1575	1575	1575	1575	1575
Sucrose	540	405	270	135	___
Sucralose	___	0.225	0.45	0.675	0.9
Xanthan gum	4.5	4.5	4.5	4.5	4.5
Citric acid	2.25	2.25	2.25	2.25	2.25
Water	2385	2385	2385	2385	2385
TOTAL	4506.75	4371.98	4237.20	4102.43	3967.65

The sucralose concentrations were selected taking into account the sucrose concentration of commercial fruit based beverages and the sweetness equivalence sucralose/sucrose.

The mixture of juice and water were heated to 60 °C and sucrose was added, then the blend stirred in a stainless steel kettle. The xanthan gum was dissolved in a small quantity of hot water to prevent the clusters and added to the blend. The blend heated at 80 °C for 15 min then sucralose and citric acid were added (Sindhu and Khatkar, 2018). The hot juice blends were filled into pre-sterilized bottles 250 mL capacity and closed, then cooled under running tap water. The juice blends were stored at room temperature (25±5 °C) for further storage studies and analyzed at 60 days intervals for six months.

Analytical Methods

Chemical analysis

Moisture, pH value, Tss (Total soluble solids) and titratable acidity were determined according to the methods of AOAC (2012). Total phenolics content was determined using Folin- Ciocalteu reagent as described by Singleton & Rossi (1965). Total flavonoids content was measured by $AlCl_3$ colorimetric assay according to the method by Tacouri et al. (2013). The content of anthocyanin was determined by the spectrophotometric method (Abdel-Aal & Hucl, 1999). Radical scavenging activity of samples extracts was determined by DPPH radicals according to the modified method by (Lu et al., 2007). The Trolox calibration curve (y=968.96x+15.604) was plotted as a function of the percentage of DPPH radical scavenging activity. The antiradical activity was expressed as micromoles of Trolox equivalents (TE) per gram of dry weight (μmol TE/g on dry weight basis). Fractionation and identification of phenolic compounds were determined by HPLC (Hewllet Packard series, 1050) according to the method of (Goupy et al., 1999; Mattila et al., 2000) as follows: the extracts were centrifuged at 10000 rpm (in ICE Micro-MB Centrifuge/NARP 64606 instrument) for 10 min and the supernatant was filtrated through a 0.2 μm Millipore membrane filter, then 1-3 mL were collected in a vial for injection into HPLC Agilent (Series 1200) equipped with auto sampler injector, solvent degasser, ultraviolet (UV) detector set at 280 nm and quaternary HP pump (Series 1100). The column [Agilent 5HCC18 (2) 250×4.6 mm] temperature was maintained at 35 °C. Gradient separation was carried out with methanol and acetonitrile as a mobile phase at flow rate of 1 mL/min. Phenolic acid standards from Sigma Co. USA were dissolved in a mobile phase and injected into HPLC. Retention time and peask area of the tested samples were calibrated against standard solutions of different phenolic and aromatic compounds concentration by the data analysis of Hewllet Packed (HP) software.

Sensory evaluation

Sensory evaluation was carried out by a properly well trained panel of 12 panelists (staff members from the Food Science Department, Faculty of Agriculture, Benha University). They were selected if their individual scores in 10 different tests showed reproducibility of 90%. The 12 members internal panel evaluated low calories pomegranate juice blends for color (20), appearance (25), taste (25), odor (10), mouth feel (20), and overall acceptability (sum of all scores) (Onweluzo et al., 1999).

Statistical analysis

The Statistical analysis was carried out using ANOVA with two factors under a significance level of 0.05 for the whole results using SPSS (ver. 11 SPSS Inc., USA) and Data were treated as complete randomization design according to Steel et al. (1997). Multiple comparisons were carried out applying LSD.

Results and Discussion

Different external and internal factors, such as genetic and agronomic factors, light intensity, temperature, processing method, and storage conditions, may cause the chemical composition to differ among fruits of similar types (Fernandes et al., 2015). As shown in Table 2. The moisture content and TSS of pomegranate pulp were 85.08±0.73 and 14.30±0.71%, respectively. While titratable acidity and pH value were 2.63% (as citric acid) and 3.77, respectively. According to the results are presented in Table 2, total phenols, flavonoids, anthocyanin and DPPH were 29.66 mg/g, 21.44 mg/g, 194.82 mg/100 g, and 87.24%, respectively. These results are in agreement with those obtained by Tehranifar et al. (2010).

Polyphenol profile of pomegranate pulp

The results in Table 3. showed that the produced fresh pomegranate juice had several phenolics acid. They were pyrogallol acid (7.34 mg/g DW) that was the predominant followed by catechol acid (5.68 mg/gm DW). -OH-benzoic, catechein and -coumaric acid content were 2.88, 2.85 and 2.01 mg/g on dry weight basis for the pomegranate pulp, respectively, Chlorogenic and gallic acid content were 0.83 and 0.49 mg/g, respectively. The obtained results are closed in accordance with those obtained by Elfalleh et al. (2011). The differences in phenolic compounds profile and concentration can be evidenced, allowing different pomegranate fruit to be distinguished on the basis of the concentration of compounds of specific phenolic classes.

Also, from Table 3. the results indicated that the major flavonoids fractions in pomegranate pulp were hespirdin, naringin, rutin, quercetin and hespirtin which were found at the level of 397.65, 87.27, 11.80, 7.10 and 5.90 µg/mL, respectively. In addition, the pomegranate pulp contained adequate amounts of flavonoids (Naringenin, 3.28 and Quercetrin, 2.82 µg/mL).

TABLE 2. Physicochemical properties, bioactive compounds content, and antioxidant activity of pomegranate pulp.

Components	Mean
Moisture (%)	85.08±0.73
TSS (%)	14.30±0.71
Titratable acidity (as citric acid) (%)*	2.63±0.07
pH value	3.77±0.07
Total phenolics (mg/g) *	29.66±2.88
Total flavonoids (mg/g) *	21.44±0.38
Total anthocyanin (mg/100 g) *	194.82±7.47
DDPH (%)*	87.24±0.4

*: On dry weight basis.

TABLE 3. Identification of phenolics (mg/g DW) and flavonoids (µg/mL) of fresh pomegranate pulp.

Phenolics acid	mg/g	Flavonoid	µg/mL.
Gallic	0.49	Naringin	87.27
Pyrogallol	7.34	Rutin	11.80
Catechein	2.85	Hespirdin	397.65
Chlorogenic	0.83	Quercetrin	2.82
Catechol	5.68	Quercetin	7.10
ρ -OH-benzoic	2.88	Naringenin	3.28
ρ –Coumaric	2.01	Hespirtin	5.90

Bioactive compounds of resultant low calorie pomegranate juices

The pomegranate fruit is clearly thought to be a carrier of bioactive compounds, including hydroxycinnamic acids, hydroxybenzoic acids, flavons, flavonol-3-ols, anthocyanidins, anthocyanins and conjugated and nonconjugated fatty acids, phytosterols, vitamins and minerals **(**Akhtar et al., 2019).

Total phenolics, flavonoids and anthocyanin content of low calorie pomegranate juice are shown in Table 4. the total phenolic and flavonoid compounds in the pomegranate juice treatments ranged from 50.41 to 185.40 mg/g as Gallic acid and 7.20 to 28.81mg/g as catechol, respectively. Total anthocyanin content in the produced pomegranate fruit juice was 46.52, 9.45, 71.90, 100.87 and 142.34 mg/g Cynidian-3-glycoside from T1 to T5, respectively. These results showed that the values of bioactive compounds content were increased gradually from T1 to T5. Carbonell-Capella et al. (2019) reported that beverages sweetened with stevia showed a significant increase (3-fold and 4-fold higher, respectively) in phenolic compounds also as in antioxidant properties as compared with the beverage without Stevia.

TABLE 4. Bioactive compounds of resultant low calorie pomegranate juices (on dry weight) (mean ±SD).

Bioactive compounds	Treatments				
	T1	T2	T3	T4	T5
Total phenolics (mg gallic /g)	50.41[e] ±0.64	68.22[d] ±2.50	84.81[c] ±1.36	121.78[b] ±203	185.40[a] ±5.73
Total flavonoids (mg catechol /g)	7.20[e] ±0.12	9.53[d] ±0.28	10.84[c] ±0.66	19.73[b] ±1.06	28.81[a] ±0.41
Total anthocyanins (mg Cynidian-3-glycoside/100g)	46.52[e] ±0.22	59.45[d] ±3.14	71.90[c] ±3.09	100.87[b] ±5.97	142.34[a] ±3.22
Antioxidant activity(µmol TE/g)	2.98[e] ±0.14	3.06[d] ±0.14	3.72[c] ±0.05	4.06[b] ±0.13	4.44[a] ±0.07

Tl (100% Sucrose), T2 (75% sucrose+25% Su), T3 (50% sucrose+50% Su), T4 (25% sucrose+75% Su), T5 (100% Su). Means within a raw showing the same letters are not significantly different (P 0.05).

The radical-scavenging activity on DPPH was expressed as (µmol TE/g). Data in Table 4. revealed that T5 exhibited the highest activity value followed by T1, T2 and T3, respectively. Wongsa et al. (2012) reported that the antioxidant activity may also contribute from the other antioxidant secondary metabolites such as volatile oils, carotenoids and vitamins. Synergistic interactions observed between phytochemicals and steviol glycosides in the complex food beverages when Trolox Equivalent Antioxidant Capacity (TEAC) method was used suggest an improved solubility or stability of antioxidant compounds (Carbonell-Capella et al., 2019).

Effect of storage at room temperature on some properties of resultant low calorie pomegranate juices

The ambient storage period affected the chemical and physical attributes of juice. Castro-López et al. (2016) demonstrated that the importance of storage conditions for the stability of phenolic compounds, total carotenoids and total antioxidant activity, and the consideration of these conditions as main quality factors in fruit juices. Results in Table 5. showed that extending the storage period of juices to 6 months accompanied by a gradual decrement in total phenolic and flavonoid content.

The results are consistent with those of (Liu et al., 2014) who found that the decrease in phenols was primarily due to oxidation and polymerization of these compounds. Klimczak et al. (2007) found that the flavonoids decreased in orange juices stored for 6 months. Also, reported that the small changes in total flavonoids content could be explained by the high stability of these compounds. Effect of storage period on anthocyanin content was studied and the results showed that the content of anthocyanin decreased during the storage period. According to Malacrida & Motta (2005), the reduction in anthocyanin content in fruit juices can be attributed to oxidation, which can start during the juice extraction process and continue during the storage period.

Data in Table 5. observed that the acidity of Low-calorie pomegranate juice decreased notably during storage. Reduction in acidity could be attributed to chemical interaction between organic constituents of juice induced by temperature and action of enzymes during storage (Sindhu & Khatkar, 2018). Similar results were found by (Dusman et al., 2017) who reported that the acidity decreased in organic grape juice during storage for 6 months, could be due to the copolymerization of organic acids with other compounds present in their products.

Sensory evaluation of low calorie pomegranate juice

The results were statistically analyzed and illustrated in Table 6. for the scores of sensory evaluation in terms of color, taste, odor, appearance, mouse feel and overall acceptability were tested and the effect of different levels of sucralose as a replacer to sucrose on the sensory characteristics of produced low calories pomegranate juice samples. The scores of color were 18.33, 18.67, 18.00, 17.33 and 16.50 for T1, T2, T3, T4 and T5, respectively. The scores of color decreased after 6 months of storage.

TABLE 5. Effect of storage period for 6 months at (25±5 ºC) on chemical properties (mean±SE) of resultant low calorie pomegranate juices (on dry weight basis).

Storage periods (months)	Treatments				
	T1	T2	T3	T4	T5
Total phenolic compounds(mg gallic /g)					
0	50.41±0.64^{eA}	68.22±2.50^{dA}	84.81±1.36^{cA}	121.78±2.03^{bA}	185.40±5.73^{aA}
2	48.86±0.32^{eB}	62.94±0.84^{dB}	80.94±0.55^{cB}	114.79±2.4^{bB}	180.33±0.13^{aB}
4	45.40±0.56^{eC}	60.28±0.15^{dC}	78.22±0.39^{cC}	103.84±0.74^{bC}	172.03±0.45^{aC}
6	41.66±0.26^{eD}	57.87±0.54^{dD}	73.49±0.69^{cD}	101.59±0.33^{bD}	162.84±0.68^{aD}
Total flavonoid compounds (mg catechol /g)					
0	7.20±0.12^{eA}	9.53±0.28^{dA}	10.84±0.66^{cA}	19.73±1.06^{bA}	28.81±0.41^{aA}
2	6.36±0.10^{eB}	8.67±0.13^{dB}	10.76±0.16^{cA}	19.36±0.13^{bA}	26.50±0.22^{aB}
4	5.96±0.04^{eB}	8.35±0.10^{dB}	9.42±0.24^{cB}	18.21±0.06^{bB}	24.43±0.22^{aC}
6	5.44±0.05^{eC}	6.90±0.41^{dC}	8.49±0.14^{cC}	15.75±0.37^{bC}	23.18±0.14^{aC}
Total anthocyanins mg Cynidian-3-glycoside/100g					
0	46.52±0.22^{eA}	59.45±3.14^{dA}	71.90±3.09^{cA}	100.87±5.97^{bA}	142.34±3.22^{aA}
2	43.65±0.11^{eB}	53.43±0.22^{dB}	69.90±0.48^{cA}	92.57±0.60^{bB}	139.33±0.41^{aB}
4	41.92±0.25^{eB}	52.42±0.24^{dB}	66.25±0.15^{cB}	90.48±0.12^{bBC}	136.51±0.16^{aC}
6	38.52±0.34^{eC}	51.33±0.31^{dB}	63.92±0.15^{cC}	88.24±0.13^{bC}	131.12±0.61^{aD}
Titratable acidity (as citric acid) (%)					
0	2.99±0.07^{cdA}	2.88±0.11^{dA}	3.04±0.05^{bA}	3.01±0.04^{bcA}	3.49±0.08^{aA}
2	2.69±0.14^{cB}	2.84±0.08^{bA}	2.94±0.02^{bAB}	2.93±0.03^{bAB}	3.40±0.12^{aAB}
4	2.61±0.06^{cBC}	2.83±0.03^{bA}	2.89±0.03^{bB}	2.87±0.17^{bB}	3.34±0.05^{aB}
6	2.54±0.02^{cC}	2.82±0.13^{bA}	2.84±0.11^{bB}	2.82±0.03^{bB}	3.33±0.08^{aB}

T1 (75% sucrose+25% Su), T2 (50% sucrose+50% Su), T3 (25% sucrose+75% Su) and T4 (100% Su).

$^{a,\ b\ \&\ c}$: There is non-significant difference (P>0.05) between any two means, within the same row have the same superscript letter.$^{A,\ B\ \&\ C}$: There is non-significant difference (P>0.05) between any two means for the same attribute, within the same column have the same superscript letter.

The highest value for taste obtained by T3 22.17 followed by T1 21.42, while the minimum values obtained by T5, T2 and T4 were recorded 19.75, 20.50 and 20.83, respectively. The maximum score for the odor was recorded by T1 7.75 followed by T4 7.08, while the minimum score obtained by T5 6.75, T3 6.92 and T2 7.08. In the present investigation, it is concluded that the T3 was found to be the most suitable in terms of mouthfeel and recorded 15.75 followed by 15.67 obtained by T1 while the minimum value was 14.67 obtained by T5 followed by 15.08 and 15.17 obtained by T2 and T4. The overall acceptability scores were 84.75, 83.83, 83.08, 81.67and 78.75 for T1, T3, T2, T4 and T5, respectively.

The highest value for taste obtained by T3 22.17 followed by T1 21.42, while the minimum values obtained by T5, T2 and T4 were recorded 19.75, 20.50 and 20.83, respectively. The maximum score for the odor was recorded by T1 7.75 followed by T4 7.08, while the minimum score obtained by T5 6.75, T3 6.92 and T2 7.08. In the present investigation, it is concluded that the T3 was found to be the most suitable in terms of mouth feel and recorded 15.75 followed by 15.67 obtained by T1 while the minimum value was 14.67 obtained by T5 followed by 15.08 and 15.17 obtained by T2 and T4.

TABLE 6. Effect of storage period for 6 months at (25±5 ºC) on Sensory characteristics (mean±SE) of resultant low calorie pomegranate juices.

Storage periods (months)	Treatments				
	T1	T2	T3	T4	T5
			Color (20)		
0	18.33±0.45^{aA}	18.67±0.54^{aA}	18.00±0.6^{abA}	17.33±0.73^{bA}	16.50±0.54^{cA}
2	18.08±0.47^{aAB}	18.42±0.50^{aAB}	17.75±0.54ab^{AB}	17.08±0.68^{bA}	16.25±0.49^{cAB}
4	17.92±0.48^{aAB}	18.25±0.49^{aAB}	17.58±0.57^{abAB}	17.00±0.69^{bA}	16.08±0.48^{cAB}
6	17.50±0.45^{aB}	17.83±0.52^{aB}	17.17±0.59^{abB}	16.67±0.70^{bA}	15.67±0.43^{Cb}
			Taste (25)		
0	21.42±0.60^{bA}	20.50±0.69^{cA}	22.17±0.11^{aA}	20.83±0.27^{bcA}	19.75±0.72^{dA}
2	21.17±0.59^{bA}	20.25±0.66^{cAB}	21.92±0.19^{aAB}	20.58±0.31^{bcAB}	19.50±0.68d^{AB}
4	20.92±0.61^{bAB}	20.08±0.61^{cAB}	21.75±0.28^{aAB}	20.50±0.34^{bcAB}	19.33±0.67^{dAB}
6	20.50±0.66b^{B}	19.67±0.58^{cB}	21.33±0.28^{aB}	20.08±0.34^{bcB}	18.92±0.67^{dB}
			Odor (10)		
0	7.75±0.35^{aA}	7.08±0.31^{bA}	6.92±0.45^{bA}	7.08±0.43^{bA}	6.75±0.30^{bA}
2	7.50±0.26^{aA}	6.83±0.27^{bA}	6.67±0.40^{bA}	6.83±0.37^{bAB}	6.50±0.34^{bA}
4	7.33±0.26^{aAB}	6.67±0.26^{bAB}	6.50±0.38^{bAB}	6.83±0.37^{bAB}	6.33±0.33^{bAB}
6	6.92±0.26^{aB}	6.25±0.33^{bcB}	6.08±0.40^{bcB}	6.42±0.26^{bB}	5.92±0.43^{cB}
			Appearance (25)		
0	21.58±0.65^{aA}	21.75±0.57^{aA}	21.00±0.79^{aA}	21.25±0.68^{aA}	21.08±0.92^{aA}
2	21.33±0.61^{aA}	21.50±0.57^{aA}	20.75±0.74^{aA}	21.00±0.67^{aA}	20.42±0.88^{aAB}
4	21.17±0.60^{abA}	21.33±0.54^{aA}	20.58±0.70^{aA}	21.00±0.67^{abA}	20.25±0.83^{bAB}
6	20.75±0.63^{aA}	20.92±0.50^{aA}	20.17±0.74^{abA}	20.58±0.72^{abA}	19.83±0.85^{bB}
			Mouth-feel (20)		
0	15.67±1.05^{aA}	15.08±0.84^{aA}	15.75±0.65^{aA}	15.17±0.78^{aA}	14.67±0.64^{aA}
2	15.42±1.03^{aA}	14.83±0.85^{aA}	15.50±0.63^{aA}	14.92±0.76^{aA}	14.42±0.62^{aA}
4	15.25±0.99^{aA}	14.75±0.84^{aA}	15.33±0.63^{aA}	14.92±0.76^{aA}	14.25±0.58^{aA}
6	14.83±0.93^{abA}	14.42±0.87^{abA}	14.92±0.57^{aA}	14.50±0.76^{abA}	13.83±0.60b^{A}
			Overall palatability (100)		
0	84.75±1.73^{aA}	83.08±1.43^{aA}	83.83±1.51^{aA}	81.67±1.47^{bA}	78.75±1.58^{cA}
2	83.50±1.56^{aAB}	81.83±1.05^{bAB}	82.58±1.36^{bAB}	80.42±1.12^{cA}	77.08±1.29^{dA}
4	82.58±1.70^{aB}	81.08±1.42^{bB}	81.75±1.38^{bB}	80.25±1.09^{bA}	76.25±1.03^{cA}
6	80.50±1.58^{aC}	79.08±1.37^{abC}	79.67±1.36^{abC}	78.25±1.10^{bB}	74.17±0.94^{cB}

T1 (75% sucrose+25% Su), T2 (50% sucrose+50% Su), T3 (25% sucrose+75% Su) and T4 (100% Su).

$^{a,\ b\ \&\ c}$: There is non-significant difference (P>0.05) between any two means, within the same row have the same superscript letter.$^{A,\ B\ \&\ C}$: There is non-significant difference (P>0.05) between any two means for the same attribute, within the same column have the same superscript letter.

The overall acceptability scores were 84.75, 83.83, 83.08, 81.67and 78.75 for T1, T3, T2, T4 and T5, respectively. The results revealed that during the storage period, all sensory attributes decreased. The sensory profile of juice made with sucrose and sucralose was similar (P 0.05), with no bitter taste. The flavor of low-calorie pomegranate juice samples influenced sample acceptance positively. Sucralose - sweetened samples and sucrose T3 samples received higher palatable scores for taste and overall impression. Sucralose can be used as a sucrose substitute in pomegranate juice.

Conclusions

Sucralose can be used to replace sugar in pomegranate juice, resulting in a low-calorie product with the same desirable physicochemical and sensory properties. Sucralose, a non-caloric sweetener used to make low-calorie pomegranate juice, may be a significant issue for many people with diabetes, obesity, and sugar allergies. Additionally, by substituting sucralose for sucrose, production costs will be reduced. Finally, this research suggests that 50% sucralose can be added to pomegranate juice without degrading its sensory quality. The addition of sucralose to the juice may improve the nutritional value of the juice and, as a result, the consumer’s perception of its palatability. Suggestion for further studies may be given.

References

Abdel-Aal, E.S.M. and Hucl, P. (1999) A rapid method for quantifying total anthocyanins in blue aleurone and purple pericarp wheats. *Cereal Chemistry*, **76,** 350-354. https://doi.org/10.1094/CCHEM.1999.76.3.350.

Akhtar, S., Ismail, T. and Layla, A. (2019). Pomegranate Bioactive Molecules and Health Benefits. In: Mérillon JM., Ramawat K. (Eds) *Bioactive Molecules in Food. Reference Series in Phytochemistry*, pp. 1253-1279. https://doi.org/10.1007/978-3-319-78030-6-78.

Al-Dabbas, M.M. and Al-Qudsi, J.M. (2012) 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. *International Food Research Journal,* **19 (**2), 679-683.

AOAC (2012). Official Methods of Analysis Association of Official Analytical Chemists International, 19th ed., Maryland, USA.

Aviram, M., Rosenblat, M. and Gaitini, D. (2004) Pomegranate juice consumption for 3 years by patients with carotid artery stenosis reduces common carotid intima-media thickness, blood pressure and LDL oxidation. *Clinical. Nutration,* **23**, 423-433. https://doi.org/10.1016/j.clnu.2003.10.002.

Carbonell-Capella, J.M, Blesa, J., Frígola, A. and Esteve, M.J. (2019) Study of the interactions of bioactive compounds and antioxidant capacity of an exotic fruits beverage that sweetened with stevia. *MOJ Food Processing & Technology,* **7**(3), 79-86. https://doi.org/DOI: 10.15406/mojfpt.2019.07.00224.

Castro-López, C., Sánchez-Alejo, E.J., Saucedo-Pompa, S., Rojas R., Aranda-Ruiz, J. and Martínez-Avila,G.C.G. (2016). Fluctuations in phenolic content, ascorbic acid and total carotenoids and antioxidant activity of fruit beverages during storage. *Heliyon*, **2**, 1-16. https://doi.org/10.1016/j.heliyon.2016.e00152.

Dhumal, S.S., Karale, A.R., More, T.A., Nimbalkar, C.A., Chavan, U.D. and Jadhav S.B. (2015). Preparation of Pomegranate Juice Concentrate by Various Hea ting Methods and Appraisal of Its Physico chemical Characteristics. *Acta* Horticulturae, 1089, 476-484. https://doi.org/10.17660/ActaHortic.2015.1089.65.

Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.T. and Smith, F. (1956) Colorimetric method for determination of sugars and related substances. *Analytical Chemistry,* **28** (3), 350-356. https://doi.org/10.1021/ac60111a017.

Dusman, E., A lmeida, I., Pinto, E., Lucchetta, L., and Vicentini, V. (2017) Influence of processing and storage of integral grape juice (*Vitis labrusca* L.) on its phy sical and chemical characteristics, cytotoxicity, and mutagenicity in vitro. *Genetics and Molecular Rese arch,* **16** (2), 1-12. DOI: 10.4238/gmr16029670.

El-Dengawy, R.A.H, El-said, S.M.M., El-Kadi, S.M.L., and Shalata, A.A.M. (2016) Effect the Industrial Process and the Storage Periods on the Nutritional Value of Tomato Juice. *Indian Journal of Nutrition and Food Science,* **3** (1), 121-125.

Elfalleh, W., Tlili, N., Nasri, N., Yahia, Y., Hannachi, H., Chaira, N., Ying, M. and Ferchichi, A. (2011). Antioxidant capacities of phenolic compounds and tocopherols from Tunisian pomegranate (*Punica granatum*) fruits. *Journal of Food Science,* **76** (5), 707-713. DOI: 10.1111/j.1750-3841.2011.02179.x.

Fernandes, L., Prereira, J.A., Lopéz-Cortés, I., Salazar, D.M. and Ramalhosa. T. E.C. (2015). Physicochemical changes and antioxidant activity of juice skin, pellicle and seed of pomegranate (cv. Mollar de Elche) at different stages of ripening. *Food Technology and Biotechnology,* **54**, 397-406. DOI:10.17113/ftb.53.04.15.3884.

Gibson, S., Drewnowski, A., Hill, J., Raben, A. B., Tuorila, H. and Widstrom, E. (2014). Consensus statement on benefits of low-calorie sweeteners. *Nutrition Bulletin,* **39**, 386–389. DOI: 10.1111/nbu.12116.

Goupy, P., Hugues, M., Boivin, P. and Amiot, M. (1999). Antioxidant composition and activity of barley (*Hordeum vulgare*) and malt extracts and of isolated phenolic compounds. *Journal Science Food and Agriculture.,* **79**, 625–1634. https://doi.org/10.1002/(SICI)1097-0010(199909)79:12<1625.

Jurenka, J. (2008).Therapeutic Applications of Pomegranate (*Punica granatum* L.): A Review. *Alternative Medicine Review,* **13**, 128-144. https://pubmed.ncbi.nlm.nih.gov/18590349/.

Klimczak, I., Małecka, M., Szlachta, M. and GliszczyńskaŚwigło, A. (2007). Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices. *Journal of*

Food Composition Analysis, **20** (3-4), 313-322. DOI: 10.1016/j.jfca.2006.02.012.

Li, X., Wasila, H., Liu, L., Yuan, T., Gao, Z., Zhao, B. and Ahmed, I. (2015) Physicochemical characteristics, polyphenol compositions and antioxidant potential of pomegranate juices from 10 Chinese cultivars and the environmental factors analysis. *Food Chemistry,* **175**, 575-584. DOI: 10.1016/j.foodchem.2014.12.003.

Liu, F., Wang, Y., Li, R., Bi, X. and Liao, X. (2014) Effects of high hydrostatic pressure and high temperature short time on antioxidant activity, antioxidant compounds and color of mango nectars. *Innovative Food Science and Emerging Technologies,* **21**, 35-43. https://doi.org/10.1016/j.ifset.2013.09.015.

Lu, J., Zhao, H., Chen, J., Fan, W., Dong, J., Kong, W., Sun, J., Cao, Y., and Cai, G. (2007) Evolution of Phenolic Compounds and Antioxidant Activity during malting. *Journal of Agricultural and Food Chemistry,* **55**, 10994-11001. https://doi.org/10.1021/jf0722710.

Malacrida, C.R. and Motta, S.D. (2005) Total Phenolic Compounds and Anthocyanin In Grape Juice. *Food Science and Technology,* **25** (4), 659-664. https://doi.org/10.1590/S0101-20612005000400006.

Mandel, L.D. and Grotz, V.L. (2002) Dental considerations in sucralose use. *Journal Clinical Dental,* **13**(3), 116-8. https://pubmed.ncbi.nlm.nih.gov/11887514/.

Mansour, E.H., and Khalil, A.H. (1997) Characteristics of low-fat beefburger as influenced by various types of wheat fibers. *Journal Food Research International,* **30** (3-4), 199-205. https://doi.org/10.1016/S0963-9969(97)00043-4.

Mattila, P., Astola, J. and Kumpulainen, J., (2000) Determination of flavonoids in plant material by HPLC with diode-array and electro-array detections. *Journal of Agricultural and Food Chemistry,* **48** (12), 5834-5841. DOI: 10.1021/jf000661f

Moazzem, M. S., M. B. H. Sikder, and W. Zzaman (2019) Shelf-life extension of wood apple beverages maintaining consumption-safe parameters and sensory qualities. *Beverages,* **5**, 25. https://doi.org/10.3390/beverages5010025.

Onweluzo, J.C., Vijayalakshmi, M.R., Vijayanand, P. and Eipeson, W.E. (1999) Detarium microcarpum polysaccharide as a stabilize r in processed fruit products. *Lebenson Wiss Techn ol- Food Science and Technology,* **32** (8), 521-5 26. https://doi.org/10.1006/fstl.1999.0592.

Pielak, M., Czarniecka-Skubina, E. and Głuchowsk, A. (2020). Effect of Sugar Substitution with Steviol Glycosides on Sensory Quality and Physicochemical Composition of Low-Sugar Apple Preserves. *Foods,* **9**, 293, 1-19. DOI: 10.3390/foods9030293.

Rodero, A. B., rodero, L. S. and azoubel, R. (2009). Toxicity of sucralose in humans: a review. *International Journal of Morpholog,* **27** (1), 239-244. http://dx.doi.org/10.4067/S0717-95022009000100040.

Sindhu, R., and Khatkar, B.S. (2018). Effects of Chemical Treatments on Storage Stability of Lemon (*Citrus Limon*) Juice. *International Advanced Research Journal in Science, Engineering and Technology,* **5** (2), 76-79. https://iarjset.com/upload/2018/february-18/IARJSET%2013.

Singleton, V.L. and Rossi, A.J. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture,* **16** (3), 144-158. https://www.ajevonline.org/content/16/3/144.

Steel, R., Torrie, J. and Dickey, D. (1997) Principles and procedures of Statistics: A Biometrical Approach, 3rd ed., McGraw-Hill, New York, NY.

Tacouri, D.D., Ramful-Baboolall, D. and Puchooa, D. (2013) In vitro bioactivity and phytochemical screening of selected spices used in Mauritian foods. *Asian Pacific Journal of Tropical Disease,* **3**(4), 253-261. https://doi.org/10.1016/S2222-1808(13)60066-3.

Tehranifar, A., Zarei, M., Nemati, Z., Esfandiyari, B. and Vazifeshenas, M.R. (2010) Investigation of physico-chemical properties and antioxidant activity of twenty Iranian pomegranate (*Punica granatum* L.) cultivars. *Scientia Horticulturae,* **126**, 180-185. DOI: 10.1016/j.scienta.2010.07.001.

Terefe, N. S., R. Buckow, and C. Versteeg (2014) Quality related enzymes in fruit and vegetable products: Effects of novel food processing technologies, Part 1: High-pressure processing. *Critical Reviews in Food Science and Nutrition,* **54**, 24-63. DOI: 10.1080/10408398.2011.566946

Vroegrijk, I.O.C.M., Van Diepen, J.A.S. and Van den Berg et al. (2011) Pomegranate seed oil, a rich source of punicic acid, prevents diet-induced obesity and insulin resistance in mice. *Food and Chemical Toxicology,* **49**(6), 1426-30. DOI: 10.1016/j.fct.2011.03.037

Wongsa, P., Chaiwarit, J. and Zamaludien, A. (2012) In vitro screening of phenolic compounds, potential inhibition against α-amylase and α glucosidase of culinary herbs in Thailand. *Food Chemistry,* **131**, 964–971. https://doi.org/10.1016/j.foodchem.2011.09.088

Yan, L., Zhou, X., Shi, L., Shalimu, D., Ma, C. and Liu, Y. (2017) Phenolic profiles and antioxidant activities of six Chinese pomegranate (*Punica granatum* L.) cultivars. *International Journal of Food Properties,* **20**(1), 94-107. https://doi.org/10.1080/10942912.2017.1289960

إنتاج وتقييم عصير الرمان منخفض السعرات الحرارية بالسكرولوز

يعد الحد من استهلاك الأطعمة والعصائر عالية السعرات الحرارية لمختلف الفئات العمرية للمستهلكين امرا هاماً بهدف الحفاظ على الصحة العامة والوقاية من العديد من الأمراض مثل مرض السكري والسمنة وتسوس الأسنان وأمراض القلب وتصلب الشرايين ، ويعد ذلك تحدياً من الناحية التكنولوجية لمصنعى الاغذية والمشروبات. لذلك كان الهدف من هذا البحث هو إنتاج عصير رمان منخفض السعرات الحرارية من ثمار الرمان عن طريق استبدال السكروز بالسكرالوز بمستويات مختلفة. تم تحضير خمس معاملات من عصير الرمان منخفض السعرات الحرارية من لب الرمان ثم تحليته باستخدام السكروز (عينة مقارنة) واستبداله بالسكرالوز بمستويات (25 ، 50 ، 75 و 100٪) ودراسة تأثير الاستبدال على عصير الرمان الناتج خلال فترة التخزين لمدة 6 أشهر على درجة حرارة الغرفة على الخصائص الكيميائية والفيزيائية والحسية للعصير المنتج. أظهرت النتائج المتحصل عليها أن الزيادة في مستويات إحلال السكرالوز أدت إلى انخفاض المحتوى الكلي من الكربوهيدرات وإجمالي السعرات الحرارية. خلصت النتائج إلى أن استخدام السكرالوز كبديل للسكروز بنسبة 50٪ سجل درجة عالية من القبول الحسي من حيث التذوق والقبول العام ، مقارنة بالمعاملات الأخرى بعد 6 أشهر بالتخزين على درجة حرارة الغرفة. أشارت نتائج الخصائص الحسية إلى أن عصير الرمان منخفض السعرات الحرارية كان له لون جيد وطعم مقبول خلال فترات التخزين.