

Physicochemical Properties of Sugar Substituted Apple Jam

Leila M.A. Taghian^{1,2}, Lobna A.M. Haridy², Sherif M. Abed, and Mohamed A.S. Abdel-Samie^{1*}

¹ Department Food and Dairy Sciences and Technology, Faculty of Environmental Agricultural Sciences, Arish University, Arish, 45511, Egypt.

² Department of Horticultural Crops Research, Food Technology Research Institute, Agricultural Research Center, Giza, 12511, Egypt.

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Abstract: Apple jam, a sweet product, rich in fiber and antioxidants, a source of fruit-derived components and energy. This study aimed to substitute sucrose using date syrup and white grape juice concentrate, and to investigate the effects of sugar substitution on physicochemical, microbial, and sensory properties of apple jam during a 6-month of storage at room temperature (25°C±5°C). The findings revealed that apple jam with date syrup showed the highest content of antioxidants, phenols, and flavonoids. Substituting sugar with date syrup and white grape juice concentrate slightly decreased sensory properties compared to the control apple jam. Moreover, replacement of sugar using date syrup had the most significant effect in reducing the total bacterial count of the apple jam samples during the storage period. In conclusion, the substitution of sugar with date syrup and white grape juice concentrate improved the nutritional and health-related values of apple jam, as well as extended its shelf life.

Keywords: Apple jam, Functional foods, Date syrup, White grape juice concentrate.

1. Introduction

Apples (*Malus domestica*) rank among the most widely cultivated fruits globally. Beyond their palatability, they are a rich source of bioactive compounds associated with diverse health benefits, including cardiovascular improvement and cancer prevention. Apples contain essential vitamins, flavonoids, carotenoids, micronutrients, and dietary fiber, which participate in critical biochemical pathways to maintain physiological homeostasis. Furthermore, their pleiotropic bioactive constituents contribute to disease prevention through multifaceted mechanisms. (Bator et al., 2024).

Jam production is a fruit preservation process aimed at inhibiting spoilage, minimizing quality and nutritional degradation, and extending shelf life (Darkwa et al., 2016). Jams are produced by boiling fruit pulp with a sufficient concentration of sugar until a thick, firm consistency is achieved, which helps retain the structural integrity of the fruit tissue. The high sugar content contributes to preservation by imparting sweetness, facilitating gel formation, and enhancing color retention (Rahman et al., 2018).

Excessive sugar consumption has emerged as a significant public health concern, affecting individuals across all age groups. High dietary sugar intake is associated with an increased risk of metabolic disorders such as obesity and diabetes, as well as cardiovascular diseases (Alkhaldi et al., 2021). Growing health awareness among consumers has spurred interest in healthier dietary

* Corresponding Author: masabdelSamie@aru.edu.eg

alternatives. Consequently, natural sugar sources are increasingly preferred due to their demonstrated nutritional advantages over refined sugars (Arshad et al., 2022).

White grape juice concentrate is a nutrient-rich sweetener, containing high levels of natural sugars, vitamins, and polyphenols, making it a valuable functional ingredient (Sheida and Hannan, 2021). Similarly, date syrup exhibits significant antioxidant properties and is abundant in sugars, essential minerals (including potassium, iron, magnesium, and calcium), and vitamins (such as thiamine [B1], riboflavin [B2], nicotinic acid, pro-vitamin A, and vitamin C). Additionally, date syrup contains substantial amounts of unsaturated fatty acids, including linolenic, palmitoleic, oleic, and linoleic acids (Castro Munoz et al., 2022).

The present study aimed to assess the impact of substituting refined sugar with white grape juice concentrate and date syrup as natural sweeteners in apple jam, and to evaluate the resulting effects on the jam's chemical, physical, and sensory characteristics.

2. Material and methods

2.1. Materials

Fresh apples (*Malus domestica*) and grapes (*Vitis vinifera*) were procured from open markets in El Giza, Egypt. Date syrup was obtained from a local retailer in Giza, Egypt. Microbiological media including plate count agar, potato dextrose agar, and nutrient broth were acquired from Oxoid (Hampshire, England). Analytical grade chemicals - 2,2-diphenyl-1-picrylhydrazyl (DPPH), Folin-Ciocalteu reagent, and gallic acid - were purchased from Sigma-Aldrich (Steinheim, Germany). All chemicals used were of analytical grade purity.

2.2. Methods

2.2.1. Preparation of Apple Jam

The apple jam was prepared according to the modified method of El-Ghandour et al. (2019). Fresh apples underwent washing, peeling, and dicing into uniform 1 cm³ cubes before cooking in stainless steel vessels. The fruit cubes were combined with sweeteners (sugar or alternatives) in a 45:55 (w/w) ratio and heated gradually to 105°C until reaching 65°Brix total soluble solids content. During processing, pectin (5 g/kg fruit-sweetener mixture) and citric acid (3 g/kg sucrose equivalent) were incorporated, with the final product adjusted to pH 4.0 using a calibrated pH meter. The prepared jam was hot-filled into sterilized glass jars, pasteurized at 85°C for 15 minutes to ensure microbial stability, and subsequently stored at controlled room temperature (25°C ± 5°C) for further analysis.

Table 1. The different formula of apple jam

Control	Apple fruit (45%) + sugar (55%).
AD	Apple fruit (45%) + date syrup (55%).
AG	Apple fruit (45%) + grape juice concentrate (55%).

2.2.2. Microbiological analyses:

Microbiological analyses were performed following standard methods as outlined by APHA (1992). The aerobic plate count (APC) was determined using the pour plate method on plate count agar (PCA), with duplicate plates incubated at 30°C for 48 h. Yeast and mold (YM) counts were enumerated similarly using potato dextrose agar (PDA), with incubation at 25°C for 5 d. Coliform group (CG) counts were assessed on MacConkey agar (MA) incubated at 37°C for 24 h, employing the same dilution series. All microbial counts were expressed as colony-forming units per milliliter (CFU/mL), with dilutions prepared and plated in accordance with standardized microbiological protocols.

2.2.3. Chemical composition determination

Physicochemical characterization was performed using standardized analytical methods. Moisture content was determined according to AOAC (2012) official methods. pH measurements were conducted at 25°C using a calibrated digital pH meter (Jenway 3510, UK). Total carbohydrate content was quantified spectrophotometrically (Jenway 67 Series, UK) via the phenol-sulfuric acid method (Dubois et al. (1956)). Total phenolic compounds were assayed using the Folin-Ciocalteu method (Singleton and Rossi (1965)), with total flavonoids determined according to Jia et al. (1999).

Antioxidant capacity was evaluated through DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity as described by Brand-Williams et al. (1995), with absorbance measurements recorded at 517 nm.

2.2.4. Sensory properties determination

The sensory attributes of prepared jams (appearance, texture, color, and taste) were evaluated using a 9-point hedonic scale (1 = "not pleasant" to 9 = "very pleasant"). The panel consisted of 15 evaluators, including 5 trained panelists from the research staff and 10 untrained consumers, following the standardized sensory evaluation protocol described by Yassine et al. (2015). All evaluations were conducted under controlled conditions with randomized sample presentation to minimize bias.

2.2.5. Statistical Analyses

Statistical analyses were performed using one-way analysis of variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$) with the Costat statistical software (Version 6.400). The experimental data were analyzed as a completely randomized design according to Steel et al. (1997). Post-hoc comparisons of means between treatment groups were conducted using Fisher's Least Significant Difference (LSD) test to identify statistically significant differences among sample means.

3. Result and discussion

3.1. Physico-Chemical Analysis

3.1.1. Moisture content (%)

Moisture content serves as a critical determinant of product shelf-life and quality stability, with higher moisture levels typically correlating with reduced preservation potential (Sutwal et al., 2019). As shown in Table 2, complete (100%) substitution of refined sugar with natural sweeteners (date syrup or white grape juice concentrate) significantly increased ($p < 0.05$) the moisture content compared to the control. The AD treatment (date syrup) exhibited the highest moisture content (39.27%), followed by AG (white grape juice concentrate; 39.80%), while the control sample showed the lowest value (36.84%). These findings are consistent with previous studies reporting similar moisture retention patterns in sugar-substituted products (Correa et al., 2014 ; Ahmad et al., 2022).

Throughout the 6-month storage period, all jam formulations exhibited progressive moisture loss, with statistically significant differences ($p < 0.05$) observed between treatments. The control sample demonstrated the highest moisture reduction (6.2%), while the AD treatment (date syrup substitution) showed the most favorable moisture retention with only 5.0% loss. This moisture decline likely results from gradual water evaporation through packaging materials, consistent with the findings of (Kumar et al., 2017). The superior moisture retention in sugar-substituted samples may be attributed to the higher hygroscopicity of natural sweeteners compared to sucrose.

3.1.2. pH values

pH represents a critical quality parameter affecting jam gelation properties and microbial stability. Complete (100%) sugar substitution with natural sweeteners significantly increased ($p < 0.05$) the pH values compared to the control (Table 2). The AG treatment (white grape juice concentrate) showed the highest pH (4.55), followed by AD (date syrup; 3.94). while the control sample maintained the lowest pH (3.65). These findings corroborate previous reports by Ahmad et al. (2022). on the pH-modifying effects of natural sweetener substitution in fruit preserves. The observed pH elevation may be attributed to the inherent buffering capacity and organic acid profiles of the alternative sweeteners.

Throughout the 6-month storage period, all jam formulations exhibited a gradual pH reduction, with statistically significant differences ($p < 0.05$) observed between treatments. The control sample demonstrated the most pronounced pH decrease (3.2% reduction), while the AG treatment (white grape juice concentrate) showed superior pH stability with only 1.02% reduction. This progressive acidification likely results from two concurrent processes: (1) liberation of free acids through chemical breakdown of jam constituents, and (2) pectin hydrolysis generating uronic acids, as previously reported by Ahmad et al. (2022). The enhanced pH stability observed in sugar-substituted samples may reflect the superior buffering capacity of natural sweeteners' complex carbohydrate matrices.

3.1.3. Total carbohydrate content %

As presented in Table 2, complete (100%) sugar substitution with natural sweeteners significantly reduced ($p < 0.05$) the total carbohydrate content compared to the control. The AD treatment (date syrup) showed 58.27% carbohydrates, followed by AG (white grape juice concentrate) at 53.06%, while the sucrose-based control maintained the highest level (64.07%). During 6-month storage, all formulations exhibited a marginal but consistent increase in carbohydrate content (approximately 1.2-2.5% relative increase), likely attributable to sucrose inversion into reducing sugars as described by Manik, (2022). This phenomenon was most pronounced in control samples, suggesting natural sweeteners may exhibit greater carbohydrate stability during storage.

Table 2. Physico-chemical analysis of apple jam during storage at 25°C±5°C for 6months

Parameter	Treatment	Shelf life (months)			
		0	2	4	6
Moisture %	control	36.84 ^b ± 0.58	36.52 ^b ± 0.01	35.51 ^b ± 0.34	34.55 ^b ± 0.04
	AD	39.27 ^a ± 0.04	38.53 ^a ± 0.01	38.25 ^a ± 0.04	37.29 ^a ± 0.22
	AG	39.80 ^a ± 0.16	38.86 ^a ± 0.3	38.13 ^a ± 0.08	37.02 ^a ± 0.06
	LSD 0.05 %	0.84	0.38	0.49	0.32
pH	Control	3.65 ^c ± 0.00	3.61 ^c ± 0.00	3.59 ^c ± 0.00	3.53 ^c ± 0.00
	AD	3.94 ^b ± 0.00	3.91 ^b ± 0.00	3.89 ^b ± 0.00	3.87 ^b ± 0.00
	AG	4.55 ^a ± 0.00	4.54 ^a ± 0.00	4.53 ^a ± 0.00	4.51 ^a ± 0.00
	LSD 0.05 %	0.01	0.02	0.01	0.01
Total Carbohydrate%	Control	64.07 ^a ± 0.5	64.40 ^a ± 0.4	64.69 ^a ± 0.3	65.44 ^a ± 0.4
	AD	58.27 ^b ± 0.9	58.65 ^b ± 1.0	59.14 ^b ± 0.1	60.02 ^b ± 0.8
	AG	53.06 ^c ± 0.2	53.53 ^c ± 0.1	53.89 ^c ± 0.5	54.25 ^c ± 0.4
	LSD 0.05 %	1.88	2.52	0.78	1.39

3.2. Antioxidant activity

As demonstrated in Table 3, complete (100%) sucrose substitution with natural sweeteners significantly enhanced ($p < 0.05$) the DPPH radical scavenging activity compared to the control. The AD treatment (date syrup) exhibited the highest antioxidant capacity (58.6%), followed by AG (white grape juice concentrate; 36.99%), while the control sample showed the lowest activity (22.34%). These results align with previous findings by (Correa et al., 2014; El-Ghandour et al. 2019), confirming the superior antioxidant potential of natural sweetener-based formulations.

During six months of room temperature storage, all jam samples experienced progressive antioxidant activity loss, though treatment AD demonstrated remarkable stability. The control sample showed the most significant degradation (21.5% reduction), while AD maintained the highest retention with only 8.9% activity loss. This pattern corroborates the work of Rababah et al. (2011), who reported similar antioxidant decline trends ($p < 0.05$) in stored fruit preserves. The enhanced stability of natural sweetener formulations may be attributed to: Higher initial phenolic content in date syrup and grape concentrate, Synergistic protection effects between natural antioxidants, Reduced oxidative degradation rates in complex sweetener matrices

3.2.1. Total phenolic compounds (mg/g)

Phenolic compounds have been shown in numerous studies to offer important health benefits, especially when consumed in foods like fruits. In addition to their antioxidant properties, these compounds possess various biochemical characteristics that may help prevent diseases such as cancer and heart conditions (Djaoudene et al., 2024). Their presence in food contributes significantly to these protective health effects.

The data in Table 3 demonstrate a significant enhancement in total phenolic content (TPC) across the various apple jam formulations. The AD sample (apple jam with date syrup) showed the highest TPC levels, whereas the control sample displayed the lowest values. This clearly indicates that replacing sugar with natural sweeteners - specifically date syrup and white grape juice concentrate -

substantially boosted the phenolic content. These observations align with previous findings reported by El-Ghandour et al. (2019). The data in Table 3 reveal a gradual decrease in total phenolic compounds (TPC) across all jam samples during the 6-month storage period at room temperature. Initial TPC values measured 3.85, 1.59, and 0.43 mg/g for the AD (date syrup), AG (grape juice concentrate), and control samples, respectively. By the end of storage, these values declined to 3.64, 1.47, and 0.32 mg/g, demonstrating relative reductions of 5.5%, 7.5%, and 25.6% respectively. This pattern of phenolic degradation during storage is consistent with the findings of Banaś et al. (2018), who reported a 16% decrease in polyphenol content in apple jam over a similar storage duration.

Parameter	Treatment	Shelf life (months)			
		0	2	4	6
(DPPH) %	control	22.34 ^c ± 0.4	20.06 ^c ± 0.4	19.64 ^c ± 0.6	17.53 ^c ± 0.2
	AD	58.6 ^a ± 0.2	56.96 ^a ± 0.5	55.14 ^a ± 0.9	53.37 ^a ± 0.2
	AG	36.99 ^b ± 0.4	35.17 ^b ± 0.2	33.42 ^b ± 0.4	31.68 ^b ± 0.05
	LSD 0.05 %	0.78	0.93	1.61	0.61
Total phenolic compound mg/g	control	0.43 ^c ± 0.01	0.40 ^c ± 0.04	0.35 ^c ± 0.01	0.32 ^c ± 0.01
	AD	3.85 ^a ± 0.04	3.82 ^a ± 0.01	3.77 ^a ± 0.02	3.64 ^a ± 0.04
	AG	1.59 ^b ± 0.01	1.56 ^b ± 0.02	1.52 ^b ± 0.01	1.47 ^b ± 0.05
	LSD 0.05 %	0.05	0.17	0.03	0.08
Total flavonoids compound mg/g	control	0.18 ^c ± 0.01	0.17 ^c ± 0.01	0.16 ^c ± 0.01	0.15 ^c ± 0.01
	AD	1.68 ^a ± 0.02	1.67 ^a ± 0.01	1.66 ^a ± 0.01	1.61 ^a ± 0.001
	AG	0.77 ^b ± 0.01	0.75 ^b ± 0.03	0.74 ^b ± 0.03	0.72 ^b ± 0.03
	LSD 0.05 %	0.04	0.10	0.04	0.03

Table 3. antioxidant activity of apple jam during storage at 25°C±5°C for 6months

3.2.3. Total Flavonoid Compounds (mg/g)

As presented in Table 3, complete (100%) substitution of sucrose with natural sweeteners (date syrup and white grape juice concentrate) significantly increased ($p \leq 0.05$) the total flavonoid content in apple jam. The AD treatment (date syrup) exhibited the highest flavonoid concentration (1.68 mg/g), followed by AG (white grape juice concentrate; 0.77 mg/g), while the control sample showed the lowest value (0.18 mg/g). These findings are consistent with those reported by Shahein et al. (2022).

During the 6-month storage period, all samples demonstrated a gradual decline in flavonoid content. The control sample experienced the most substantial reduction (15.09%), whereas the AD treatment showed the greatest stability with only a 3.96% decrease. This pattern of flavonoid degradation during storage corroborates previous observations by (Rababah et al., 2011), confirming the superior retention of bioactive compounds in natural sweetener-based formulations.

3.3. Sensory Characteristics of Apple Jam

Organoleptic assessment serves as a critical quality parameter in jam production, directly reflecting consumer preferences. The complete (100%) substitution of sugar with natural sweeteners significantly affected ($p \leq 0.05$) the overall acceptability scores, as shown in Table 4. The control sample (37.75) maintained higher acceptability compared to AD (date syrup; 35.32) and AG (white grape juice concentrate; 33.18) formulations. This preference pattern was consistent across all sensory parameters, likely attributable to panelists' familiarity with the conventional sucrose-sweetened apple jam flavor profile.

Table 4. Changes in sensory evaluation of apple jam at zero time of storage at 25°C±5°C

Parameter	Treatment			
	Control	AD	AG	LSD 0.05 %
Appearance (10)	9.50 ^a ±0.5	8.66 ^b ± 0.7	8.43 ^b ± 0.5	0.81
Texture (10)	9.37 ^a ±0.4	8.81 ^{ab} ±0.6	8.50 ^b ±0.8	0.78
Taste (10)	9.37 ^a ±0.6	9.10 ^a ±0.8	8.60 ^a ±0.8	1.03
Color (10)	9.50 ^a ± 0.5	8.75 ^{ab} ±0.8	7.83 ^b ±0.7	1.09
Overall palatability (40)	37.75 ^a ±0.7	35.32 ^b ±0.5	33.18 ^c ±0.8	1.9

3.4. Microbiological Analyses

Microbiological study is a very important tool for ensuring the ability of food product to withstand microbial growth or spoilage and also to determine the storage conditions required to keep microbial growth or spoilage at bay (Ellin, 2007). As shown in Table 5, no bacterial counts were detected at initial time (zero time) and during storage period at room temperature for 2, 4, and 6 months. Meanwhile, mold and yeast were detected in control sample and apple jam with white grape juice concentrate AG at (3×10^3 , 6×10^3 , 9×10^3 and 11×10^3) C.F.U/g and (6×10^3 , 8×10^3 , 10×10^3 and 12×10^3) C.F.U/g at zero time, 2, 4 and 6 months of storage period respectively. Although there was a slight increase in yeast and mold counts in jam samples during storage, it remained within the allowable limit. Result also reveal that substituting sugar with date syrup in apple jam were not detected in total bacterial count, yeast and mold at initial time (zero time) and during storage period at room temperature for 2, 4, and 6 months due to the antimicrobial effect of date syrup could be attributed to its phenolic content. Previous work of Taleb et al. (2016) reported that date syrup polyphenols, the most abundant bioactive constituent in date syrup, have antibacterial activity.

Table (5) Effect of storage period on total visible counts of apple jam (cfu/g)

Blends	Total bacterial count log cfu/g					Yeast & mold log cfu/g				
	Zero Time	After 2month	After 4 months	After 6month	Acceptability range count (per plate)	Zero time	After 3month	After 4 months	After 6 months	Acceptability range (per plate)
control	ND	ND	ND	ND		3×10^3	6×10^3	9×10^3	11×10^3	
AD	ND	ND	ND	ND	30 cfu.-300 cfu	ND	ND	ND	ND	15cfu-120cfu
AG	ND	ND	ND	ND		6×10^3	8×10^3	10×10^3	12×10^3	

4. Conclusion

This study demonstrates that replacing sucrose with natural sweeteners (date syrup and white grape juice concentrate) in apple jam enhances its bioactive compounds, including phenolics and flavonoids, while improving antioxidant capacity—particularly in date syrup-enriched jam. However, these nutritional benefits come with slight reductions in sensory acceptability compared to traditional sucrose-based jam, likely due to flavor preferences. Although all samples experienced gradual declines in bioactive content during storage, the natural sweetener formulations showed better retention than the control. These findings highlight the potential of natural sweeteners to produce functional jams with health-promoting properties, though further optimization is needed to balance nutritional value with consumer appeal. Future research should explore blended sweetener systems to improve taste without compromising health benefits.

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