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The Development of A Functional Chocolate Spread Based on Sweet Potato and Dried Fruits

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Abstract

This study introduces a functional chocolate spread formulated with sweet potato, dried fruits (dates or figs), and chickpeas. The new product is free of hydrogenated oils, added sugars, and allergenic compounds such as milk and nuts. Six formulations were developed, with varying percentages of sweet potato puree and dried fruits. The sensory attributes of the spread were well-received by consumers. Nutritionally, the spread outperforms commercial options, boasting higher levels of vitamins A, E, and K, along with essential minerals like potassium and magnesium. Vitamin A content ranges from 408.99 to 224.46 µg RAE/100 g, significantly higher than the control's 23.50 µg RAE/100 g. Nearly all treatments substantially demonstrated improvements in the essential amino acid index (EAAI), biological value (BV), protein efficiency ratios (PER), and protein digestibility-corrected amino acid scores (PDCAAS), indicating that they are high-quality protein sources. Additionally, phenolic content ranged from 370.7 to 646.7 mg GA/100 g, total flavonoids from 156.6 to 197.1 mg QE/100 g, and total antioxidant capacity between 56.2% and 82.0%, demonstrating significant antioxidant potential. Microbiological analysis confirmed the product's safety over an 8-week storage period. Overall, those who desire a balance of taste, texture, and functionality may prefer the T2 and T5 treatments, which contain equal amounts of sweet potato and dried fruit. These alternatives offer consumers a nutritious, functional, safe, and cost-effective option.

Keywords: chocolate spread; sweet potatoes; dried dates; dried figs; chickpea; carotenoids

1. Introduction

The chocolate spread (CS) is a popular confectionery enjoyed by people of all ages, especially children. It is usually spread on toast, pancakes, or used as a bakery filling. Notably, the Middle East and Africa chocolate-based spreads market is projected to be valued at USD 0.16 billion, with an estimated compound annual growth rate (CAGR) of 3.88%, reaching USD 0.20 billion by 2029 [1]. While many households use cocoa spread, health experts worry about the existence of trans-fats, sugar, and caffeine [2]. In warnings from WHO [3], there are concerns over marketing foods high in sugar, saturated fats, and trans-fatty acids, especially when targeted at children. Through these precautions, experts aim to promote a healthier environment for children and reduce diet-related illnesses in the future.

In chocolate spread, the oils and fats in the chocolate spread provide desirable qualities such as spreadability and stability. The most commonly used fat is hydrogenated palm oil. While this can improve texture and stability, it contains trans fats, which are associated with many health risks. On the other hand, palm oil itself may be cost-effective, but it has many disadvantages linked to deforestation, loss of biodiversity, and socio-environmental problems. Additionally, palm oil is high in saturated fats, which can raise cholesterol levels and pose health risks when consumed in excess. This concern has prompted many manufacturers to explore alternatives to both palm oil and hydrogenated palm oil [4].

Furthermore, milk and hazelnuts, both recognized as common allergens, are common ingredients in chocolate spread. According to the Codex Alimentarius Commission [5], these allergens can

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restrict the product's use among specific groups of people, particularly those with allergies. It is imperative that these products are labeled appropriately to prevent accidental consumption and ensure consumer safety.

The fight against micronutrient deficiencies can be aided by an innovative food-based strategy known as food-to-food fortification. There are promising fortificant compounds that might raise the bioavailability of iron, zinc, and provitamin A content in starchy staple foods. Fortifiers usually consist of a lot of fruits and vegetables that are rich in minerals and vitamins; however, research on the subject is sparse and the data inconsistent [6].

Vitamin A deficiency (VAD) is a global health issue that persists despite substantial investments and efforts. While chocolate spread provides some vitamin B complexes, it lacks essential nutrients like carotenoids. Carotenoids are a widespread class of naturally occurring fat-soluble pigments that are known to protect the liver and lower the risk of heart disease, several types of cancer, and macular degeneration [7]. For instance, β-carotene, an antioxidant, functions as an immune regulator, neutralizes singlet oxygen, and diminishes peroxyl radicals when oxygen levels are low [8].

A rich source of carotenoids is the sweet potato (*Ipomoea batatas* (L.) Lam.), which is crucial for food security, notably in developed nations. It is nutritious, containing high levels of dietary fiber, minerals like iron, and vitamins like β-carotene, B, and C. Furthermore, it boasts antioxidant properties [9]. Sweet potatoes, categorized as "starchy vegetables," not only offer raw materials but also serve as a superb thickening agent for starch and starch-based foods [9]. They are well-suited for producing resistant starch, a high-value starch product that helps lower postprandial blood glucose levels and reduces the risk of obesity and diabetes [11].

Beside providing pharmaceutical benefits, dried fruits are also viewed as natural sweeteners. Dried dates (*Phoenix dactylifera* L.) and figs (*Ficus carica*) primarily contain fructose and glucose, both being reduced sugars. Due to their easy absorption, these sugars can provide a dense energy source. Unlike sucrose, which leads to rapid increases in blood sugar levels post-digestion, fructose—twice as sweet as glucose—can enhance satiety feelings and potentially reduce overall calorie consumption [12].

Moreover, figs are known to possess proteins, minerals, alkaloids, tannins, glycosides, flavonoids, saponins, coumarins, sterols, terpenes, and phenols. Research has indicated that *Ficus carica* exhibits hepatoprotective, immunological, antibacterial, antiviral, antioxidant, anticancer, anti-inflammatory, hypolipidemic, and antidiarrheal effects [13].

On the other hand, numerous compositional investigations reveal that dates offer substantial levels of polyphenolics, minerals, vitamins, and dietary fiber [14]. The abundant carotenoids in dates are lutein, neoxanthin, and beta-carotene. Dates contain various antioxidants such as glutathione, polyamines, and phenolics, including hydroxycinnamates. These properties make dates suitable as a functional food or as a component in functional food [15].

One of the most significant pulse crops is chickpea (*Cicer arietinum* L.). This plant contains a high amount of protein, which is superior in quality compared to other pulses and is rich in essential amino acids. It further contains high levels of minerals like Mg, P, Ca, and K, as well as vitamins like β-carotene, thiamin, riboflavin, and folate. Furthermore, chickpea has multiple health advantages, including its positive effect on cardiovascular disease, gastrointestinal diseases, certain types of cancer, and type 2 diabetes [16].

Consumers today seek products that provide more health benefits, leading to increased awareness and interest in the health-enhancing properties of certain foods or nutrients [17]. This study aims to create a highly nutritious chocolate spread enriched with carotenoids and polyphenols. Utilizing sweet potato for their content of carotenoid as well as starch for thickening purposes offers an additional advantage. Dried fruits will act as a natural sweetener, while chickpeas will offer protein, starch, and carotenoids. These innovative items will be allergen-free, excluding common allergens like milk and nuts, making them suitable for consumption by most children.

2. Experimental

2.1 Materials

Pure dark cocoa powder (Dreem, Egypt), roasted chickpea (Abu Auf, Egypt), sunflower oil (Efco Company, Suez, Egypt), sweet potato (orange flesh), and other ingredients such as vanillin were obtained from the local market in Giza, Egypt. Dried figs and dates at the full ripening stage (Tamar) were obtained from the Abu Auf company.

All compounds utilized were analytical grade. DPPH (2,2-diphenyl-1-picrylhydrazyl), gallic acid, quercetin, ethyl alcohol and Na_2CO_3 were purchased from Sigma-Aldrich (St. Louis, USA). Folin-ciocalteu and hexane were obtained from Merck (Darmstadt, Germany).

2.2. Preparation of component

1 kg of sweet potato (*Ipomoea batatas* (L.) Lam.) was meticulously washed before being cooked by boiling for 20 minutes with their skins on. After cooking, the skins were removed, and the sweet potato was blended into a smooth puree using a Braun hand blender (Model MQ 5245) for five minutes. Separately, 100 g of dried figs and 100 g of dried dates were soaked in boiling water until softened, then blended with 30 mL of water using a hand blender to create a smooth puree. Prior to usage, all blends were stored in plastic containers in the refrigerator at 4 °C. The roasted chickpeas were heated to 70 °C for about 10 minutes to remove excess moisture. Following this, they were ground into a fine powder using a Braun KSM 1 Coffee Grinder (Model 4024, Germany), and then sieved through a 60-mesh stainless-steel sieve to ensure a uniform consistency.

2.3. Preparation of chocolates spread

Table 1 outlines the components of formulated chocolate spreads. These formulations involved different proportions of sweet potato and dried fruits puree. The base formulation was modeled after a standard commercial chocolate spread, typically containing 7% cocoa, 42% sugar, 29% palm oil, 13% hazelnut, 4% skim milk, 4% whey, vanillin, soy lecithin, and salt. This formulation was developed in accordance with standards of chocolate [18] and was based on typical commercial chocolate spread recipes. In this new formulation, the percentages of sugar, palm oil, whey, and skim milk were replaced with sweet potato and dried fruit. Each base formulation was divided into three treatment variations for each type of fruit: Treatment 1 (75% sweet potato, 25% dried fruit), Treatment 2 (50% sweet potato, 50% dried fruit), and Treatment 3 (25% sweet potato, 75% dried fruit). The remaining ingredients (cocoa powder, chickpeas, sunflower oil, vanillin, and salt) were consistent across all treatments. Initially, powdered ingredients were weighed and then gently incorporated into a mixture of sweet potato-dried fruit puree and sunflower oil. The blends were then placed in glass jars, heated to 100 ºC for one minute, cooled to 42 ºC, covered, and left to cool at ambient temperature.

Table 1

Formulations used in the preparation of the sweet potato's chocolate spread (SWPCS) samples

Treatments / Ingredient (%)	DSWPCS			FSWPCS		
	T1	T2	T3	T4	T5	T6
Sweet potato puree	52.35	34.9	17.45	52.35	34.9	17.45
Dried dates puree	17.45	34.9	52.35	-	-	-
Dried figs puree	-	-	-	17.45	34.9	52.35
Pure Dark Cocoa Powder	7	7	7	7	7	7
Chickpea flour	13	13	13	13	13	13
Sunflower oil	10	10	10	10	10	10
Vanillin	0.1	0.1	0.1	0.1	0.1	0.1
Salt	0.1	0.1	0.1	0.1	0.1	0.1

DSWPCS: dates sweet potato-based chocolate spread; FSWPCS: figs- sweet potato-based chocolate spread

2.4. Sensory evaluation

A group of thirty panelists, consisting of 18 women and 12 men aged between 30 and 50 (members from the Food and Technology Research Institute (FTRI), Egypt), evaluated various chocolate spread formulations. They assessed marked samples using a 9-point hedonic scale, considering attributes such as color, consistency, spreadability, taste, odor, aftertaste, as well as overall acceptability. The panelists were served all six samples simultaneously on white disposable plastic plates, with variations in the order of presentation. The panelists also had access to water to rinse their mouths between rounds of treatments.

2.5. Physicochemical analysis

2.5.1. Water activity (a_w) and pH

a_w was determined in each chocolate spread using a thermostat apparatus (AquaLab 4 TE, Pullman, a_w, US) at 25 °C. The pH meter (HI 9025C) was used to determine the pH of the samples.

2.5.2. The accelerated oil separation (AOS)

The accelerated oil separation (AOS) preparation process was modified from [19]. A sample of 7.5 grams was weighed into a tube and centrifuged for 10 minutes at 20 °C and 20,000 g (3–30 KS, SIGMA, Germany). Sleek oil was pipetted into a tube and weighed after centrifugation. The proportion of AOS (g 100 g−1) was determined using the weight of oil

extracted from the 7.5 g specimen. There were two tests performed.

2.6. Physical properties

2.6.1. Color analysis

Determined on the HunterLab® colorimeter (Konica Minolta CR-410, Osaka, Japan), using a D65 illuminant and 10° visual angle. Color images were converted into the CIELAB system and expressed as *L**, *a** and *b** values. *a** denotes a color range from red to blue, *b** denotes a color range from yellow to green, and *L** stands for lightness. The following equation was utilized to get the color difference ΔE:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

The outcomes were obtained by calculating the averages of the values from five consecutive measurements.

2.6.2. Texture analysis

A Universal Testing Machine texture analyzer (825 University Ave., Norwood, MA 02062–2643, USA) fitted with a 250 lbf load cell and a 1 cm diameter cylinder probe was used to examine the texture profiles of the samples. Plastic containers with a 40-mm diameter and a temperature of 30 ±2 C were used to hold each chocolate spread [20]. All the parameters were calculated using the food texture analysis application TL-Pro.

2.7. A proximate analysis

The AOAC [21] method was used to assess the contents of moisture, ash, protein, and lipid. The formula for calculating total carbohydrate content was as follows: total carbs (%) = 100% - (moisture% + ash% + proteins% + lipids%).

Whereas the caloric value was calculated using the equation:

TCV (total caloric value - Kcal/100 g) = [proteins (g) x 4)] + [carbohydrates (g) x 4] + [lipids (g) x 9]. And results were converted to joules by the equation: Joules = Calories × 4184

The GI of each product was then calculated as follows:

The available carbohydrate (AvCH) is defined as total carbohydrate minus dietary fiber. The glycemic index values of the individual components were sourced from tables published by Foster-Powell *et al*. [22].

$$GI = \sum_{n}^{a=1} (GI(a) \times gAvCHO(a)/GAvCHO)$$

where GI is the test meal GI, n is the number of carbohydrate-containing foods in the meal, GI(a) = GI of the first component, gAvCH(a) is the grams of available carbohydrate in the first component (a), and GAvCH is the grams of available carbohydrate in the entire product [23].

The glycemic load (GL) of each test meal was calculated as:

GL= GI ×GAvCH/100

The relative glycemic response (RGR) was calculated as:

RGR= 1.5 ×GI (1- $e^{-0.018 \times GAvCH}$) +13

2.8. The mineral and vitamin contents of chocolate spreads

2.8.1. Minerals

The minerals (Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorus (P), Iron (Fe), Copper (Cu), Zinc (Zn), Manganese (Mn), and Selenium (Se)) were determined using an Atomic Absorption Spectrometer (AAS—VGP 210 Model). Then the percent increase was calculated for each mineral according to

$$\text{Percentage Increase} = \frac{Treatment\ Value - Control\ Value}{control\ value} * 100$$

2.8.2. The Vitamin contents of chocolate spread

Water soluble Vitamins

Standard stock solutions for thiamine, riboflavin, niacin, pyridoxine, and cobalamin (Sigma-Aldrich, Germany) were used. The vitamin B group was first extracted using a method previously described [24]. Twenty microliters of each filtrate sample and also from a standard solution were delivered into the HPLC system. The separation was accomplished using a reversed phase (RP) HPLC column (Agilent ZORBAX Eclipse Plus C18; 250 × 4.6 mm i.d., 5 μm) through the isocratic delivery mobile phase (A/B 33/67; A: MeOH, B: 0.023 M H_3PO_4, pH = 3.54) at a flow rate of 0.5 mL/min. Ultraviolet (UV) absorbance was recorded at 270 nm at room temperature. The

vitamin B content was determined by comparison to vitamin B standards [25].

In the case of ascorbic acid, UV detection was carried out at 254 nm. The separation utilized a mobile phase comprising 15% methanol and 85% water, pH adjusted to 2.5 with metaphosphoric acid. The mobile phase flowed at a rate of 0.9 mL/min, with ascorbic acid eluting at a retention time of 5.1 minutes [26].

Carotenoids and Fat-soluble vitamins

Fat-soluble vitamins and carotenoids were identified employing RP-HPLC analysis. Serial dilution was used to create standard solutions of vitamin E, K1, A, and β-carotene at concentrations of 1, 2, 5, and 10 mg/L, respectively. Next, standard curves were created by injecting 20 µL of each solution.

Methanol was used as a solvent for fat-soluble vitamins. Isocratic elution served as the basis for separating the vitamins. Water and methanol (5:95) were utilized in the mobile phase and pumped at a rate of one milliliter per minute [27]. Vitamins were measured at 325 nm for vitamin A, 290 nm for vitamin E, and 265 nm for vitamin K1. By contrasting the retention times of each vitamin with those of real standards, all vitamins were identified. All operations were completed in dimly lit environments. Software from ChemStation was used to process the data.

Whereas the elution conditions for β-carotene quantification include acetonitrile, methanol, tetrahydrofuran, and ammonium acetate (1% w/v) in the ratio of 68:22:7:3 (%). Flow rate: 1.0 mL /min. The UV absorbance was recorded at 453 nm for β-carotene. E-violaxanthin (440 nm), E-lutein (445 nm), and zeaxanthin (450 nm) [28].

RAEs (Retinol Activity Equivalents) were calculated assuming that 12 µg dietary (all-E)-β-carotene and 24 µg other detected carotenoids correspond to 1 µg RAE [29] using the following formula:

RAE =β-carotene/12+ (other provitamin A/24).

2.9. Amino Acids Analysis

The AOAC Official Method 994.12 [30] and 985.28 [31] were followed in the amino acid (AA) analysis of the spread samples. In glass tubes, the materials were hydrolyzed for 24 hours at 110 ± 2 °C with 6 N HCl containing phenol. This was followed by HPLC separation (Agilent 1200 HPLC, Agilent Technologies, Palo Alto, CA, USA). Dedicated software (Agilent Open Lab software, USA) was used to integrate the chromatograms detected at 570 nm and 440 nm. Methionine sulphone was identified for the sulfur-containing AA by oxidizing it with performic acid-phenol for 16 hours at 0°C before hydrolysis [32].

2.9.1. Protein quality determination

Using the amino acid profile of each product (mg/100 g), the following calculations were made to determine total amino acids (TAA), total essential amino acids (ESAA), and total non-essential amino acids (NEAA). In addition to total aromatic amino acids (AAA), total delicious amino acids (TDAA) which comprise glycine, glutamic acid, asparagine, serine, threonine, and alanine, and branched chain amino acids (BCAA), including leucine, isoleucine, and valine, and F= (BCAA/AAA).

After conversion of the amount of each essential amino acid (EAA) to mg/g protein, the following estimations were made for protein quality evaluation:

$The\ chemical\ score=$ limiting EAA in product protein /EAA content in whole cooked egg protein [33].

-Amino acid score = (limiting EAA amount for the product [mg/g]) / (EAA amount for reference protein [mg/g] in reference pattern)

Based on pre-school child ESS requirements for ages 2–5 years [34], including His 19, Ile 28, Leu 66, Lys 58, SAA 25, AAA 63, Thr 34, Trp 11, and Val 35 mg/g protein.

The essential amino acid index (EAAI) and the predicted biological value (BV) were calculated in accordance with Oser [33] and the predicted protein efficiency ratio (P-PER) was estimated according to Alsmeyer *et al*. [35] using the following equations:

-Essential amino acid index $(EAAI)= \sqrt[n]{(aap/Aas\ x\ aa2/AA2x\ \dots xaan/AAn)}$

Where: EAAI = Essential amino acid index; aa = amino acid (mg/g protein) in the product; Aas = refers to the standard essential amino acids (whole egg); and n, the number of amino acids (counting pairs such as methionine and cystine as one) [33].

-BV= 1.09 (EAAI) — 11.73

-P-PER = -0.468 + 0.454 (Leu) - 0.105 (Tyr)

Finally, the Protein Digestibility Corrected Amino Acid Score (PDCAAS) of each chocolate spread was estimated using the weighted average digestible amino

acid content approach given in the Joint WHO/FAO/UNU [36] which is as follows:

PDCAAS= AAS× calculated Weighted digestibility (CWD)

Atlassian.net was used to determine the protein digestibility of components, with CWD equaling digestible protein/total protein in the product.

2.10. Functional properties

2.10.1. Phenolic and flavonoids compounds

The specimens were permitted to air dry for four hours after being defatted twice at 30 °C using 10 mL of n-hexane. 10 milliliters of 70% methanol were used to extract the phenolic components from the defatted samples [37].

To detect the TPC, the following ingredients were prepared: 2.0 mL of 7.5% sodium carbonate, 2.5 mL of 10% Folin-Ciocalteu reagent, and 100 µL of methanol extract or blank. After one hour of incubation in the dark, the absorbance was recorded at 760 nm. The TPC was represented as milligrams of gallic acid equivalents per 100 grams of dry material [38].whereas the modified technique of Pourmorad *et al.* [39] was used to measure the TFC. After mixing 1.5 mL of methanol, 0.1 mL of AlCl3 (10%), 0.1 mL of Na2CO3 (1 M), and 2.8 mL of water with an aliquot of sample (500 µL), the mixture was stored for 30 minutes. At 430 nm, the optical density was recorded. TFC was presented as quercetin equivalents (mg QE/100 g dry weight).

2.10.2. Antioxidant potential

In accordance with Boly *et al.* [40]100 µL of the pre-prepared sample solution and standard were mixed with 100 µL of the DPPH (2,2-diphenyl-1-picryl-hydrazine-hydrate free radical reagent, 1 mg in 10 mL methanol) on a 96-well plate (n = 6). and the absorbance was attained with a microplate reader at 540 nm after 30 minutes of dark incubation.

2.11. Microbiological analysis

The cocoa spread samples were first diluted by using a physiological saline solution. coliforms were assessed by plating on Violet Red Bile Agar and incubating at 35°C for 24 hours. *Staphylococcus aureus* was plated on PetrifilmTM (3M Microbiology, USA). *Salmonella* spp. detection was performed on Salmonella-Sigma agar (Merck, Germany). A total bacterial count (TBC) was conducted on plate count agar (Merck, Germany). Every sample was incubated at 37 °C for 48 hours [41]. Whereas yeast and mold (TYM) were examined on PDA (Potato Dextrose Agar, Himedia®, India) and incubated for 5 days at 25 °C [42]. The colonies were quantified as colony-forming units per gram of sample (CFU/g) and expressed as log (CFU/g).

2.12. Statical analysis

The results from proximate analysis, physicochemical, texture, functional, color, and sensory analyses were evaluated using one-way analysis of variance (ANOVA) to identify differences between the samples and the control. Following ANOVA, Duncan's Multiple Range Test was applied to determine which specific means were significantly different. Correlation studies were conducted using Microsoft Excel to further analyze the data.

3. Results and discussion

3.1. Sensory evaluation of chocolate spread

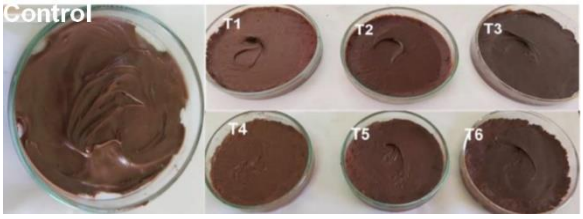

Figure 1: prepared chocolate spread; control: reference brand; T1, T2, T3: dried date sweet potato-based chocolate spread. T4, T5, T6; dried figs sweet potato-based chocolate spread.

The sensory evaluation results revealed some interesting findings (Table 2). It was realized that almost all samples (Figure 1) were generally accepted, as evolution was >7 on the nine hedonic scale. The difference in estimation was related to the consumer's degree of acceptance of the sweetness of the samples. Firstly, there was a noticeable difference in color between the samples and the commercial control, with all colors appearing slightly darker than the control. and mostly no significant difference ($p<0.5$) in color, odor, or aftertaste was recorded between samples. However, when it came to taste, texture, and overall acceptability, T3 and T5 emerged as the clear winners.

In the spreadability test, the most significant records were for T2, T3, and T5. The panelists reported no unliked flavor or aftertaste. Perhaps the most intriguing observation was that the FSWCS

samples had a noticeable impact on the sensory attributes of the chocolate products. Despite the slight variation in color, the addition of figs seemed to enhance the taste of chocolate without masking it, giving it a subtle but distinctive sweetness that was well-received by the panelists. The study found that consumers are willing to accept sugar-free products, with receptiveness varying across sweetness, crispness, and spread ability. This spreading capability, likely attributed to the presence of soluble fibers and starch, allows for effective spreading with minimal oil content as pointed out by Tan *et al.* [43].

Table 2
The sensory evaluation of chocolate spreads

Treatments	Color	Taste	Odor	Texture	Spread Ability	After Taste	Overall Acceptability
Control	8.17^{a}±0.22	8.71^{a}±0.26	8.61^{a}±0.21	8.97^{a}±0.23	8.83^{a}±0.28	8.71^{a}±0.28	8.66^{a}±.21
T1	7.40^{ab}±0.29	7.37^{c}±0.23	8.4^{ab}±0.33	7.43^{ab}±0.29	8.53^{b}±0.14	8.66^{ab}±0.29	7.95^{c}±0.25
T2	7.41^{b}±0.31	7.63^{b}±0.31	8.42^{ab}±0.28	7.90^{ab}±0.26	8.67^{a}±0.15	8.67^{ab}±0.29	8.11^{b}±0.22
T3	7.50^{ab}±0.24	7.93^{ab}±0.24	8.46^{ab}±0.22	7.70^{a}±0.19	8.61^{b}±0.18	8.68^{ab}±0.19	8.14^{b}±.019
T4	7.57^{ab}±0.25	7.6^{b}±0.28	8.44^{ab}±0.26	7.57^{ab}±0.20	8.43^{b}±0.24	8.71^{a}±0.21	8.05^{b}±0.16
T5	7.4^{ab}±0.20	7.93^{ab}±0.27	8.46^{ab}±0.30	7.67^{ab}±0.27	8.44^{b}±0.12	8.73^{a}±0.27	8.1^{b}±0.18
T6	7.37^{ab}±0.23	7.77^{b}±0.38	8.47^{ab}±0.34	7.03^{b}±0.30	8.31^{C}±0.20	8.77^{a}±0.34	7.98^{c}±0.30

All values are means of three replicates ± SD, numbers in the same column followed by different letters are significantly different ($p < .05$).

3.2. Physicochemical properties of chocolate spread

Figure 2a displays oil separation percentages in various spreads, showing variations in the range of 1.64% to 5.26%. It's noted that treatments T1 and T4 exhibited the highest oil separation percentages, while the control and T3 had the lowest. The data suggests that as the fig percentage increased, oil separation also increased, whereas with higher date concentrations, oil separation decreased. Oil trapping and fat binding to protein chains are key mechanisms behind oil absorption [44] reducing oil separation in products due to ingredients' high oil absorption capacity. Legume flours, like chickpea, are known for their strong oil-binding ability [45] owing to their proteins, which have hydrophilic and lipophilic structures that form stable emulsions with oil and water, enhancing their overall oil-binding capacity [46]. This trait improves food texture, smoothness, and flavor. Soluble fibers can also retain oil, increase viscosity, and serve as substitutes for high-oil-content products like spreads [47]. Dates' fibers surpass other plant-based fibers in oil holding capacity [48], suggesting that the fruit type and proportion in spreads significantly impact their stability and consistency.

Water activity (a_w) is crucial in assessing the presence of free water within food products, which greatly impacts microbial stability. In the context described, the aw of the samples ranges from 0.81 to 0.73, surpassing the control value of 0.55, indicating significant differences among them ($p<0.05$), as shown in Fig. 2b. Treatments T3 and T6 demonstrate the lowest aw, while T1 and T4 exhibit the highest values.

The observed water activity in the current Sweet Potato Chocolate Spreads (SWPCS) is consistent with the range (0.6–0.8) reported for fruit spreads by Miquelim *et al.* [49] and for gelatin-based chocolate spreads by Almeida and Lannes [50], but it exceeds a reported value below 0.5 by de Souza Correia Cozentino *et al.* [51]. The presence of moisture in existing products, along with the starch content in sweet potato and chickpeas, affects the water absorption index, because of starch gelatinization. This phenomenon involves trapping water between hydrogen bond sites, ultimately reducing water activity. The decrease in water activity can contribute to enhanced shelf stability and prolonged product quality [52].

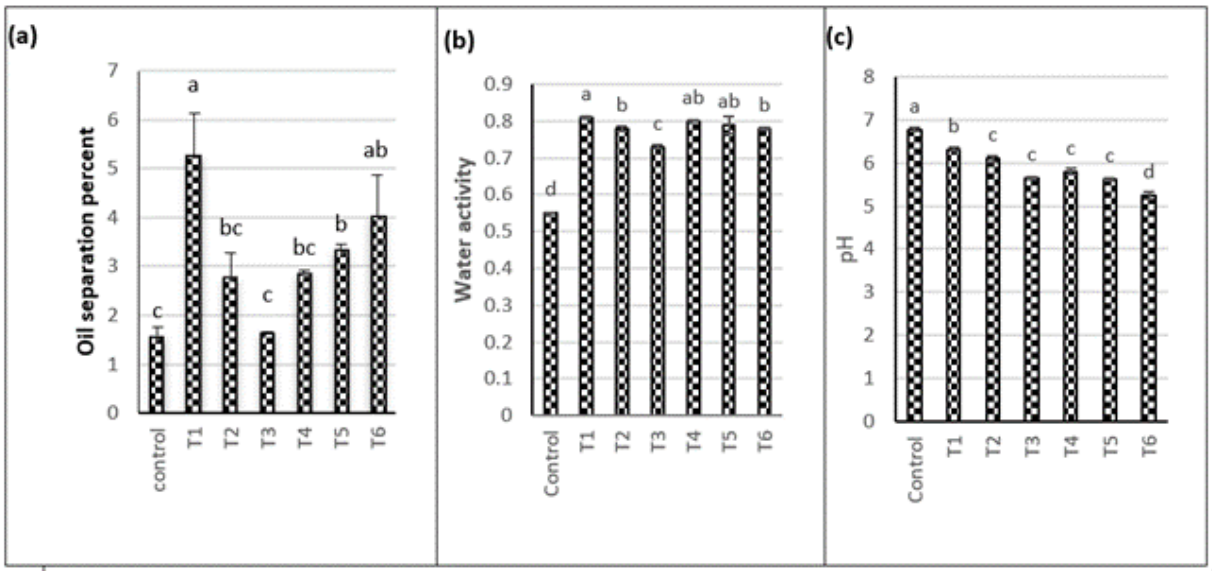

Figure 2: Physicochemical properties of chocolate spread; (a) oil separation percentage, (b) water activity, and (c) pH. Different lower-case letters in the columns indicate statistically significant differences ($p \leq .05$).

The results also show that the pH values of SWPCS samples ranged substantially, from 5.2 to 6.32, as seen in Fig. 2c. Among SWPCS samples, T6 had the lowest pH, while T1 had the highest. The control sample had the highest pH of 6.78. The pH values of SWPCS were approximately in the range (6.25–6.41) reported by Hannah *et al*. [53] and were higher than the pH 4.90 reported by Barcelon *et al*. [54] for fruit spreads. Sweet potatoes are more alkaline than dried fruits [55], so an increase in the percentage of dried fruits results in a more acidic product. It was realized that the FSWPCS showed a higher acidity value than the DSWPCS, which may be related to the higher acidity of dried figs [56].

3.3. Texture profiles of chocolate spreads

Table 3 displays the texture properties of various chocolate spread formulations, highlighting significant differences among the control sample and those containing dried dates and figs. Date-sweet potato chocolate spread (DSWPCS) exhibited higher levels of hardness, adhesiveness, and chewiness compared to fig-sweet potato chocolate spread (FSWPCS). Hardness signifies firmness and resistance to deformation, while adhesiveness is essential for spreading and adhesion to surfaces. An ideal spread should possess moderate adhesiveness to ensure ease of spreading without being excessively sticky.

The present study clarified that T1 and T4 have lower adhesiveness and higher hardness, indicating a less sticky product. T2 and T5 have balanced texture profiles with moderate hardness and springiness, making them easy to spread and consume. T3 had the highest hardness but showed no significant difference in adhesiveness, springiness, gumminess, or chewiness compared to the control sample.

Conversely, T6 does not differ significantly from the control in terms of springiness; however, its lower chewiness suggests a more elastic and chewy texture.

The enhanced hardness of the samples is attributed to various SWPCS combinations. Sweet potato increases the chocolate smoothness and gives it a creamy consistency due to the starch it contains. When heat is applied with increased moisture, starch particles increase in weight and size [57], resulting in a firmer product with less adhesion due to the absence of sugar compared to the control. Additionally, Smuda *et al*. [58] found that the high protein content of chickpea spread results in superior hardness and adhesion qualities when compared to chocolate spread.

The difference in texture between DSWPCS and FSWPCS can be attributed to the varying sugar and fiber contents of the dried fruit used, which play a crucial role in determining textural differences. Previous reports have indicated that the hardness of date fruit correlates with lignin, pectin, crude fiber, and moisture content [59]. Adhesiveness and gumminess are correlated with different types of reduced and total sugar, which significantly influences the product's stickiness by balancing adhesiveness and cohesiveness, as per Singh *et al.* [60].

Table 3

The texture properties of chocolate spreads

Treatments	Hardness (N)	Adhesiveness (mj)	Cohesiveness %	Springiness (mm)	Gumminess (N)	Chewiness (mj)
Control*	3.7^{f}±0.12	4.39^{a}±0.02	1.01^{a}±0.01	3.15^{a}±0.06	3.63^{a}±0.12	11.45^{b}±0.06
T1	5.9^{e}±0.12	1.02^{e}±0.01	0.25^{e}±0.01	0.66^{d}±0.01	1.47^{d}±0.23	0.97^{c}±0.01
T2	8.9^{b}±0.23	4.06^{b}±0.20	0.27^{d} ±0.01	2.12^{c}±0.01	2.40^{c}±0.12	5.09^{f}±0.06
T3	10.4^{a}±0.17	4.18^{ab}±0.02	0.36^{c}±0.01	3.20^{a}±0.06	3.74^{a}±0.12	11.98^{a}±0.01
T4	7.1^{c}±0.23	0.85^{e}±0.02	0.41^{a}±0.01	2.50^{b}±0.12	2.91^{b}±0.12	7.27^{e}±0.06
T5	6.7^{d}±0.12	1.44^{d}±0.01	0.37^{b}±0.02	2.95^{a}±0.23	2.48^{c}±0.06	7.31^{d}±0.13
T6	6.4^{e}±0.06	1.85^{c}±0.06	0.36^{c}±0.03	3.22^{a}±0.06	2.30^{c}±0.17	7.41^{c}±0.01

*Control, reference brand. All values are means of three replicates ± SD, numbers in the same column followed by different letters are significantly different ($p < .05$)

The texture of figs is primarily derived from pectin, cellulose, and hemicelluloses in their cell walls, with moisture content negatively affecting texture properties except for springiness and cohesion [61] Understanding and optimizing these textural traits can help food producers tailor their products to meet consumer preferences, enhance sensory experiences, and boost market appeal.

3.4. Color parameters of chocolate spreads

The *L** (lightness) values in Table 4 ranged from 22.84 (T3) to 34.83 (control), indicating that samples became darker with the addition of sweet potato and dried fruit. The DSWPCS was the darkest sample ($p < 0.05$), particularly T3, while T1 was the brightest. For a*, chocolate spreads exhibited values from 7.96 (T6) to 9.25 (T1), showing that the varying blends slightly influenced the redness, with a minor shift toward a green hue.

There was a significant difference ($p<0.05$) in yellowness values (*b**) between the treatments and the control (10.4). The *b** values for the treatments ranged from 2.59 to 4.67, indicating a lower yellowness and a shift towards blue compared to the control. Furthermore, when compared to the control, the results of the color difference factor (ΔE) varied from 7.39 to 14.3. The FSWPCS showed a smaller color difference (ΔE) than the DSWPCS. Generally, the *L**, *a**, and *b** values indicate the browning degree of the treatments, showing minimal change from yellow to blue and a decrease in red hue. This could be due to the natural sugars present in sweet potatoes and dry fruit, which can undergo Maillard reactions and caramelization during cooking or processing. These outcomes resembled the results obtained with different authors for coca cream [62][63].

Table 4

The color parameters of the chocolate spreads

Treatments	**L***	**a***	**b***	**ΔE**
Control	34.83^{a}±0.04	9.17^{a}±0.03	10.40^{a}±0.17	-
T1	24.59^{e}±0.05	9.25^{a}±0.02	3.74^{d}±0.02	12.22^{c}±0.01
T2	23.07^{f}±0.01	8.66^{b}±0.19	2.92^{e}±0.02	13.95^{b}±0.01
T3	22.84^{g}±0.02	8.45^{c}±0.06	2.59^{f}±0.02	14.33^{a}±0.02
T4	30.14^{b}±0.06	8.20^{d}±0.23	4.76^{b}±0.03	7.39^{f}±0.06
T5	29.79^{b}±0.03	8.11^{de}±0.01	4.31^{c}±0.03	7.98^{e}±0.01
T6	28.85^{d}±0.06	7.96^{e}±0.02	3.24^{e}±0.02	9.41^{d}±0.03

L* = lightness (L* = 100 for lightness and L* = zero for darkness), a* = a chromaticity on a green (−) to red (+) and b* = a chromaticity on a blue (−) to yellow (+). (ΔE) = color difference between each treatment and the control. All values are means of three replicates ± SD, numbers in the same column followed by different letters are significantly different ($p < .05$).

These reactions can result in the formation of brown pigments, leading to a darker color in the DSWPCS. Carotenoids and pigments in dried fruit can indeed contribute to the variation in color seen in the final products. Carotenoids, which are a group of pigments responsible for the red, orange, and yellow colors, and anthocyanins, responsible for the red, purple, and blue colors. These natural pigments not only contribute to the visual appeal of the fruits but also provide potential health benefits due to their antioxidant properties [64][65]

Table 5

Nutritional composition, energy value and glycemic indicator of the chocolate spreads

Treatment	Control	T1	T2	T3	T4	T5	T6
Moisture	1.12^{f}±0.06	50.98^{c}±0.58	41.43^{e}±0.46	36.01^{e}±0.09	55.56^{a}±0.48	53.48^{b}±0.86	49.05^{d}±0.33
Ash	0.98^{d}±0.02	1.69^{c}±0.01	1.85^{b}±0.02	2.11^{a}±0.07	1.73^{de}±0.02	1.92^{ab}±0.02	2.11^{a}±0.08
Protein	4.26^{c}±0.21	5.36^{b}±0.17	5.37^{b}±0.10	5.39^{b}±0.21	5.60^{a}±0.12	5.84^{a}±0.24	6.10^{a}±0.40
Fat	37.57^{a}±0.79	10.52^{b}±0.43	10.54^{b}±0.32	10.53^{b}±0.07	10.64^{b}±0.64	10.78^{b}±0.43	10.90^{b}±0.27
Carbohydrates	56.07^{a}±0.97	31.46^{d}±1.18	40.83^{c}±0.91	45.96^{b}±0.44	26.47^{e}±0.76	27.99^{d}±0.43	31.84^{d}±0.97
Fiber	5.10^{c}±0.17	6.02^{c}±0.17	7.30^{b}±0.46	8.10^{b}±0.24	7.12^{b}±0.32	8.02^{b}±0.52	9.10^{a}±0.17
Energy (Kcal)	579.47^{a}±0.82	241.98^{e}±0.19	279.65^{c}±0.32	300.23^{b}±0.29	224.12^{g}±0.67	232.35^{f}±0.34	249.92^{d}±0.51
Energy (KJ)	2424.5^{a}±0.99	1012.5^{e}±0.87	1170.1^{c}±0.35	1256.1^{b}±0.20	937.71^{g}±0.18	972.16^{f}±0.61	1045.68^{d}±0.32
Total Glycemic Value	55.09^{c}±0.88	39.09^{e}±0.32	38.49^{e}±0.79	42.77^{d}±0.38	50.17^{d}±0.85	64.38^{b}±0.94	70.83^{a}±0.81
Glycemic Loud	28.08^{a}±0.45	9.94^{e}±0.50	12.91^{c}±0.27	16.19^{b}±0.14	9.71^{d}±0.56	12.85^{c}±0.59	16.11^{b}±0.42
RGR	62.62^{a}±0.47	34.54^{f}±0.45	39.16^{e}±0.42	44.7^{c}±0.45	35.14^{f}±0.55	42.15^{d}±0.66	48.7^{b}±0.81

All values are means of three replicates ± *SD*, numbers in the same raw followed by different letters are significantly different ($p < .05$

3.5. Nutritional composition, energy value and glycemic indicator

Table 5 displays the outcomes of the proximate evaluation of chocolate spreads. The results demonstrated that the SWPCS samples exhibited significantly higher moisture levels than the commercial control, with T3 having the lowest moisture level (36%) and T4 the highest (51%). This value is significantly higher than the range of 22.19% to 24.30% reported by Smuda *et al*. [58] and corresponds with the 46% moisture content for fruit spreads reported by Barcelon *et al*. [54]. Given that the current product is a combination of fruit and chocolate spread, its substantial moisture level is to be expected. Fruit spread tends to exhibit a high moisture content [54], likewise, the addition of cooked sweet potato and the water utilized for puree preparation are connected to this increased moisture [66].

Although there were variations in constituents across SWPCS treatments, no significant differences ($p > 0.05$) in protein content were observed among the DSWPCS, with the control having the lowest at 4.3%. In contrast, FSWPCS exhibited relatively higher protein content, and T6 had the highest one. Ash content was significantly higher in the SWPCS samples, ranging from 1.2 to 2.1%, in contrast to the control sample (0.98), with T3 and T6 showing the highest ash content.

Similarly, the treatments' fiber contents varied from 6 to 9%, above the 5% of the control. Furthermore, the present fiber percentage exceeds the range of 0.2–4.9% stated by Smuda *et al.* [58] and the 0.1% mentioned for the cashew nut-chocolate spread [67]. The high fiber content in the SWPCS samples can be attributed to the inclusion of sweet potato, dates, or figs in the chocolate spread.

Regarding fat content, there was significant difference ($p<0.5$) observed between SWPCS samples, with an average of 11.7 % compared to the high value found in the control (37%). The fat content of SWPCS is much less than what was reported in other literature, either for cocoa free spreads (24–38%) reported by Smuda *et al.* [58] or for chocolate spreads (41–51%) reported by Amevor *et al.*, [67]. This is attributed to the use of a small amount of sunflower oil and sweet potato as a fat substitute. Sweet potato puree as well as dates' fibers have been reported to be successfully used in other studies as a fat replacer, which aids in maintaining the firmness and spreadability of the products [68, 69]. The European Food Safety Authority [70] stated that palm oils contain transfatty acids when refined at high temperatures. This has led to the avoidance of palm oil products by consumers and producers due to concerns

regarding their harmful effects on health. As a result, the chocolate spread industry is exploring alternative oils for improved quality and safety. In this study, we specifically utilized sunflower oil, which offers lower saturated fat content compared to hydrogenated palm oil and excels in its nutritional and technological properties [71]. The oil is essential for achieving a smooth and creamy texture while enhancing spreadability.

The control product had the highest energy level (579.5 kcal) and carbohydrate percentage (56%), twice as much as other SWPCS treatments. T3 had the highest energy value (300 kcal) and carbohydrate percentage (46%). The energy value of SWPCS is less than the reported range of 498 to 573 kcal [58] for fruit spread. According to our research, the energy value is positively correlated with both the amount of carbohydrates ($r = 0.89$) and oil content ($r = 0.97$).

The glycemic index quantifies the response to isoglucidic food items. However, due to changes in the quantity of carbohydrates, glycemic indices may not correctly represent individual portions of different meals. So glycemic load emerged to quantify the effect of typical meal amounts [72]. In the current study, T6, T5, and the control sample had the greatest glycemic index scores of 70.8, 64.4, and 55, respectively. Nonetheless, the glycemic load range of 9.7 to 16.1 for the SWPCS samples was significantly lower than the higher value of 28 for the control sample. According to reports, figs have a moderate glycemic index [73], while DSWPCS has a reduced glycemic index owing to its dates content, which is known to have a low glycemic index [74, 75].

Furthermore, the calculated relative glycemic response (RGR) of SWPCS samples ranged from 34.5 to 48.7, lower than the control's value of 62.6. The American Diabetic Association recommends regulating blood glucose levels to achieve near-normal concentrations through indorsing dietary choices with minimal postprandial hyperglycemic effects and allowing carbohydrate-rich foods with low GIs [76]. SWPCS have low-to-medium GI values, making them a suitable carbohydrate source for both healthy and diabetic individuals.

3.6. Minerals and vitamin contents

As shown in Table 6, the T6 sample from FSWCS exhibited the highest mineral content, and T5 and T3 closely followed behind. Almost all treatments exhibit an increase in mineral percentage compared to the control. The most significant increases were observed in potassium and magnesium with SWPCS treatments, and the average increases were 171% and 143%, respectively. It seems from the results that replacing sweet potato with figs results in a marked increase in P, K, and Mg that surpasses that of replacing them with dates, which is related to the richness of fig fruit with these elements [73].

Conversely, there is a moderate decrease in Ca and Mn contents in DSWPCS and slight decreases in Se content in FSWPCS samples. The drop in calcium in DSWPCS is likely due to the lack of milk. However, as the proportion of dates and figs increases in the chocolate spreads, the calcium content gradually rises, reaching its maximum in T6 and surpassing that of the control group. Figs, in particular, are known to be rich in calcium, contributing to this increase [73]. The minerals are known to be crucial for various aspects of health, including bone health, energy production, and regulating blood pressure and glucose levels [77].

In terms of vitamins, all treatments showed a significant increase, with vitamin A, K, and E levels rising by an average of 1185, 483, and 33%, respectively, compared to the control. Notably, reducing the proportion of sweet potato led to an increase in most vitamins, except for vitamins A, C, and E. The FSWPCS samples had a higher vitamin content than the DSWPCS samples. As commercial chocolate spread is typically a poor source of vitamin A, incorporating B-carotene-rich components can help offset this deficiency.

As can be seen from Fig. 3, all treatments of SWPCS provide a substantial portion of the daily recommended mineral intake for children, particularly Mn, Cu, Fe, Mg, and K, with average cover percentages of 32, 31, 19, 17, and 10.9%, respectively (Fig. 3a). These percentages represent the proportion of the mean daily value (DV) of treatments calculated for each mineral that is provided per 100 grams of the chocolate spread, calculated based on the mineral content analyzed in the study. Vitamin A and E offer the highest coverage of the daily required value, averaging 33.6 and 28% of the DV, respectively (Fig. 3b). Therefore, SWPCS samples of chocolate spread could be viewed as high- to moderate-rich foods, according to the FDA guidelines [78].

Table 6

Minerals and vitamin contents per 100 g chocolate spread

Parameters	Control	T1	T2	T3	T4	T5	T6
				Minerals(mg)			
Sodium (Na)mg	45.93	11.48	10.52	9.42	13.08	13.35	13.71
Potassium (K)	189.50	483.08	492.76	530.96	480.53	525.92	576.58
Calcium (Ca)	56.95	32.15	36.59	41.38	47.82	67.46	88.03
Magnesium (mg)	30.10	65.77	71.24	76.23	67.99	75.65	82.89
Phosphorus (P)	87.33	109.35	112.57	115.05	110.14	114.14	117.43
Iron (Fe)	3.01	3.29	3.38	3.40	3.47	3.73	3.94
Copper (Cu)	0.24	0.27	0.29	0.32	0.25	0.27	0.28
Zinc (Zn)mg	0.46	0.57	0.59	0.62	0.59	0.63	0.67
Manganese (Mn)mg	0.72	0.77	0.71	0.65	0.80	0.78	0.75
Selenium (Se)*	1.42	1.62	2.05	2.51	1.24	1.30	1.36
				Vitamins(mg)			
Vitamin A (Total RAE*)	23.50	408.99	273.08	141.40	436.77	328.04	224.46
Vitamin e	3.140	4.220	4.140	4.020	4.290	4.240	4.110
Vitamin k1 (phylloquinone)*	0.730	1.910	2.210	2.520	4.420	6.110	8.340
Thiamin (b1)	0.069	0.025	0.029	0.029	0.032	0.039	0.047
Riboflavin (b2)	0.132	0.026	0.031	0.037	0.029	0.036	0.044
Niacin (b3)	0.830	0.713	0.781	1.000	0.630	0.617	0.613
Pantothenate (b5)	0.228	0.260	0.296	0.335	0.235	0.247	0.262
Vitamin b6 (pyridoxine)	0.108	0.080	0.088	0.107	0.072	0.070	0.069
Vitamin c	1.300	2.500	1.700	0.979	2.600	2.000	1.400
Folates (B9)*	14.700	3.200	6.900	11.600	2.900	3.800	4.800

*Values in µg.

3.7. Amino acid composition

The amino acid content of samples is displayed in Table 7. Amino acid contents generally increased in SWPCS spreads compared to the control. FSWCS had the highest total amino acid content, with 3.4 g/100 g for T6 and 2.7 g/100 g for T1.

In terms of essential amino acids, SWPCS spread had significant increases in lysine, threonine, and isoleucine levels, averaging 56.8, 24.23, and 16.7%, respectively. Conversely, only DSWPCS samples showed a notable 13% decrease in histidine. For conditional AA, the largest increase in percentage was observed for arginine in both DSWPCS and FSWPCS samples, showing an average rise of 115.9%. Notably, proline in FSWPCS samples exhibited a significant increase, reaching an average of 154%.

From non-essential AA, the highest percent increase was for alanine and serine in both FSWPCS and DSWPCS samples, with an average increase of 55.7 and 26.5%, respectively. Additionally, there was a noticeable decrease in glutamic acid, with an average percent of -27%.

According to the results, the average ratios of EAA/TAA, NEAA/TAA, and DAA/TAA for SWPCS were 40, 61, and 33%, respectively, that were close to those of the control. The average EAA/NEAA ratio of SWPCS was also 63%. Notably, this percentage decreased as the percentage of sweet potato decreased, with the highest values observed in DSWPCS. In accordance with the ideal FAO/WHO model, a protein with a TEAA/TAA value of around 40% and an EAA/NEAA value above 60% is considered high-quality [32], suggesting they could be classified as high-quality proteins.

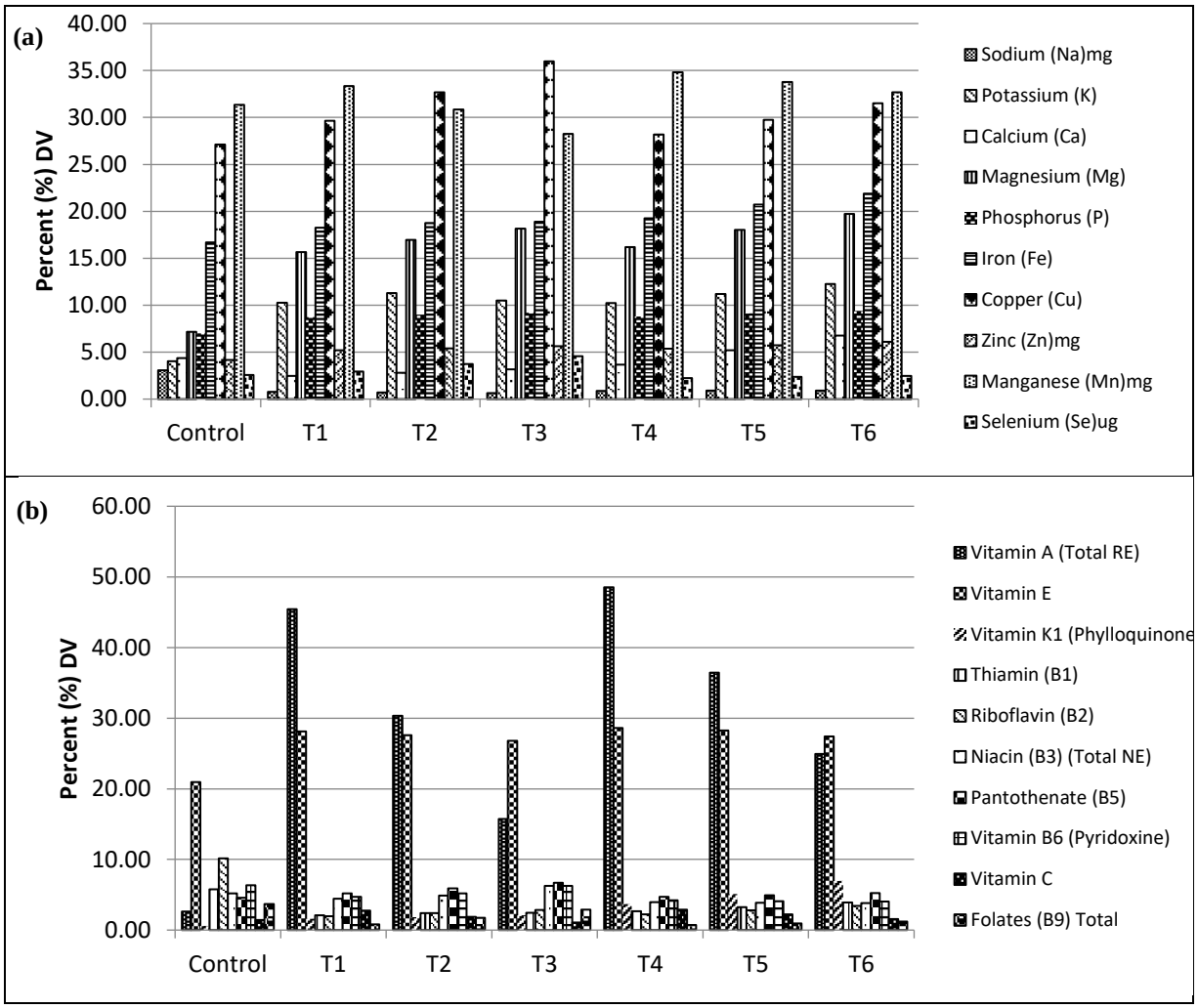

Figure 3: The percentage of the daily value that chocolate spread covers. (a) DV% for minerals; (b) DV% for vitamins. *DV = daily value for adults and children age 4 years and older**.**

The EAA/TAA percentage content of these products was strongly comparable to that of eggs (50%) and also were above the recommended ideal protein intake for children (26%) [79]. According to previous studies, high-Fischer ratio amino acids are crucial for energy supply, liver metabolism, the treatment of cardiovascular disease, and antioxidant activity since they include a larger amount of BCAAs [77]. For T2, T3, T5, T6, and control, the Fisher ratio is ≥2, which denotes favorable physiological characteristics.

Table 8 displays protein quality indicators for the chocolate spreads. Lysine was identified as the first limiting amino acid in all samples, with the maximum AAS score in T4 and the lowest in the control. This is consistent with previous studies on sweet potatoes [81, 82]. Maga [83] noted that lysine is particularly susceptible to Maillard reaction conjugation with polysaccharide carbonyl groups, reducing its availability and affecting protein quality. The AAS and CS values are significantly higher in the SWPCS spreads than in the control, suggesting a substantially more balanced amino acid profile.

The EAAI is a reliable measure of protein quality in food formulations. SWPCS has an average EAAI of 0.8, which exceeds the control's 0.55. Furthermore, the sweet potato-based chocolate spread demonstrates higher average values for PDCASS (70%), PV (75.5), and p-PER (2.8) in comparison to the control (29%, 48, and 2.1, respectively). However, these parameters slightly decline with reduced sweet potato content.

Table 7

Amino acid content of sweet potato-based chocolate spreads (mg/100g)

Amino acids (mg/100g)	Control	T1	T2	T3	T4	T5	T6
Essential Amino Acids							
Histidine	73.54	67.16	63.92	60.19	71.62	72.74	73.52
Isoleucine	114.04	127.58	126.50	124.41	134.57	140.36	145.35
Leucine	203.66	208.65	207.82	205.48	215.96	222.31	227.37
Lysine	113.31	174.07	172.86	170.27	179.48	183.57	186.45
Methronine	39.45	43.36	41.54	39.55	46.06	46.90	47.64
Phenyl Alanine	139.78	167.22	161.32	154.22	171.67	170.14	167.55
Theonine	109.30	135.33	129.30	122.33	142.17	142.84	142.80
Tryptophan	41.91	44.82	41.22	37.21	46.89	45.31	43.40
Valine	159.45	171.40	169.03	165.06	180.30	186.67	191.71
Non-Essential Amino Acids							
Arginine	97.62	207.02	208.64	208.61	209.73	214.00	216.70
Cystine	48.54	47.36	51.24	54.97	45.77	48.09	50.21
Glycine	143.14	144.83	149.61	153.39	147.70	155.28	161.96
Proline	120.95	139.95	149.74	158.66	219.29	306.92	396.18
Tyrosine	90.48	92.17	89.93	86.46	96.14	97.80	98.36
Alanine	145.46	152.51	153.19	152.83	161.41	170.83	179.48
Aspartic Acid	326.47	466.84	441.62	415.49	534.42	575.49	617.79
Glutamic Acid	445.20	301.92	318.30	336.79	306.69	327.75	351.07
Serine	88.20	105.39	100.89	97.14	115.88	121.68	128.56
TAA	2500.5	2797.6	2776.6	2743.1	3025.7	3228.6	3426.1
EAA	994.44	1139.6	1113.5	1078.7	1188.7	1210.8	1225.8
NEAA	1506.1	1658.0	1663.1	1664.3	1837.0	2017.8	2200.3
EAA/NEAA	66.03	68.73	66.95	64.81	64.71	60.01	55.71
EAA/TAA	39.77	40.73	40.10	39.33	39.29	37.5	35.78
NEAA/TAA	60.23	59.28	59.90	60.67	60.71	62.50	64.22
DAA/TAA	42.40	38.11	38.27	38.59	38.01	38.08	38.24
BCAA	477.14	507.62	503.34	494.94	530.83	549.33	564.44
AAA	230.26	259.39	251.25	240.69	267.82	267.94	265.91
F	2.07	1.96	2.00	2.06	1.98	2.05	2.12

Note: TAA: total amino acids; EAA: total essential amino acids; NEAA: total non-essential amino acid; DAA: total delicious amino acids; BCAA: total branched chain amino acid; AAA: total aromatic amino acid. F: (BCAA/AAA).

The higher EAAI value for SWPCS indicates a better balance of essential amino acids. According to Brown and Jeffre [84], proteins with an EAAI of 70% to 89% are categorized as moderate quality, and SWPCS falls within this range. The PDCAAS approach is the gold standard for evaluating human dietary protein quality, taking into account both amino acid needs and digestibility. A PDCAAS result near 100% suggests high protein digestibility and quality [85]. Under U.S. labeling regulations, SWPCS is classified as high-quality for non-infants, with a PDCAAS exceeding 0.4 (40%) [86]. Furthermore, its PER value exceeds 2, qualifying it as an "excellent source of protein" according to Friedman's classification [87].

The high protein quality indicators of SWPCS likely stem from its chickpea content, a remarkable protein source [88], which has been suggested as a suitable alternative to cow milk [89]. Furthermore, sweet potatoes are recognized for their favorable PDCASS and protein quality [82]. These findings highlight the advantages of combining chickpeas and sweet potato in the spread, providing a well-rounded amino acid profile and enabling it to be a nearly complete protein source.

Table 8
Amino acid content in mg/g protein and the protein quality of the chocolate spreads

Parameters	C	T1	T2	T3	T4	T5	T6
His	18.89	23.27	23.05	22.81	22.49	21.60	20.74
Ile	25.94	39.78	39.24	38.66	39.33	38.45	37.61
Leu	49.12	65.71	64.96	64.14	64.26	62.29	60.39
Lys	23.72	56.78	56.13	55.38	55.35	53.49	51.67
Met+Cys	21.86	27.14	27.31	27.48	26.17	25.43	24.77
Phe+Tyr	51.08	78.47	76.15	73.75	76.63	72.84	69.25
Thr	24.13	39.46	37.90	36.33	39.06	37.24	35.57
Trp	9.30	12.50	11.67	10.84	12.34	11.41	10.56
Val	34.86	48.35	47.36	46.34	47.93	46.63	45.43
AAS	0.41	0.98	0.97	0.95	0.95	0.92	0.89
Cs	0.38	0.48	0.48	0.48	0.46	0.45	0.43
EAAI	0.55	0.83	0.81	0.79	0.82	0.79	0.76
Weighted Digestibility	0.69	0.74	0.74	0.74	0.74	0.75	0.75
PDCASS	0.29	0.72	0.71	0.70	0.71	0.69	0.67
PER	2.17	2.93	2.89	2.85	2.86	2.77	2.68
PV	48.09	79.21	77.08	74.83	77.51	74.00	70.70

AAS: The amino acid score. CS: Chemical scores BV: Biological value. PER = Protein Efficiency Ratio. EAAI: The essential amino acid index. (PDCAAS): The Protein Digestibility-Corrected Amino Acid Score.

3.8. Phytochemical compounds

3.8.1. HPLC analysis of carotenoids

HPLC investigation demonstrated that total carotenoids (TCT) in DSWCS ranged from 51.67 to 18.36 µg/g and in FSWCS from 57.6 to 36.16 µg/g, compared to just 0.25 µg/g in the control, which had the lowest TCT, featuring barely traces of zeaxanthin and β-carotene (Fig. 4). Conversely, SWPCS showed an increase in various carotenoids. The majority of carotenoids were reduced with decreasing sweet potato content, including β-cryptoxanthin, β-carotene, and violaxanthin. However, lutein rose with increasing dried fruit proportions. Moreover, zeaxanthin levels rose as the proportion of fig fruit increased. The greatest carotenoid concentration was noted for β-carotene, ranging from 46.47 to 15.57 µg/g, with T1 and T4 showing the highest levels. Zeaxanthin was second, varying from 11.68 µg/g (T6) to 1.32 µg/g (T3). Other carotenoids showed the following ranges: lutein from 3.68 (T6) to 0.94 (T1), violaxanthin from 2.11 (T6) to 0.16 (T3), and β-cryptoxanthin from 1.12 (T6) to 0.32 (T1) µg/g.

Dried figs and dates are notably rich in carotenoids, especially lutein and zeaxanthin [90, 91]. This indicates an increasing lutein trend linked to the rise of dried fruits in chocolate spreads. Sweet potatoes also have a well-documented high β-carotene content [92], so reducing their amount in spreadable chocolates leads to lower β-carotene levels. HPLC analysis shows that both DSWCS and FSWCS contain significantly higher carotenoid levels than the control. The carotenoids in these spreads may enhance their nutritional value and health benefits.

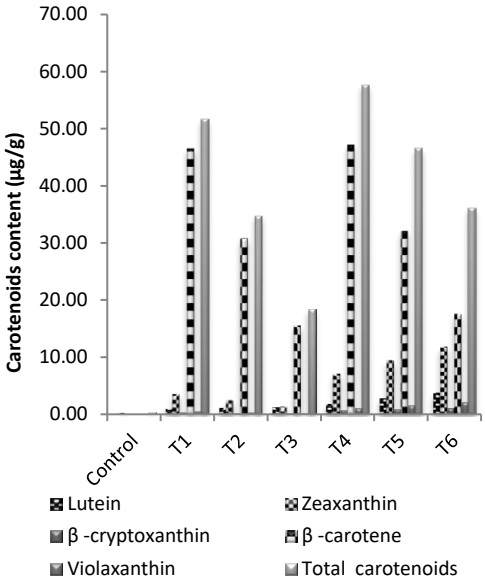

Figure 4: Carotenoid analysis by HPLC.

3.8.2. Total phenolics (TPC), Total flavonoids (TFC) and antioxidant potential (ATX)

The total TPC, TFC, and ATX of the chocolate spreads are provided in Table 9. The total carotenoids were calculated based on the results of HPLC for carotenoids determination. The phenolic content of SWPCS ranges from 370.7 to 646.6 mg GA/100 g. TFC varies between 156 and 197 mg QE/100 g, depending on the potato's substitution. The total antioxidant capacity ranges from 56.2 % to 82.0%. TFC and TPC generally rise with increasing the percentage of dried fruits, while ATX decreases. Replacing sweet potato with dried figs yields higher TFC and TPC than replacing them with dried dates.

T6 showed the highest TPC and TFC compared to the control. On average, TPC, TFC, and ATX of SWPCS have increased by 58.6, 17.5, and 53.3%, respectively, compared to the control sample. The range obtained is somewhat greater than the range reported for coca free spread (198–455 mg GAE/100 g, 62–155 mg CE/100 g, and 35–68% for TPC, TFC, and antioxidant activity, respectively) that was published by Smuda *et al*. [58]. Komes *et al*. [93] demonstrated that adding dried fruits, particularly prunes and cranberries, significantly increased the total phenolic content of dark and milk chocolates. Similarly, Fitriani *et al*. [94] reported that chocolate spread fortification with jackfruit and red palm olein showed higher polyphenol content than the control sample.

Table 10 demonstrates a substantial association between ATX and TCT ($r = 0.92$, $p < 0.5$), as well as between TPC and TFC ($r = 0.98$, $p < 0.05$). This association is more noticeable with β-carotene than with other kinds of carotenoids. TPC/TFC and ATX display negligible linear correlation ($r = -0.005$ and -0.06, respectively), suggesting that antioxidant activity positively correlates with carotenoids rather than being directly affected by phenolic and flavonoid levels.

Table 9

Phytochemical compounds of chocolate spread samples

Treatments	TPC	TFC	ATX	TCT
Control	314.30^{f}±1.50	147.74^{f}±1.50	46.93^{d}±1.27	0.25^{f}±0.56
T1	370.73^{e}±1.39	156.61^{e}±1.56	82.04^{a}±0.75	51.67^{b}±0.98
T2	464.30^{d}±.06	164.67^{d}±1.96	72.76^{b}±0.64	34.75^{d}±0.55
T3	500.50^{c}±1.39	168.92^{c}±0.87	70.62^{b}±1.27	18.36^{e}±0.41
T4	464.70^{d}±2.83	166.11^{cd}±.75	79.81^{a}±1.56	57.66^{a}±0.65
T5	543.84^{b}±1.91	183.28^{b}±.75	69.90^{b}±1.44	46.61^{c}±0.75
T6	646.71^{a}±2.42	197.10^{a}±.81	56.28^{c}±1.33	36.16^{d}±1.02

Total phenolics (TPC), total flavonoids (TFC), antioxidant potential (ATX) and total carotenoids (TCT).

Bae *et al*. [95] noted that the antioxidant potential from sweet potato increases as levels of carotenoids rise, which may explain the decline in antioxidant efficiency as sweet potato content decreases in samples. In contrast, other studies have shown an upward correlation with polyphenolics and antioxidant capacity [94]. These results highlight the importance of taking into account the specific types of antioxidants found in the food under investigation. Due to their unique chemical composition, stability, and high bioavailability, carotenoids play a significant role in the antioxidant capacity of the samples under investigation. It has been demonstrated that carotenoids, which effectively scavenge reactive oxygen species (ROS), offer protection against several chronic illnesses, such as cancer, heart disease, disorders involving the photosensitive organs, and diseases of the eyes [96].

3.9. Microbial analysis

Microbial analysis of all chocolate spread formulas was conducted to assess total plate count, yeast, and molds over 8 weeks of storage period (Figure 5). The microbial load was expressed as log (CFU/g). Results indicated lower TBC levels and the absence of TYM during the initial 2 weeks of storage. Additionally, FSWPCS samples showed no TBC or TYM presence within the first 4 weeks. By the 6th week, all treatments exhibited a low bacterial count ranging from 10 to 260 CFU/g, with yeast and mold levels between 96 to 10 CFU/g. After 8 weeks, T1 displayed the highest microbiological count (11.1×10^2 CFU/g), while T6 had the lowest (60 CFU/g) for TBC; T4 peaked the maximum count of 2.5×10^2 CFU/g, and T3 had the lowest (20 CFU/g) for TMY. Notably, all samples were devoid of *Salmonella* spp. and *coliforms*.

Table 10

Pearson correlation coefficients (r) for the correlations between phytochemical components and antioxidant capacity.

	Lutein	*Zeaxanthin*	*β -cryptoxanthin*	*β -carotene*	*Violaxanthin*	*TPC*	*TFC*	*ATX*	*TCT*
Lutein	1								
Zeaxanthin	0.96**	1							
β -cryptoxanthin	0.96**	1.00**	1						
β -carotene	0.17	0.29	0.29	1					
Violaxanthin	0.96**	1.00**	1.00**	0.21	1				
TPC	0.94**	0.80*	0.81*	0.04	0.82*	1			
TFC	0.98**	0.88**	0.88**	0.04	0.90**	0.98**	1		
ATX	0.00	0.03**	0.03	0.92**	-0.05	-0.01	-0.07	1	
TCT	0.32	0.45	0.44	0.99**	0.37	0.17	0.18	0.85**	1

TPC: total phenolic content; TFC: total flavonoids; TCT: total carotenoids; ATX: antioxidant activity of chocolate spread samples; The correlations are significant at **p-value < 0.01, *p-value < 0.05, and NS non-significant

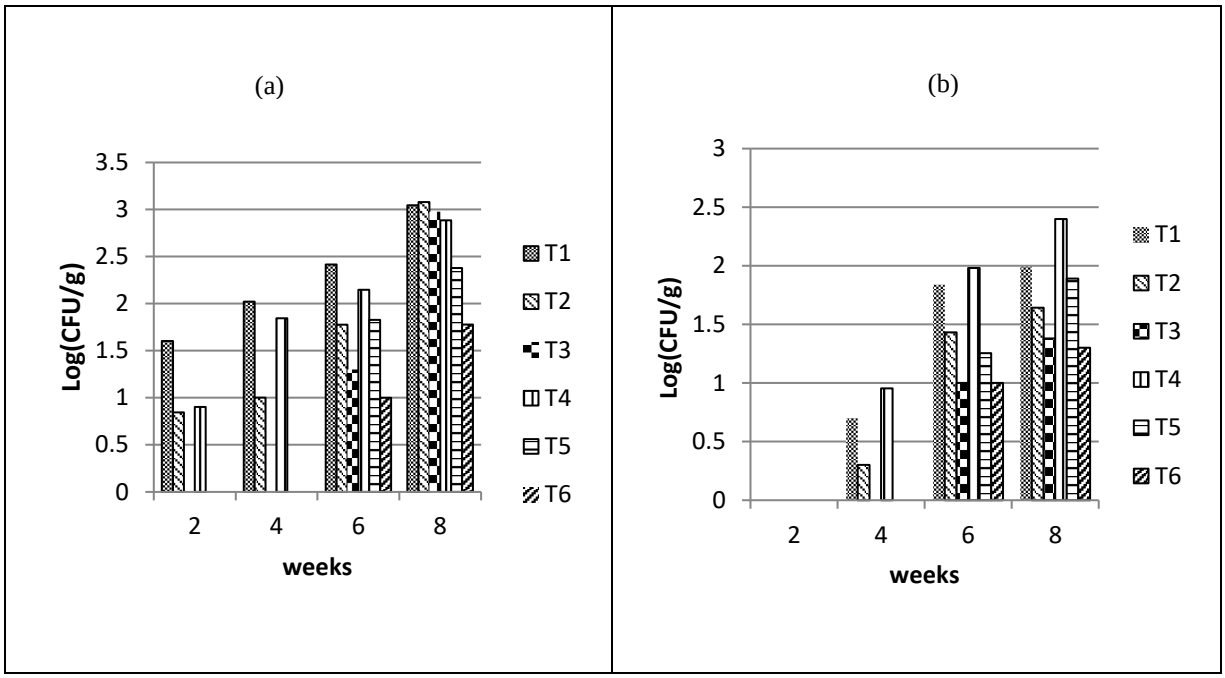

Figure 5: microbial analysis of chocolate spread during storage at room temperature expressed as (log (CFU/g). (a) Total bacterial count (TBC) (b) Total yeast and mold count.

Bacterial count is crucial for predicting the shelf life of food products, as microbial growth occurs during storage, affecting safety, quality, and taste. With bacterial counts below 1000 CFU/g for TBC and below 10 CFU/g for TMY, these products are deemed microbiologically safe for approximately 6 weeks at room temperature per chocolate confectionary standards and FDA guidelines [97]. Moreover, they are considered safe for 8 weeks following the NSW Food Authority's guidelines for ready-to-eat food under Category A ($\leq 10^4$ and $\leq 10^6$). This aligns with Ali *et al*., [98], who noted a storage period of 3 months for chocolate spread that contains eggplant puree at cold storage. Similarly, Amevor *et al*. [67] reported a count ranging from 250 to 350 CFU/g and less than 10 CFU/g for yeast and mold for cashew nut/chocolate composite spread.

The products are considered to have an intermediate water activity that inhibits pathogenic growth and toxin production while potentially allowing xerophilic yeast or mold to thrive. But their safety and shelf life can be improved by the addition of antimicrobial ingredients [96].

The microbiological stability of these products may stem from the antiviral, antibacterial, antifungal, and antioxidant properties of ingredients like sweet potatoes [100], chickpeas [101], dried figs [102], and dates [103]. These ingredients, rich in phenolic acids, flavonoids, and carotenoids, likely bolster the microbial stability and quality of the spreads. The longer shelf life of FSWPCS spread may be attributed to its higher acidity compared to DSWPCS. The notably low levels of TPC, yeast, and mold in the samples suggest proper handling of the raw materials.

3. Conclusion

This study introduced a novel chocolate spread made from sweet potato and dried fruits combined with chickpeas, providing a healthier alternative to traditional options. Sweet potatoes offer carotenoids; dried fruits provide natural sweetness and nutrients; and chickpeas offer high-quality protein. The Fig-Sweet Potato Chocolate Spread (FSWPCS) and the Date-Sweet Potato Chocolate Spread (DSWPCS) each have unique advantages, but both surpass commercial spreads in vitamins, minerals, carotenoids, polyphenols, and protein content, delivering lower glycemic load, high-quality protein, and antioxidants. Although both spreads have commendable properties, DSWPCS is preferred for its sensory and texture appeal, particularly treatment T3, while FSWPCS excels in nutritional and functional benefits, with T6 as the top treatment. Ultimately, the choice depends on individual priorities. For those seeking balanced options, treatments T2 and T5, with their intermediate characteristics, may be sufficient.

This formulation targets health-conscious consumers by removing common allergens, added sugars, and hydrogenated oils. It overcomes the limitations of traditional chocolate spreads, creating a functional food product that surpasses in nutrition, and market innovation while maintaining low costs, thus establishing a benchmark for future developments in the chocolate spread market.

4. Conflicts of interest

"There are no conflicts to declare".

5. Funding sources

No funding sources

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