

Production and Evaluation of an Innovative Vegetable-Based Functional Jam from Zucchini and Orange-Fleshed Sweet Potatoes

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ABSTRACT

Vegetables are rich sources of bioactive compounds that support human health. However, zucchini is often less preferred by children. This study aimed to develop a functional vegetable-based jam from zucchini (*Cucurbita pepo*) and orange-fleshed sweet potatoes (*Ipomoea batatas* L.) to improve both composition and sensory appeal. Five jam formulations with varying zucchini to sweet potato ratios (100:0, 0:100, 75:25, 50:50, and 25:75) were prepared and analyzed for their chemical composition, mineral content, antioxidant activity, physicochemical properties, and sensory characteristics. All experiments were conducted in triplicate, and data were statistically analyzed using ANOVA and Duncan's multiple range test ($p < 0.05$). Sweet potato exhibited higher phenolic (3.91mg GAE/g) and flavonoid (1.59mg QE/g) contents compared to zucchini. The jam containing 100% sweet potato had the highest protein (4.80%) and crude fiber (2.42%) content, whereas the mixed jams (50:50 and 25:75) were richer in potassium, zinc, and iron. All jam samples were sensorily acceptable, with only minor differences in color. The jams provided 21-23% of the recommended daily energy intake for children aged 4-6 years. These findings demonstrate that combining zucchini and sweet potato in jam produces a nutritious, child-friendly product suitable for school feeding programs and functional food applications.

1. Introduction

Regular consumption of fruits and vegetables is associated with a lower risk of chronic diseases due to their rich content of nutrients and phytochemicals (Liu, 2013). Jam is a semi-solid sweet spread produced by cooking fruits, vegetables, or a mixture of both with sugar (Codex, 2009). Proper formulation with fruit, acid, pectin, and sugar ensures extended availability beyond seasonal harvests and provides optimal texture and shelf life. In response to growing health-conscious consumer demand, innovative products such as vegetable-based jams are gaining attention; however, their production and market presence remain limited. Zucchini (*Cucurbita pepo*), a member of the Cucurbitaceae family, is classified as a summer squash. Its skin color varies from light to dark green and may display fine white mottling or striped patterns (Cagliani and Consonni, 2024). From a nutritional

perspective, zucchini is a rich source of essential nutrients, including vitamins, minerals, and bioactive compounds. Moreover, it is abundant in antioxidants that contribute to various health benefits (Zhang et al., 2023; Cagliani and Consonni, 2024; Jhanani et al., 2024). In Egypt, the total cultivated area of zucchini was approximately 24,923 hectares in 2016, yielding about 471,571 metric tons, according to the Ministry of Agriculture and Land Reclamation (2016), as cited by Tolba et al. (2021). Sweet potato (*Ipomoea batatas*), a member of the convolvulaceae family, is recognized for its high nutritional value. Its roots are rich in starch, protein, dietary fiber, phenolics, vitamins and minerals, while being low in fat. Depending on the flesh color, sweet potatoes contain varying levels of bioactive compounds, including β -carotene, anthocyanins, and other antioxidants.

Orange-fleshed varieties are rich in energy and β -carotene a provitamin A compound making them an effective food-based strategy for combating vitamin A deficiency (Natocho et al., 2024; He et al., 2025; Kuyu et al., 2025). Additionally, sweet potatoes exhibit beneficial physiological properties such as the regulation of blood glucose and lipids, immune enhancement, and antioxidant and anticancer effects (Hou et al., 2019). In Egypt, sweet potato is a major vegetable crop, with approximately 28,526 feddans cultivated in 2018, yielding an average of 11.77 tons per feddan (FAOSTAT, 2020). Both zucchini and orange-fleshed sweet potatoes are rich in dietary fiber, essential minerals, antioxidants, and carotenoids. Therefore, this study aimed to develop innovative jams using orange-fleshed sweet potatoes and zucchini, to evaluate their nutritional, physicochemical, and sensory properties, and to assess their potential contribution to children's dietary energy requirements, thereby addressing the limited availability of vegetable-based jams in the market.

2. Materials and Methods

Materials

Sweet potatoes (*Ipomoea batatas* L.), zucchini (*Cucurbita pepo*), pectin, citric acid, and sugar were purchased from a local market in Giza, Egypt. All

other chemicals and reagents used were of analytical grade and obtained from Sigma-Aldrich (Germany/USA) and Gomhouria Co. The Folin-Ciocalteu phenol reagent was purchased from Fluka (France).

Jam Preparation

The vegetable jam was prepared using a modified method described by Alqahtani (2020). Whole sweet potatoes and zucchini were washed and cut into small slices. For each batch, 500 g of zucchini and/or sweet potato were mixed with sugar and orange peel (used as a flavor enhancer). The mixture was allowed to stand at room temperature ($25\pm 2^\circ\text{C}$) for 45 minutes. It was then slowly cooked with continuous stirring until the temperature reached 100°C . At this point, pectin was added while stirring continued. Citric acid was added at the final stage of the cooking process. The mixture was cooked for approximately 35 minutes until the final product contained approximately 70% total soluble solids (TSS), as determined by a refractometer. The hot jam was poured into pre-sterilized glass jars and allowed to cool. Five different formulations were prepared, as detailed in Table 1 and illustrated in Figure 1. All jam samples were stored at room temperature ($25\pm 5^\circ\text{C}$) until analysis.

Table 1. Ingredients of vegetable-based jam

Types of mixture	Ingredients					
	Zucchini (g)	sweet potato (g)	Sugar (g)	citric acid (%)	pectin powder (%)	orange peel (g)
T1:100% whole zucchini	500	-	500	0.5	1.5	1
T2:100% whole sweet potato	-	500	500	0.5	1.5	1
T3:75% whole zucchini +25% whole sweet potato	375	125	500	0.5	1.5	1
T4:50% whole zucchini + 50% whole sweet potato	250	250	500	0.5	1.5	1
T5:25% whole zucchini +75 % whole sweet potato	125	375	500	0.5	1.5	1

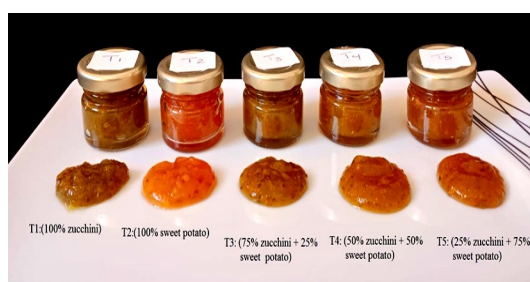


Figure 1. Vegetable based jam samples

Methods of analysis

Determination of phytochemicals in raw materials

The total phenolic content was determined using the Folin-Ciocalteu reagent according to the method of Franková et al. (2022). Results were expressed as milligrams of gallic acid equivalent per gram of sample (mg GAE/g). The total flavonoid content was determined by a colorimetric method as described by Barros et al. (2010), and the results were expressed as milligrams of quercetin equivalent per gram (mg QE/g). The free radical scavenging activity of the extracts was evaluated based on the reduction in absorbance of a methanolic solution of the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical, following the procedure outlined by Brand-Williams et al. (1995).

Chemical analysis

The samples were chemically analyzed for moisture, ash, protein, fat, and crude fiber using the standard methods described by AOAC (2019). The available carbohydrate content was calculated by difference $[100 - (\text{moisture} + \text{ash} + \text{protein} + \text{fat} + \text{crude fiber})\%]$ as outlined by FAO (2003). Mineral contents (Fe, K, Ca, and Zn) were determined according to AOAC (2019) using an Atomic Absorption Spectrophotometer (Perkin Elmer, Model 3300, USA). The contents of total sugars, reducing sugars, and non-reducing sugars were analyzed according to the methods described in AOAC (2019). The carotenoid content in the samples was determined according to the method described by Lee et al. (2001). Briefly, five grams of each sample were homogenized with 30 mL of 85% acetone in amber bottles and kept at room temperature for 15 hours in the dark. The mixture was then filtered through glass wool into a 100 mL volumetric flask. The residue was washed, and the flask was made up to the mark with 85% acetone. The absorbance of the prepared extracts was measured using a spectrophotometer at wavelengths of 662, 644, and 440 nm. A blank was prepared using 85% acetone. The contents of total carotenoids and chlorophylls were calculated using the following equations:

$$\text{Chlorophyll A } (\mu\text{g/g}) = (9.784 \times E_{662}) - (0.99 \times E_{644}).$$

$$\text{Chlorophyll B } (\mu\text{g/g}) = (21.426 \times E_{664}) - (4.65 \times E_{662}).$$

$$\text{Chlorophyll A+B } (\mu\text{g/g}) = (5.134 \times E_{662}) + (20.436 \times E_{644}).$$

$$\text{Total carotenoids } (\mu\text{g/g}) = 4.695 \times E_{440} - 0.268 \times (\text{Chlorophyll A+B}).$$

Where E. = Optical density at the wavelength indicated.

Physicochemical Properties of Jam Samples

The physicochemical properties, including pH, total acidity, and total soluble solids (TSS), were determined according to the methods described by AOAC (2019).

Determination of Viscosity

The viscosity of the jam was measured using a Brookfield Engineering Labs DV-III Ultra Rheometer. The sample was placed in a small sample adapter, and a constant-temperature water bath was used to maintain the desired temperature. The viscometer was operated at 10 rpm. Viscosity data, reported in centipoise (cP), were obtained directly from the instrument; the HA-07 spindle was selected for measurements conducted at room temperature ($25 \pm 1^\circ\text{C}$), according to Salama et al. (2020).

Water Activity

The water activity (a_w) of the jam samples was measured using a water activity meter (AL 1823, Aqua Lab, USA). A small amount of each sample was placed in the sample cup, and the measurement was conducted at $25 \pm 0.50^\circ\text{C}$, following the procedure described by Rongtong et al. (2018). After equilibration, the water activity value was recorded.

Color Attributes

The color of the jam samples was measured instrumentally using a hand-held Chroma meter (model CR-400, Konica Minolta, Japan). The results were expressed in terms of L^* (lightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness). The total color difference (ΔE) between jam samples was calculated using the following equation: $\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$

The detailed procedure is outlined in Francis (1983). All measurements were performed in triplicate, and average values are reported.

Texture Profile Analysis

The texture of the jam samples was determined using a universal testing machine (Cometech, B type, Taiwan). A flat-headed stainless steel cylindrical probe with a diameter of 2 mm was used for the penetration test. The test commenced upon contact between the probe and the sample surface and concluded when the probe had penetrated to 50% of the sample's height. The probe speed was set at 1 mm/s, as described by Bourne (2002).

Sensory Evaluation

Sensory evaluation was performed by 15 trained panelists from the Food Technology Research Institute. The sensory attributes, including taste, color, odor, spreadability, appearance, and overall acceptability, were evaluated immediately after preparation. All jam samples were coded and presented randomly to the panelists. The degree of liking or disliking was assessed using a 9-point hedonic scale with descriptive categories, ranging from "like extremely" (9) to "dislike extremely" (1), where "neither like nor dislike" (5) represented the neutral point. The scale categories were defined as follows: like very much (8), like moderately (7), like slightly (6), dislike slightly (4), dislike moderately (3), and dislike very much (2), according to Akinlolu-Ojo et al. (2022). The estimated energy contribution of the jams for pre- and primary school children aged 4–12 years was calculated based on the recommended daily energy requirements (kcal/

day) according to the World Health Organization (2004).

Statistical Analysis

All experiments were conducted in triplicate. Data were analyzed using SAS (2003) software (Version 9.1, SAS Institute, Cary, NC, USA). One-way analysis of variance (ANOVA) was applied, and mean comparisons were performed using Duncan's multiple range test at a significance level of $p < 0.05$. Results are expressed as mean $\pm$ standard deviation (SD).

3. Results and Discussion

Phytochemical properties of raw materials

The phytochemical composition of orange-fleshed sweet potato and green zucchini is presented in Table 2. Sweet potato exhibited significantly higher levels of total phenolic content (3.91 ± 0.13 mg GAE/g) and flavonoids (1.59 ± 0.09 mg QE/g) compared to zucchini (1.55 ± 0.07 mg GAE/g and 1.34 ± 0.12 mg QE/g), respectively. Similarly, the DPPH radical scavenging activity of sweet potato ($48.95 \pm 0.6\%$) was superior to that of zucchini ($35.31 \pm 0.2\%$). These results demonstrate that orange-fleshed sweet potato is a richer source of bioactive compounds contributing to higher antioxidant capacity. Similar findings were reported by Huang et al. (2005), who observed that phenolic and flavonoid levels in sweet potatoes depend on genotype and processing. Although zucchini contains antioxidants (Pandey et al., 2024), its total content is comparatively lower. Thus, incorporating sweet potato enhances the antioxidant potential of the developed vegetable-based jams.

Table 2. Bioactive properties in sweet potatoes and zucchini (on fresh weight basis)

Sample	Total phenolic (mg Gallic acid /g)	Total flavonoids (mg quercetin /g)	DPPH %
Whole sweet potato orange	$3.91^a \pm 0.13$	$1.59^a \pm 0.09$	$48.95^a \pm 0.6$
Whole zucchini green	$1.55^b \pm 0.07$	$1.34^b \pm 0.12$	$35.31^b \pm 0.2$

The mean values ($n=3 \pm$ S.D) have different superscript letters at the same column, indicating a significant difference ($P < 0.05$).

Nutritional qualities of raw materials and vegetable-based jam

Table 3 presents the proximate composition of both raw materials and formulated jams. Sweet potato had higher contents of fiber (2.11%), protein

(4.76%), fat (0.72%), and carbohydrates (18.25%) compared to zucchini, which exhibited higher moisture (90.45%). Among the jam samples, moisture content ranged from 20.01% (T3) to 27.30% (T1). The jam containing 100% sweet potato (T2)

exhibited the highest protein (4.80%) and crude fiber (2.42%) levels, while the mixed formulations (T4 and T5) showed intermediate values. These differences reflect the distinct compositional profiles of the raw materials. These trends are consistent with findings reported by Adepoju and Adejumo (2015) and Zhang et al. (2003), who highlighted the nutrient-dense profile of sweet potato and the characteristically high water content of zucchini. In summary, the partial substitution of zucchini with sweet potato improved the nutritional quality of the jam by increasing its protein, fiber, and carbohydrate contents, while maintaining acceptable moisture levels.

Table 3. The chemical composition of the raw materials and vegetable-based Jam (on fresh weight basis)

Item	Contents (%)					
	Moisture	Ash	Fiber	protein	Fat	*Available carbohydrates
Whole sweet potato orange	73.60 ^b ±1.15	0.56 ^a ±0.012	2.11 ^a ±1.15	4.76 ^a ±0.15	0.72 ^a ±0.20	18.25 ^a ±0.15
Whole zucchini	90.45 ^a ±1.26	0.52 ^a ±0.56	1.53 ^b ±1.18	1.51 ^b ±0.18	0.15 ^b ±1.18	5.84 ^b ±0.54
Types of mixture						
T1	27.30 ^a ±0.56	0.65 ^a ±0.78	1.74 ^b ±1.56	1.62 ^d ±1.23	0.16 ^c ±0.78	68.53 ^c ±0.18
T2	24.0 ^b ±0.22	0.72 ^a ±0.45	2.42 ^a ±1.72	4.80 ^a ±1.12	0.75 ^a ±1.14	67.31 ^d ±1.78
T3	20.01 ^d ±0.16	0.53 ^{ab} ±0.56	1.67 ^b ±1.78	2.32 ^c ±0.66	0.29 ^c ±1.56	75.18 ^a ±1.34
T4	22.95 ^c ±0.78	0.54 ^a ±0.76	1.82 ^{ab} ±0.98	3.14 ^b ±0.98	0.44 ^b ±0.98	71.11 ^b ±0.92
T5	24.24 ^b ±0.96	0.55 ^{ab} ±0.85	1.96 ^{ab} ±0.78	3.44 ^b ±0.34	0.58 ^b ±1.14	69.23 ^c ±1.34

Data are presented as mean (n = 3) with standard deviation. Mean values at the same column with different letters are significantly different at $p \leq 0.05$. *Available carbohydrates in the mixture was calculated by difference. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato.

Chlorophyll A, chlorophyll B and total carotenoids

As shown in Table 4, zucchini contained significantly higher chlorophyll A (632.48µg/g) and chlorophyll B (520.70µg/g) than sweet potato, whereas sweet potato exhibited significantly higher total carotenoid content (51.43µg/g). Among the jam samples, chlorophyll concentrations decreased with increasing proportions of sweet potato, while carotenoid levels increased concurrently. The jam made entirely from sweet potato (T2) exhibited the highest carotenoid content (83.00 µg/g). This pattern demonstrates that orange-fleshed sweet potatoes are an excellent source of β-carotene, while zucchini contributes chlorophylls to the product. These findings are consistent with those of Adepoju and Adejumo (2015) and Salehi et al. (2019), who emphasized the nutritional and functional importance of carotenoids and chlorophylls in vegetables.

Sugar Content in raw materials and vegetable-based Jam

The total, reducing, and non-reducing sugars of raw materials and jams are shown in Table 5. Zucchini contained slightly higher natural sugar content than sweet potato, which resulted in higher total and reducing sugar levels in the T1 jam (100% zucchini). After processing, all jam samples exhibited a substantial increase in total sugar content (>54%), attributable to the addition of sucrose. This elevated sugar level is consistent with the Codex Alimentarius standards for jam stability and quality (Codex, 2009). The zucchini-rich jam (T1) had the highest reducing sugar content (52.11%), while the sweet potato-based jams (T2 and T5) contained higher levels of non-reducing sugars, reflecting the starchy nature of sweet potatoes. According to Bekele et al. (2020), the ratio between reducing and non-reducing sugars strongly affects sweetness, color development, and texture during thermal processing

Table 4. Chlorophyll A, chlorophyll B, and total carotenoids ($\mu\text{g/gm}$) in raw materials and vegetable-based jam

Item	Chlorophyll A	Chlorophyll B	Total carotenoids
Whole sweet potato orange	238.00 ^b $\pm$ 1.23	393.21 ^b $\pm$ 1.45	51.43 ^a $\pm$ 0.276
Whole Zucchini green	632.48 ^a $\pm$ 1.11	520.70 ^a $\pm$ 1.11	25.90 ^b $\pm$ 1.45
Types of mixture			
T1	511.64 ^a $\pm$ 1.04	269.35 ^a $\pm$ 0.2	42.29 ^c $\pm$ 1.23
T2	197.52 ^c $\pm$ 1.10	191.54 ^c $\pm$ 1.07	83.00 ^a $\pm$ 2.14
T3	303.27 ^b $\pm$ 1.11	245.41 ^{ab} $\pm$ 1.10	48.28 ^{bc} $\pm$ 1.45
T4	243.41 ^{bc} $\pm$ 1.07	201.51 ^b $\pm$ 1.34	69.83 ^b $\pm$ 1.47
T5	185.33 ^d $\pm$ 1.05	133.67 ^d $\pm$ 1.22	62.051 ^b $\pm$ 1.11

Data are presented as mean (n = 3) with standard deviation. Data values of each parameter at the same column with different superscript letters are significantly different at $p < 0.05$. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato.

Table 5. Total, reducing and non-reducing sugars (%) in raw materials vegetable-based jam

Item	Total sugars	Reducing sugars	Non reducing sugars
Whole sweet potato orange	1.43 ^a $\pm$ 0.17	0.120 ^a $\pm$ 0.23	1.31 ^a $\pm$ 0.34
Whole Zucchini green	1.74 ^a $\pm$ 0.23	0.240 ^a $\pm$ 0.16	1.50 ^a $\pm$ 0.36
Types of mixture			
T1	57.35 ^a $\pm$ 1.10	52.11 ^a $\pm$ 1.15	5.24 ^b $\pm$ 1.40
T2	54.98 ^b $\pm$ 1.15	47.87 ^b $\pm$ 1.25	7.11 ^{ab} $\pm$ 1.12
T3	55.72 ^{ab} $\pm$ 1.12	47.94 ^b $\pm$ 1.45	7.78 ^{ab} $\pm$ 1.23
T4	56.31 ^{ab} $\pm$ 1.45	46.96 ^b $\pm$ 1.33	9.35 ^a $\pm$ 1.12
T5	54.48 ^b $\pm$ 1.23	46.07 ^b $\pm$ 1.45	8.77 ^a $\pm$ 1.11

Data are presented as mean (n = 3) with standard deviation. Data values of each parameter with different superscript letters are significantly different at $p < 0.05$. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato

Mineral Content in Vegetable-Based Jam

The mineral content of the raw materials and jam samples is presented in Table 6. Potassium was the most abundant mineral across all samples, followed by calcium, iron, and zinc. Both sweet potato and zucchini provided valuable mineral contributions; however, the sweet potato-based jams (T2 and T5) contained higher calcium levels, whereas the zucchini-rich formulations exhibited slightly higher iron content. Blending zucchini and sweet potato improved the overall mineral balance of the jams, particularly in treatments T4 and T5, which were richer in potassium and zinc. These findings are in agreement with Laurie et al. (2012) and Alam et al. (2020), who noted that mineral profiles vary with cultivar and growing conditions. The slight mineral loss observed may result from leaching during heat processing (Xu et al., 2022).

Physicochemical Properties of Jam Treatments

The physicochemical parameters of the jam the ratio between reducing and non-reducing sugars strongly affects sweetness, color development, and texture during thermal processing. The pH values varied between 3.20 (T1) and 5.30 (T5), exhibiting the expected inverse relationship with titratable acidity, which ranged from 0.42% (T3) to 0.62% (T1). Viscosity ranged from 250cP in T1 to 500cP in T3. The general increase in viscosity associated with higher sweet potato ratios can be attributed to the higher starch and dietary fiber content of sweet potatoes. No significant differences were observed in water activity among the treatments. These results align with findings from previous studies (Jain et al., 2011 and Shen et al., 2021), confirming that sugar concentration, pectin content, and acidity are key factors determining jam texture and stabil-

Table 6. Minerals content of vegetable-based jam (on fresh weight)

Item	Minerals content (mg/100g)			
	K	Ca	Zn	Fe
Whole Sweet potato orange	260 ^a ± 0.62	30 ^a ± 0.87	0.50 ^a ±0.24	0.60 ^a ± 1.45
Whole Zucchini green	259 ^a ± 1.12	16 ^b ± 0.98	0.25 ^b ± 0.12	0.73 ^a ± 0.71
Types of mixture				
T1	229.12 ^c ±1.02	16.53 ^e ±0.97	0.26 ^a ±1.05	0.54 ^{ab} ±1.45
T2	234.02 ^b ±1.07	24.8 ^b ±1.01	0.27 ^a ±1.05	0.44 ^{ab} ±1.26
T3	239.23 ^b ±1.23	19.45 ^d ±1.45	0.24 ^a ±1.06	0.70 ^a ±1.14
T4	249.31 ^a ±1.25	22.85 ^c ±1.17	0.28 ^a ±1.02	0.67 ^a ±1.11
T5	249.75 ^a ±1.12	26.54 ^a ±1.23	0.29 ^a ±1.12	0.65 ^a ±1.45

Data are presented as mean (n = 3) with standard deviation. Data values of each parameter with different superscript letters are significantly different at p < 0.05. **T1:**100% whole zucchini. **T2:** 100% whole sweet potato. **T3:** 75% whole zucchini +25% whole sweet potato. **T4:** 50% whole zucchini +50 % whole sweet potato and **T5:** 25% whole zucchini +75 % whole sweet potato

Table 7. Water activity, total soluble solids, pH, acidity and viscosity in vegetable-based jam

Type of mixture	Water activity	T. S. S (°Brix)	pH	Acidity (%)	Viscosity(cP)
T1	0.756 ^a ±0.12	70.75 ^c ±0.15	3.20 ^c ±0.25	0.62 ^a ±0.71	250 ^c ±0.71
T2	0.761 ^a ±0.15	71.51 ^b ±0.15	4.00 ^b ±0.10	0.47 ^d ±0.35	300 ^d ±0.34
T3	0.708 ^a ±0.12	75.30 ^a ±0.15	4.59 ^b ±0.23	0.42 ^c ±0.21	500 ^a ±0.56
T4	0.730 ^a ±0.17	74.75 ^{ab} ±0.25	3.55 ^c ±0.12	0.61 ^b ±0.89	440 ^b ±0.78
T5	0.791 ^a ±0.12	70.53 ^c ±0.45	5.30 ^a ±0.12	0.51 ^c ±0.25	316 ^c ±0.41

Data are presented as mean (n = 3) with standard deviation. Data values of each parameter with different superscript letters are significantly different at p < 0.05. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato.

Color Attributes of Vegetable-Based Jam

Color parameters (L*, a*, b*) are presented in Table 8. Lightness (L*) increased with higher sweet potato content, reaching the highest value of 26.03 in sample T5. The redness (a*) value shifted from - 0.68 in T1 (indicating greenness) to 1.47 in T2 (indicating redness), demonstrating a clear transition towards reddish-orange hues. Yellowness (b*) also

increased with sweet potato content, peaking at 8.04 in T5. The calculated total color difference (ΔE) confirmed significant visual variations among the different formulations. These results demonstrate that sweet potato contributes strong natural pigments, enhancing the color intensity and consumer appeal of the jam. Similar color trends were reported for vegetable-based jams by Perumpuli et al. (2018).

Table 8. Color attributes of vegetable-based jam

Types of mixture	L*	a*	b*	ΔE
T1	22.33 ^{bc} ±0.24	-0.68 ^c ±0.15	6.32 ^c ±0.12	7.23 ^c ±0.24
T2	23.29 ^b ±0.10	1.47 ^a ±0.12	7.39 ^b ±0.14	8.61 ^b ±0.12
T3	20.43 ^c ±0.12	0.01 ^d ±0.15	4.77 ^d ±0.14	5.45 ^c ±0.23
T4	21.55 ^c ±0.35	0.90 ^b ±0.12	5.58 ^c ±0.14	6.38 ^d ±0.23
T5	26.03 ^a ±0.11	0.74 ^c ±0.11	8.04 ^a ±0.11	10.27 ^a ±0.21

Data are presented as mean (n = 3) with standard deviation. Data values of each parameter at same column with different superscript letters are significantly different at p < 0.05. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75% whole sweet potato.

Texture profile analysis (TPA) of vegetable-based jam

The textural profile of the jams are presented in Table 9. Firmness ranged from 0.93N in T1 (100 % zucchini) to 2.50N in T4, with sweet potato incorpo-

ration significantly increasing firmness and cohesiveness. The highest cohesiveness (0.49) and gumminess (0.81N) were recorded in T2, indicating stronger structural integrity. Springiness and chewiness also improved with sweet potato content,

reflecting the influence of its starch and pectin on gel formation. These results align with findings from previous studies (Jain et al., 2011 and Shen et al., 2021), confirming that sugar concentration, pectin content, and acidity are key factors determining jam texture and stability.

Table 9. Texture profile analysis (TPA) of vegetable-based jam

Types of mixture	Firmness, N	Cohesiveness	Gumminess, N	Springiness, mm	Chewiness, mj
T1	0.93 ^b ±0.17	0.30 ^c ±0.22	0.49 ^d ±0.12	0.50 ^c ±0.241	0.23 ^{ab} ±0.23
T2	2.26 ^a ±0.13	0.49 ^a ±0.16	0.81 ^a ±0.11	1.49 ^a ±0.115	0.40 ^a ±0.140
T3	2.16 ^a ±0.16	0.44 ^b ±0.17	0.36 ^c ±0.12	0.63 ^c ±0.071	0.36 ^a ±0.351
T4	2.50 ^a ±0.22	0.37 ^d ±0.12	0.65 ^b ±0.11	0.93 ^b ±0.124	0.20 ^{ab} ±0.37
T5	2.44 ^a ±0.15	0.39 ^c ±0.24	0.55 ^c ±0.04	1.27 ^a ±0.126	0.38 ^a ±0.112

Data are presented as mean (n = 3) with standard deviation. Data values of each parameter with different superscript letters are significantly different at $p < 0.05$. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato.

Sensory Evaluation of Vegetable-Based Jam

The mean sensory scores of the jam samples are presented in Table 10. No significant differences ($p > 0.05$) were observed among the treatments for taste, odor, or spreadability. However, significant differences were detected in color, appearance, and overall acceptability. Jams containing higher proportions of sweet potato (T4 and T5) received the highest overall acceptability scores, ranging from

7.70 to 8.00 on the 9-point hedonic scale. These results demonstrate that the incorporation of sweet potato enhances both the visual appeal and overall sensory quality of vegetable-based jams. Although the sensory evaluation was conducted with a panel of 15 trained members, which is a relatively small sample size, the results provide a valid preliminary assessment of consumer acceptance and product liking.

Table 10. Sensory evaluation of vegetable-based jam

Types of mixture	Taste	Color	Odor	Appearance	Spreadability	Overall acceptability
T1	7.63 ^a ±1.26	6.63 ^{bc} ±1.75	6.75 ^a ±1.73	7.00 ^b ±1.75	7.06 ^a ±1.44	7.31 ^{ab} ±1.54
T2	7.67 ^a ±1.25	8.31 ^a ±1.078	7.38 ^a ±1.36	8.13 ^a ±1.09	7.25 ^a ±1.34	6.94 ^b ±1.29
T3	7.19 ^a ±1.64	6.19 ^c ±1.974	6.63 ^a ±1.71	6.63 ^b ±1.66	7.06 ^a ±1.39	7.75 ^{ab} ±1.38
T4	7.00 ^a ±1.55	7.38 ^{ab} ±1.31	6.81 ^a ±1.60	7.50 ^{ab} ±1.15	7.13 ^a ±1.75	7.70 ^{ab} ±1.20
T5	7.88 ^a ±1.45	8.06 ^a ±0.929	7.44 ^a ±1.75	8.13 ^a ±0.95	7.69 ^a ±1.92	8.00 ^a ±1.27

Values are means of 15 replicates ± SD, Data values of each parameter at same column with different superscript letters are significantly different at $p < 0.05$. T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato.

Contribution of vegetable-based jam to daily energy requirements

Table 11 presents the calculated energy contribution of the jams. Energy values ranged between 282 and 313 kcal/100 g, representing 21–23% of the recommended daily energy intake for children aged 4–6 years. Sample T3 (75% zucchini + 25% sweet potato) provided the highest energy value (312.61

kcal/100 g). These results confirm that the developed jams can serve as energy-rich, nutrient-dense foods suitable for school nutrition programs. Similar complementary nutritional benefits have been reported by Zhang et al. (2003) and Martínez-Valdivieso et al. (2017).

Table 11. Percentage contribution of vegetable-based jam (by fresh weight) to the recommended daily energy intake for pre- and primary school children aged 4–12 years.

Types of mixture	Total energy (kcal/100g)	%Contribution to RDA*for children from energy(kcal/day)		
		4-6 years	7-9 years	10-12 years
T1	282.01	21.04	15.84	12.93
T2	295.19	22.03	16.58	13.54
T3	312.61	23.33	17.56	14.34
T4	300.96	22.45	16.88	13.80
T5	295.90	22.10	16.62	13.57
Recommended daily energy requirements		1340 (kcal/day)	1780 (kcal/day)	2180 (kcal/day)

T1:100% whole zucchini. T2: 100% whole sweet potato. T3: 75% whole zucchini +25% whole sweet potato. T4: 50% whole zucchini +50 % whole sweet potato and T5: 25% whole zucchini +75 % whole sweet potato. RDA*= Recommended Dietary Allowances.

4. Conclusion

The present study successfully demonstrated that the combination of zucchini and orange-fleshed sweet potatoes in jam formulations yields a nutritious and sensorily acceptable product with enhanced functional properties. Sweet potato significantly contributed higher levels of protein, dietary fiber, phenolic, and flavonoid compounds. In contrast, zucchini enriched the final product with chlorophyll and essential minerals, particularly potassium and iron. All jam formulations exhibited good sensory acceptability, with the blends containing higher proportions of sweet potato (T4 and T5) being the most preferred. These findings indicate that vegetable-based jams can serve as a healthy and appealing alternative to traditional fruit jams. The developed formulations show promise for incorporation into school meal programs to bolster children's energy and micronutrient intake. It is recommended that future research focuses on evaluating the product's shelf stability, microbiological safety, and economic viability for large-scale production.

References

- Adepoju, A.L. and Adejumo, B.A. (2015). Some Proximate Properties of Sweet Potato (*Ipomoea Batatas* L) As Influenced by Cooking Methods. *Int. J. Sci. Technol. Res.*, 4(3):146-148.
- Akinlolu-Ojo, T., Nwanna, E.E. and Badejo, A.A. (2022). Physicochemical constituents and antioxidative properties of ripening hog plum (*Spondias Mombin*) fruits and the quality attributes of jam produced from the fruits. *Measurement Food*, 7, 100037.
- Alam, M.K., Sams, S., Rana, Z.H., Akhtaruzzaman, M. and Islam, S.N. (2020). Minerals, vitamin C, and effect of thermal processing on carotenoids composition in nine varieties orange-fleshed sweet potato (*Ipomoea batatas* L.). *Journal of Food Composition and Analysis*, 92:103582.
- Alqahtani, N.K. (2020). Effects of replacing pectin with date pits powder in strawberry jam formulation. *Basic Appl. Sci. Sci. J. King Faisal Univ.*, 8: 69-77.
- AOAC (2019). Association of Official Analytical Chemists, AOAC International 21st edition Association of Official Analytical Chemists. Washington, D.C.
- Barros, L., Carvalho, A.M. and Ferreira, C.F.R. (2010). Leaves, flowers, immature fruits and leafy flowered stems of *Malva sylvestris*: A comparative study of the nutraceutical potential and composition. *Food Chem. Toxicol.*, 48:1466-1472.
- Bekele, M., Satheesh, N. and Sadik J.A. (2020). Screening of Ethiopian mango cultivars for suitability for preparing jam and determination of pectin, sugar, and acid effects on physicochemical and sensory properties of mango jam. *Scientific African*, 7:e00277.
- Bourne, M.C. (2002). *Food Texture and Viscosity. Concept and Measurement*, 2nd Ed. Academic Press, London. pp. 427.
- Brand-Williams, W., Cuvelier, M.E. and Berest, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT. Food Sci. Technol.*, 28:25-30.
- Cagliani, L.R. and Consonni, R. (2024). Monitoring the metabolite content of seasoned zucchinis

- during storage by NMR-based metabolomics. *Heliyon*, 10: e25976.
- Codex Alimentarius Commission (2009). Codex Standard for Jams, Jellies and Marmalades. Codex Stan., 296-2009.
- FAOSTAT (2020) <http://www.fao.org/faostat/fr/#data/QC/visualize>. Accessed, 8 Feb 2020.
- Food and Agriculture Organization of the United Nations-FAO (2003). Food Energy-Methods of Analysis and Conversion Factors. FAO Food and Nutrition Paper, 77:1-87.
- Francis, F.J. (1983). Colorimetry of foods, in physical properties of foods, M. Peleg and E.B. Bagly, Eds., pp. 105–123, The AVI publishing company Inc., Westport, Connecticut, USA.
- Franková, H., Jančo, I., Čeryová, N., Lidiková, J. and Musilová, J. (2022). Total polyphenols and antioxidant activity in sweet potatoes (*Ipomoea batatas* L.) after heat treatment. *Journal of microbiology, biotechnology and food sciences*, 11 (6):e5356-e5356.
- He, S., He, S., Niu, L., Sun, C., Zeng, Z. and Xiao, J. (2025). Effects of different roasting conditions on sugars profile, volatile compounds, carotenoids and antioxidant activities of orange-fleshed sweet potato. *Food Chemistry: X*, 25:102201.
- Hou, F., Mu, T., Ma, M., Blecker, C. and Sun, H. (2019). Cultivar selection as a tool for nutritional and functional value enhancement of roasted sweet potato. *J. Food Process. Preserv.*, 43 (11):e14200.
- Huang, Y.C., Chang, Y.H. and Shao, Y.Y. (2005). Effects of genotype and treatment on the antioxidant activity of sweet potato in Taiwan. *Food Chem.*, 98(3):529-538. doi.org/10.1016/j.foodchem.2005.05.083.
- Jain, S.K., Verma, R.C., Murdia, L.K., Jain, H.K. and Sharma, G.P., (2011). Optimization of process parameters for osmotic dehydration of papaya cubes. *J. Food Sci. Technol.*, 48:211-217.
- Jhanani, G.K., Alsalihi, M.S. and Shanmuganathan, R. (2024). As assessment of shelf life increasing competence of pectin (Zucchini) based edible coating on tomatoes. *Environmental Research*, 258, 119368.
- Kuyu, C.G., Tola, Y.B., Mohammed, A., Yazew, T. and Negeyie, S.N. (2025). Optimization of pre-treatment and convective drying temperature for better nutritional and bioactive contents of orange fleshed sweet potatoes flour, *LWT*, 217:117414.
- Laurie, S.M., Van Jaarsveld, P.J., Faber, M., Philippott, M.F. and Labuschagne, M.T. (2012). Trans- β -carotene, selected mineral content and potential nutritional contribution of 12 sweetpotato varieties. *Journal of Food Composition and Analysis*, 27(2):151-159.
- Lee, H.S., Castle, W.S. and Coates, G.A. (2001). High-performance liquid chromatography for the characterization of carotenoids in the new sweet orange (Earlygold) grown in Florida, USA. *Journal of Chromatography A*, 913(1-2): 371-377.
- Liu, R.H. (2013). Health-promoting components of fruits and vegetables in the diet. *Adv. nutr.*, 4 (3):384S-392S.
- Martínez-Valdivieso, D., Font, R., Fernández-Bedmar, Z., (2017). Role of Zucchini and its distinctive components in the modulation of degenerative processes: genotoxicity, antigenotoxicity, cytotoxicity and apoptotic effects. *Nutrients.*, 9(7):755.
- Natocho, J., Mugabi, R. and Muyonga, J.H. (2024). Optimization of formulation and processing conditions for the production of functional noodles containing orange-fleshed sweet potatoes and biofortified beans. *Food Sci. Nutr.*, 12 (7):5201–5219.
- Pandey, R., Behera, S.R. and Chatterjee, G. (2024). Zucchini and Zoodles. *Just Agriculture*, 4 (7):324-328.
- Perumpuli, P.A.B.N., Fernando, G., Kaumal, M., Arandara, M. and Silva, S. (2018). Development of low sugar vegetable jam from beetroot (*Beta vulgaris* L.): Studies on Physicochemical Sensory and Nutritional Properties, *International Journal of Theoretical and Applied Sciences*, 10(2):22-27.
- Rongtong, B., Suwonsichon, T., Ritthiruangdej, P.

- and Kasemsumran, S. (2018). Determination of water activity, total soluble solids and moisture, sucrose, glucose and fructose contents in osmotically dehydrated papaya using near-infrared spectroscopy. *Agr. Nat. Resour.*, 52:557-564.
- Salama, H.H., Elsaid, M.M., Abdel Hamid, S.M., Abozed, S.S. and mounier, M. (2020). Effect of Fortification with sage loaded liposomes on the Chemical, Physical, Microbiological Properties and Cyctotoxicity of Yoghurt. *Egyptian Journal of Chemistry*, 63(10): 3879-3890.
- Salehi, B., Capanoglu, E., Adrar, N., Catalkaya, G., Shaheen, S., Jaffer, M. and Capasso, R. (2019). *Cucurbits* plants: A key emphasis to its pharmacological potential. *Molecules*, 24(10):1854.
- SAS (2003). Statistical Analysis System. SAS Release 9.1 for windows, SAS Institute Inc. Cary, NC, USA.
- Shen, M., Liu, L., Zhang, F., Jiang, Y., Huang, Z., Xie, J., Zhong, Y., Nie., S. and Xie, M (2021). Effects of processing parameters on furan formation in canned strawberry jam. *Food Chem.*, 358:129819.
- Tolba, M., Farid, I.M., Siam, H., Abbas, M.H., Mohamed, I.; Mahmoud, S. and El-Sayed, A.E.K. (2021). Integrated management of K-additives to improve the productivity of zucchini plants grown on a poor fertile sandy soil. *Egypt. J. Soil Sci.*, 61(3):355-365.
- World Health Organization (2004). Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation: Rome, 17-24 October 2001 (Vol. 1). Food and Agriculture Org.
- Xu, E., Wang, J., Tang, J., Ruan, S., Ma, S., Qin, Y.; and Liu, D. (2022). Heat-induced conversion of multiscale molecular structure of natural food nutrients: A review. *Food Chemistry*, 369:130900.
- Zhang, L.M., Wang, Q.M. and Wang, Y.X. (2003) The Main Nutrient Components and Health Care Function of Sweet Potato. *Rain Fed Crops*, 23(3):162-166.
- Zhang, Y., Wang, Y., Yang, B., Han, X., He, Y., Wang, T., Sun, X. and Zhao, J. (2023). Effects of zucchini polysaccharide on pasting, rheology, structural properties and in vitro digestibility of potato starch. *International Journal of Biological Macromolecules*, 253:127077.