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Research Article

Formulation and Evaluation of Iron-Rich Chocolate Spread from Sugarcane Syrup and Sunflower Seeds

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Anemia is widely recognized as a serious public health problem and the most common type of micronutrient deficiency globally. Developing a product enriched with iron to overcome this issue has received excessive attention. For this purpose, sugarcane syrup and sunflower seeds were utilized as sugar and hazelnut substitutes in chocolate spread production. Four formulations were created and assessed for their chemical, texture, and sensory attributes, as well as their iron content by microwave plasma-atomic emission spectrometry (MP-AES) and compared with a commercial product. Fat and sugar levels were reduced by 2–1.3 and 1–1.5 times, respectively, in the samples. Increasing the percentage of sugarcane syrup raised the iron content 3- to 6-fold. Peroxide and free fatty acid values indicate that iron negatively affects the oil quality of the developed samples. The samples could be recommended as novel products that are preferred as a healthy and low-cost chocolate spread.

1. Introduction

For many years, cocoa beans (*Theobroma cacao* L.) and chocolate goods have been consumed for their flavor and so are polyphenols such as catechins, procyanidins, and caffeic acid, all of which have beneficial health benefits [1]. Chocolate spread (Gianduja) is a popular chocolate product among teens who use it to fill various confectionary items or spread it on bread and wafers [2]. According to the Codex (2016), chocolate spread contains a minimum total dry cocoa solid content of 32%, including a minimum dry nonfat cocoa solid content of 8%. This type of chocolate contains a high percentage of fat (≥40%), mostly saturated fat (palm oil), which contributes to the global increase in the prevalence of cardiovascular diseases, according to Ismail et al. [3]. One previous study [4] reduced the fat content of chocolate spread by substituting milk fat/cellulose ether emulsions for palm fat; however, this has the disadvantage of decreasing digestibility. In response to the rising consumer demand for healthier foods with good textural properties, researchers have developed a variety of these products [5–9]. They explored maltitol and grape pomace as sugar substitutes, as well as sunflower, soybean, coconut oils, and structured triacylglycerols as alternatives to palm oil. Furthermore, there have been few studies to fortify this type of chocolate with healthier ingredients or more micronutrients. Tolve et al. [8], for example, fortified the chocolate spread with Ca^{+2} and vitamin D using Mg–$CaCO_3$ nanoparticles or by adding 166 μg of vitamin D/kg to the finished product, respectively.

Poor dietary habits and sedentary lifestyles have contributed to an increase in different malnutrition- or obesity-related diseases. Iron deficiency is still one of the world's most serious public nutritional deficiencies [10]. Anemia is associated with the more severe stages of iron deficiency, which primarily affects children and pregnant women. Iron deficiency is described as the absence of mobilizable iron stores, and the marks of a compromised iron supply to tissues, called erythron, are familiar. The main predictors are a hemoglobin level of 110 g/l and a ferritin level of 12 g/l [11]. According to the World Health Organization [12], anemia affects 42% of children, 40% of pregnant women, and 33% of nonpregnant women worldwide, and 280 million children as well as 614 million women globally still suffer from it. In

Egypt, 21% of girls and 17.5% of boys (5–19 years old) were found to be anemic. Furthermore, a quarter of women of reproductive age (15–49 years old) and 28.2% of lactating women had anemia [13]. Therefore, the consumption of foods containing iron is more effective than medications to treat this deficiency. One of the excellent sources of iron is sugarcane syrup [14].

Sugarcane syrup is a dark syrup or honey produced in many sugar-producing countries, including Egypt and Portugal [15, 16], and it is most likely consumed as a confectionary or with certain bakery products. It is primarily made by thermally treating filtered juice obtained by mechanically pressing fresh sugarcane stalks [17]. It contains at least 95% sugar by weight, with sucrose accounting for 30% of total sugar [16]. Sugarcane syrup has been approved to boost the levels of hemoglobin in children and pregnant women because it is an excellent source of iron, containing around 0.7% of iron by weight [14]; however, it has not been used to enrich any food with iron. On the other side, the sunflower (*Helianthus annuus* L.) seed is one of the world's most important oilseed crops [18]. Sunflower seed contains 35%–42% oil and is naturally high in linoleic acid (55%–70%) but low in oleic acid (20%–25%). In addition to the polyunsaturated fatty acids, sunflower seeds contain flavonoids, antioxidants, and vitamins that may lower total cholesterol, particularly low-density lipoprotein (LDL) cholesterol [19]. Recently, Bascuas et al. [20] investigated the replacement of 50% of the coconut fat in chocolate spread with sunflower oil. However, sunflower seeds have not been explored as an alternative to hazelnut to reduce the cost of the final chocolate spread product.

This study aimed to increase dietary iron intake by developing a healthier chocolate spread free of palm fat. The effects of substituting sugar for sugarcane syrup and hazelnuts for sunflower seeds on the physicochemical and nutritional properties of this form of chocolate were assessed in particular.

2. Materials and Methods

2.1. Materials and Reagents. The main ingredient, sugarcane syrup, was provided by the Harvest Foods Company (Alexandria, Egypt), while the roasted sunflower seeds were purchased from a local market, peeled, milled, and sieved (32 μm). Milk powder was obtained from Oknaz, Advanced Global Industry (Giza, Egypt), and sunflower oil from Sunny (Efco Company, Suez, Egypt). Nutella (Ferrero Company, Stadtallendorf, Germany) served as the control commercial product. DPPH (2,2-diphenyl-1-picrylhydrazyl), Folin-Ciocalteu reagent, H_2SO_4, n-hexane, and methanol (HPLC grade) were purchased from Sigma-Aldrich, St. Louis, Mo., USA. The other chemicals and reagents used in this experiment were of analytical grade.

2.2. Chocolate Spread Preparation. The components of the chocolate spread listed in Table 1 were combined to generate four chocolate spread formulae. Their quantities were selected based on the standard for chocolate spread products [21], in which the chocolate spread must contain ≥13% hazelnut and ≥7% cacao powder. Formulation 4 contains the closest amount to the control commercial product, with 13% hazelnut, 10% milk, and >7% cocoa powder, with the remainder being sugarcane syrup. The other formulations gradually reduce the sugarcane syrup content by increasing the other ingredients within these limits. The formulations were prepared with some modifications, according to Bascuas et al. [20]. The dry ingredients, such as cocoa and milk powder, as well as the sunflower seed paste, were initially sieved separately and then combined. The sugarcane syrup was then added and blended for 15 min at 50°C with a hand blender (ST-FP0053 D, Saturn Home Appliances, Guangdong, China). Finally, in a constant ratio, sunflower oil and lecithin were added to all formulations after cooling to room temperature (30 ± 2°C) and mixing for 5 min. All examinations were conducted after 24 h.

2.3. Chemical Analysis. The chemical composition of the formulations produced was analyzed according to AOAC methods [22]. The fat, moisture, crude fiber, and protein contents were determined using methods #963.15, #925.10, #962.09, and #939.02, respectively. Total sugar was determined by the Anthrone reagent at 630 nm using a UV-spectrophotometer (Unico, UV 2000, USA) [23].

2.3.1. Total Phenolic Content Estimation. The samples were first defatted twice with 10 ml of n-hexane at 30°C and then air-dried for 4 h. The phenolic compounds were extracted from the defatted samples using 10 ml of 70% methanol [24]. The total phenolic content (TPC) was determined as follows: 100 μl extract or blank (methanol) was mixed with 2.5 ml Folin-Ciocalteu reagent (10%) and 2.0 ml sodium carbonate (7.5%). The mixture was mixed and incubated in the dark for 1 h, followed by measuring the absorbance at 760 nm using the specified spectrophotometer. Total phenolic content was calculated as mg gallic acid equivalents/100 g dry sample [25].

2.3.2. Antioxidant Potential Activity Estimation. The DPPH free radical assay was applied to detect the antioxidant effect of the prepared samples. Briefly, 1 ml of the previously diluted methanolic extract was mixed with the same volume of methanolic DPPH solution (0.2 mM). After 30 min of incubation in the dark, the absorbance was measured at 517 nm with methanol as a control instead of the sample [24]. The DPPH scavenging activity was calculated using the following equation:

$$\%\ \text{DPPH scavenging} = \frac{A\ \text{control} - A\ \text{sample}}{A\ \text{control}} \times 100. \quad (1)$$

2.3.3. Oil Quality Assessment. The samples were evaluated after 1 month of storage at 30°C by analyzing the peroxide value and free fatty acid content, as described by Tarakçi & Yildirim [26], with some modifications. After mixing about 5.0 g of chocolate sample with 5.0 ml of petroleum ether for

Table 1: The ingredient contents of the proposed chocolate spread formulae (%).

*Ingredients		†Control	Sample			
			1	2	3	4
Sugarcane syrup		—	33.0	43.0	53.0	63.0
Cacao		7.4	18.0	18.0	9.0	9.0
Milk		10	21.0	21.0	10.0	10.0
Sunflower seed		—	23.0	13.0	23.0	13.0
Hazelnut		13.0	—	—	—	—
Sugar		ND	—	—	—	—
Oil	Sunflower	—	5.0	5.0	5.0	5.0
	Palm	ND	—	—	—	—

*Lecithin (1%) was added to all formulations. †The ingredients of the control sample according to the label declaration. ND = not declared.

1 min, the tubes were centrifuged at 2795 × g (Hermle, Z300, Germany) for 10 min to separate the upper phase. The extraction was carried out twice more, and the combined extract was collected. The ether was evaporated, and the extract was resuspended in 1 ml n-hexane. The peroxide value of the extracted oil was determined by titration with sodium thiosulfate solution (0.002 N) in the presence of starch (1.0%) as an indicator. The results were expressed as mg equivalent O_2/kg of oil. Meanwhile, the acidity as free fatty acids (FFA) was determined by titration with KOH solution (0.05 N) and calculated as a percentage of oleic acid.

2.3.4. Iron Content Estimation. To determine the iron content, the sample was first digested with HNO_3 at 180°C for 8 min according to the microwave digestion system (Multiwave GO Plus, Anton Paar GmbH 208054, GRAZ, Austria). The iron was then detected using microwave plasma atomic emission spectrometry (MP-AES 4210, Agilent Technologies, Santa Clara, CA, 95051, USA) and calculated using the following equation:

$$\text{iron concentration (ppm)} = \frac{(a-b) \times v \times \mathrm{d}f}{m}, \quad (2)$$

where a = concentration of the metal in the test solution (ppm); b = mean concentration in the blank concentration; v = the volume of the undiluted solution in ml; df = dilution factor; and m = weight of the test sample (g) according to the AOAC method of #999.10 [22]. All measurements were performed in triplicate, with the samples being maintained at an ambient temperature of 30 ± 2°C.

2.4. Physical Analysis. Minolta (Chroma Meter, DP-301, Japan) was used to estimate the color parameters (L^*, a^*, and b^*) of the final prepared samples. L^* denotes lightness, a^* denotes a color range from red to blue, and b^* denotes a color range from yellow to green. ΔE was calculated using the following equation:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}. \quad (3)$$

A Universal Testing Machine texture analyzer (825 University Ave, Norwood, MA, 02062–2643, USA) equipped with a cylinder probe (1 cm diameter) and a load cell of 250 lbf was used to analyze the texture profiles of the tested formulae (placed in cylindrical plastic containers, 40 mm diameter) at 30 ± 2°C [27]. All parameters were calculated using TL-Pro food texture analysis software.

2.5. Sensory Analysis. An informed panel of 50 panelists (35 women and 15 men between the ages of 18 and 30) from Cairo University's Food Science Department, Faculty of Agriculture, evaluated the prepared chocolate spread formulations. All participants gave informed consent. Parameters such as color, taste, flavor, texture, spreadability, and overall acceptability were evaluated. The samples were served at room temperature (30°C) on white plates with bread slices. The sample was classified using the 9 hedonic scales, with a scale of 1 indicating dislike and a scale of 9 indicating extreme liking [6].

2.6. Statistical Analysis. A one-way analysis of variance (ANOVA) was performed on the data using CoStat statistical software. The mean of three replicates was compared using Duncan's test [28] at a significant level of $p < 0.05$.

3. Results and Discussion

3.1. The Chemical Composition of the Chocolate Spread. According to the findings (Table 2), all samples were within the permissible moisture limit for fungi and bacterial growth, as moisture levels may affect the shelf life of the packed product [29]. It could be realized that increasing the percentage of sugarcane syrup results in a significant increase in the moisture content of the spread created. Sample 1 has the lowest moisture level due to its high dry solids content (i.e., cacao and milk powder, as well as sunflower seeds), which improves the final product's water absorption. In accordance, the moisture content of chocolate spread created by Jeyarani et al. [5] that contains 85% soybean oil or a blend of 85% soybean oil and coconut oil (1 : 1), ranged from 5.0% to 6.3%. Moisture increased to 21.5%–24.7% when fluid skim milk was substituted for powdered skim milk. Although sugarcane syrup is high in sugar, all samples in this study exhibited a significant reduction (by 1–1.5 times) in sugar levels compared to the commercial control sample ($p < 0.05$). The total fat content in the proposed formulations followed a similar pattern, with samples being lower than the control sample. The first formula had the

Table 2: The chemical composition, total phenolic compounds, and antioxidant activity of the prepared chocolate spread formulae.

Sample	Chemical composition (%)								Oil quality	
	Moisture	Sugar	Protein	Fat	Fiber	Ash	TPC (mg GAE/100 g)	Antioxidant activity (% DPPH)	PV (Meq O_2/kg)	Acidity (% fat as oleic acid)
Control	*$2.57^{c} \pm 0.09$	$52.46^{a} \pm 0.08$	$7.08^{e} \pm 0.11$	$30.96^{a} \pm 0.08$	$4.88^{e} \pm 0.08$	$2.05^{e} \pm 0.07$	$515.75^{a} \pm 8.15$	$88.03^{a} \pm 0.58$	$0.01^{c} \pm 0.01$	$0.48^{e} \pm 0.00$
1	$5.32^{b} \pm 0.02$	$33.33^{e} \pm 0.46$	$16.39^{a} \pm 0.12$	$23.79^{b} \pm 0.13$	$12.72^{a} \pm 0.02$	$8.45^{d} \pm 0.14$	$117.31^{b} \pm 14.82$	$85.89^{a} \pm 3.34$	$0.14^{c} \pm 0.03$	$2.01^{d} \pm 0.00$
2	$6.08^{ab} \pm 0.11$	$40.20^{d} \pm 0.28$	$15.50^{b} \pm 0.70$	$18.89^{d} \pm 0.12$	$9.73^{b} \pm 0.04$	$9.60^{c} \pm 0.84$	$91.83^{bc} \pm 8.87$	$74.30^{b} \pm 3.39$	$0.35^{bc} \pm 0.03$	$3.07^{c} \pm 0.00$
3	$6.71^{a} \pm 1.00$	$42.93^{c} \pm 0.04$	$11.42^{c} \pm 0.02$	$20.09^{c} \pm 0.12$	$7.90^{c} \pm 0.00$	$10.95^{b} \pm 0.07$	$81.27^{c} \pm 10.46$	$71.75^{b} \pm 0.22$	$0.83^{ab} \pm 0.22$	$3.76^{b} \pm 0.00$
4	$7.37^{a} \pm 0.52$	$49.86^{b} \pm 0.08$	$8.91^{d} \pm 0.01$	$15.11^{e} \pm 0.15$	$6.45^{d} \pm 0.07$	$12.30^{a} \pm 0.05$	$30.01^{d} \pm 3.81$	$60.73^{b} \pm 0.89$	$1.33^{a} \pm 0.37$	$4.51^{a} \pm 0.13$

*Different superscript letters within rows show the significance between samples ($p < 0.05$). TPC = total phenolic compounds (mg gallic acid equivalent/100 g) and antioxidant potential as determined by the DPPH assay. PV = peroxide value. All experiments were performed in triplicate and the data are presented as means ± S.D (one-way ANOVA).

highest percentage of fat, whereas the fourth formula had the lowest. This could be because sample 1 contained the highest percentage of fat-containing ingredients (sunflower seeds, cacao, and milk powder). Previous research found that chocolate spreads with hazelnut paste had a fat content of 66.8% [30], which was higher than that reported in this study. Our findings evidenced a reduction in the protein and fiber content by increasing the sugarcane syrup, but all samples were significantly higher than the control ($p < 0.05$).

The total phenolic content (TPC) of the samples ranged from 30.01 to 117.31 mg/100 g, with significant differences, and was 4.39 to 17.18 times lower than the commercial reference sample. Samples 3 and 4 were close to the control sample in cacao and milk content, but they had the lowest TPC level. This contradicts previous research, which found that sunflower kernels have a higher phenolic content (2938.8–4175 mg/100 g) [31] than different hazelnut cultivars (68.5–1704.9 mg/100 g) [32]. On the other side, Roda & Lambri [30] detected a TPC level of 31 mg GAE per 100 g hazelnut paste, which was also lower than that detected in the current study. It may be due to differences in analytical methodologies, sample materials, or their geographic origin. Similar trends were evident in the antioxidant potential activity. The top antioxidant potential activity was detected in sample 1, which was the most similar to the control sample ($p \geq 0.05$) and had the highest TPC. There are no significant differences between the other samples, which have DPPH values ranging from 60.73% to 74.3%. Antioxidants, as well known, protect against free radical damage by preventing radicals' formation, scavenging them, or promoting their decomposition [33]. Antioxidants naturally present in hazelnut and sunflower seeds, such as tocopherols, proanthocyanidins, and flavonols, help mitigate or slow the occurrence of these degradative reactions. Sample 1 has the highest content of sunflower seeds and cacao powder, which may be responsible for its antioxidant potential. The relative antioxidant capacity and phenolic compound content of the chocolates investigated in this study were comparable to previous reports [24], in which different chocolate types exhibited DPPH scavenging of 10.20–134.32 μmol Trolox/g.

3.2. Oil Quality. The primary lipid oxidation product, hydroperoxide, was determined in different samples after 1 month of storage. The peroxide values of the samples varied significantly (Table 2), with sample 4 having the highest peroxide value (1.33 mg equivalent O_2/kg). Sample 1 had the lowest peroxide value that was comparable to the reference sample ($p \geq 0.05$). Fresh fats have a peroxide value of less than one, and when the PV exceeds ten, unwanted sensorial properties (rancidity) occur [34]. Nonetheless, all of the tested chocolate samples reached the threshold of rancid oil.

The most serious mode of failure in nut-containing chocolate products is oxidative rancidity, which produces free fatty acids with off-flavors. The primary quality attribute of edible-grade oil or fat is free fatty acids (FFA). The maximum acceptable limit of FFA in chocolate is estimated to be 3% [35]. Referring to the results in Table 2, the samples have different acidity values ($p < 0.05$). The reference sample had the lowest value, while sample 4 had the highest. The FFA values in samples 3 and 4, which contain the highest percentages of sugarcane syrup, exceeded the acceptable limits. Due to inactivation, the action of oxidation enzymes such as lipoxygenase, which catalyzes the oxidation of linoleic acid (the main unsaturated fatty acid in sunflower seeds), had no effect in our samples because we used roasted sunflower seeds. Rancidity is classified into two types: hydrolytic and oxidative. The oxidative reaction requires the presence of oxygen and is accelerated by heat, light, moisture, and metal catalysts such as iron. Because the main abundant ingredient in the samples is sugarcane syrup, which is a rich source of iron [14], we hypothesize that metal iron is the main cause of oxidation in our samples. Iron is a known prooxidant because it can decompose lipid hydroperoxide into free radicals via a redox cycling pathway [36]. Iron-rich foods, as a result, require chelating agents such as EDTA to prevent oxidation and extend their shelf life. Although fortified chocolate spread with added iron or from natural sources has been created in some previous studies [8, 37], there is no data on its effect on the oxidative quality of its fat.

3.3. Iron Content. Iron is a necessary element that performs critical functions such as oxygen transport, muscle metabolism, and DNA synthesis [12]. Because iron is present in cacao [38] and sugarcane syrup [14], determining the iron content of the proposed samples is essential. Figure 1 compares the iron content of the suggested formulations with the control sample and the RDA for adults, male and female, as well as children aged 4–9 years. According to the data, increasing the amount of sugarcane syrup nonetheless the sunflower seed content increased the iron content by three to six times over the control. All formulations provide iron above the RDA requirement for male adults and children because they include 11.00 to 20.34 mg/100 g of product. Remarkably, formulation #4, with 20.34 mg of iron/100 g, surpasses the RDA for both male and female adults and children. An earlier study [37] increased the iron content of prepared chocolate spread to 4.13 mg/100 g by adding carob flour, which was lower than that achieved in the current study.

3.4. The Physical Properties of the Chocolate Spread

3.4.1. The Color. The color of a product is the most important physical property that influences its appeal. Color differences in the chocolate spread can be attributed to the formulation (ingredients) variations, roasting degree, and processing parameters during production [39]. Table 3 shows the color parameters of the chocolate spread samples. Based on these data, replacing sugar with sugarcane syrup and hazelnut with sunflower seeds has no significant effect ($p \geq 0.05$) on the L^* value, indicating that it does not reduce lightness compared to the control sample. The redness index

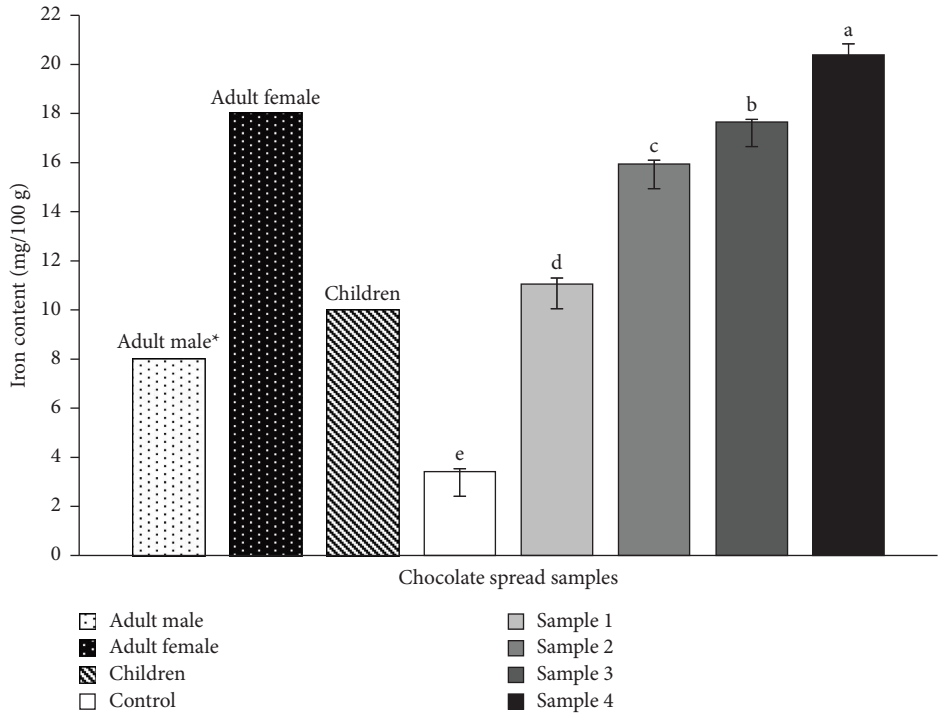

Figure 1: The iron content of the control and different chocolate spread formulae measured by MP-AES in comparison with the recommended dietary allowance (RDA) of iron. *The recommended dietary allowance (RDA) for adults (aged 19–50 years) and children (aged 4–9 years) according to Aydin & Ozdemir [37]. †Different letters show the significance between samples ($p < 0.05$). All experiments were performed in triplicate and the data are presented as means ± S.D (one-way ANOVA).

Table 3: The color parameters (L^*, a^*, and b^*) of the prepared chocolate spread formulae.

Samples	Color parameters			
	L^*	a^*	b^*	ΔE
Control	27.97 ± 0.26	$^{\dagger}1.50^{a} \pm 0.19$	$-0.20^{a} \pm 0.07$	0.00^{e}
1	27.18 ± 0.26	$0.92^{b} \pm 0.09$	$-0.61^{b} \pm 0.08$	1.06^{b}
2	27.32 ± 0.36	$0.93^{b} \pm 0.07$	$-0.64^{bc} \pm 0.16$	0.97^{c}
3	27.16 ± 0.04	$0.85^{b} \pm 0.00$	$-0.77^{bc} \pm 0.00$	1.14^{a}
4	28.39 ± 2.11	$0.97^{b} \pm 0.29$	$-0.85^{c} \pm 0.02$	0.94^{d}

†Different superscript letters within rows show the significance between samples ($p < 0.05$). All experiments were performed in triplicate and the data are presented as means ± S.D (one-way ANOVA).

(a^*) and greenish (b^*) indices differed significantly between all formulations and the control sample. Color changes could be seen as light blue and brown with positive lower a^* values and negative b^* values, respectively. a^* values of the formulations ranged from 0.85 to 0.97, with no statistically significant differences ($p \geq 0.05$). b^* values increased in a negative direction as the sugarcane syrup content increased due to the sugarcane syrup color (dark brown). Furthermore, the color difference factor (ΔE) varied from 0.94 to 1.14, showing that the substitution of sugar and hazelnut with sugarcane syrup and sunflower seeds results in a substantial shift in the instrumental color values compared to the control. In contrast to the control sample, the results also reveal that formula (3) had the greatest color difference (ΔE), followed by formula (1). This is probably due to the high proportion of roasted sunflower seeds (23%). Our results are consistent with those of Acan et al. [7], as increasing grape pomace in prepared chocolate spreads resulted in negative b^* and h° values with no significant differences in L^* values, which were attributed to the bright brown color of the pomace.

3.4.2. The Texture. While flavor is usually deemed important in product identification, chocolate texture and appearance are key qualities in customer choice and acceptance [40]. The hardness (firmness) of this product influences its spreadability, which decreases as the hardness value increases [37]. The control sample had a work shear value of 313.20 N, and the hardness of the tested samples decreased as the concentration of sugarcane syrup increased, indicating better spreadability (Table 4). Because it contains many solids, such as milk, cocoa powder, and sunflower seeds, sample 1 had the highest significant hardness value (371.30 N) compared to the control and the other samples. This finding fits well with that of Fayaz et al. [41], who revealed that adding cocoa powder and sugar to chocolate spreads increased the solids, leading to a stronger network. Compared with the control, formula 4 had the lowest hardness value, which could be explained by considering its fat content (15.11 vs. 30.96%) and moisture content (7.37 vs. 2.57%). Acan et al. [7] evidenced a negative correlation between sample spreadability and its water activity, which matches the behavior of our samples. A similar pattern was observed in adhesion scores, where all samples substantially ($p < 0.05$) exceeded the control sample. In contrast, the springiness of samples 1 and

Table 4: Texture profile of the prepared chocolate spread formulae.

Samples	Texture parameters			
	Hardness (N)	Adhesiveness (mJ)	Springiness (mm)	Gumminess (N)
Control	*$313.20^{c} \pm 0.14$	$18.52^{d} \pm 0.05$	$13.46^{a} \pm 0.02$	$114.50^{c} \pm 0.28$
1	$371.30^{a} \pm 0.28$	$54.95^{a} \pm 0.28$	$13.48^{a} \pm 0.05$	$180.80^{b} \pm 0.42$
2	$356.40^{b} \pm 0.56$	$19.34^{c} \pm 0.00$	$13.49^{a} \pm 0.14$	$68.20^{d} \pm 0.07$
3	$275.90^{d} \pm 1.41$	$17.93^{e} \pm 0.00$	$5.69^{c} \pm 0.14$	$206.00^{a} \pm 1.41$
4	$117.40^{e} \pm 0.14$	$22.96^{b} \pm 0.07$	$10.93^{b} \pm 0.05$	$41.20^{e} \pm 0.14$

*Different superscript letters within rows show the significance between samples ($p < 0.05$). All experiments were performed in triplicate and the data is presented as means ± S.D (one-way ANOVA).

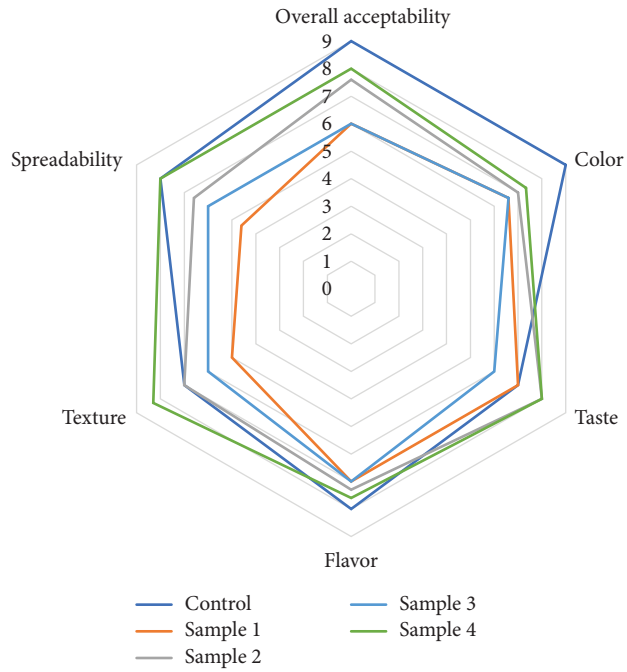

Figure 2: Organoleptic scores of formulated chocolate spread formulae compared to the control.

2 was similar to the control ($p \geq 0.05$), which could be attributed to their high content of milk and cacao powder. As evidenced by their moisture content (Table 2), these additives may absorb moisture from the finished product, resulting in more springiness. The ultimate result of hardness and cohesiveness, gumminess, is an essential component of all semisolid food items. Formula (3), which had the highest gumminess score (206.00 N), also had the lowest degree of springiness. It was followed by formula #1, despite having a low concentration of sugarcane syrup. The rheology behavior of molten chocolate is affected by many interconnected factors, including moisture level, ingredients (fat content), and processing strategy [8]. As a result of these observations, sample 1 is likely to necessitate excessive spreading effort, resulting in technological failures such as pumping, piping, and filling. Processing time during the ball mill and rotational speed should be considered for this purpose. When Aydemir & Atalar [42] used sunflower oil instead of palm oil, lower spreadability values were detected than those of the control. Meanwhile, the level of stickiness in chocolate containing coconut butter and hydrogenated palm oil was higher than in the control sample. Acan et al. [7] also found that higher solids in grape pomace decreased the spreadability of that chocolate due to its fiber content.

3.5. The Sensory Attributes. Figure 2 and its data (Supplementary 1) depict the sensory results for six parameters of the proposed chocolate spread formulations. All samples received varying ratings for color, taste, flavor, texture, spreadability, and overall acceptability. In terms of texture, flavor, and spreadability, sample 4 was the closest preferred formula to the control, which may be attributed to the presence of a high percentage of sugarcane syrup in relation to the solid components. In contrast, formulae 1 and 3 scored poorly in most characteristics, particularly spreadability and texture. These findings corroborated the texture profile study results, in which formula 1 revealed the greatest hardness value (Table 4). Spreadability, or how easily a sample can be uniformly distributed across a surface, is a critical characteristic of this type of chocolate. The high-solid ingredients, such as cacao powder and sunflower seeds,

increase the hardness, which influences the spreadability and overall product acceptance. The proportion of sunflower seeds also affected the acceptability of the formulations, with lower percentages of the latter being more acceptable. That indicates that sunflower paste at 13% was preferred over 23% for replacing hazelnuts. Color differences have also been discerned by the panelists. The color scores of the created formulae declined in the following order: formula $4 > 2 > 1 > 3$, with formula 3 scoring the lowest and having the greatest ΔE value (Table 3).

The study's weakness was that the chocolate formulae were evaluated blindly. The participants had no information about the chocolates' composition, particularly their iron content, and were unaware of the reduced amount of fat and sugar in the designed chocolates. Accordingly, if the product's benefits are revealed to consumers, acceptance may significantly increase [40]. Consequently, it was concluded that the supplement of up to 63% sugarcane syrup did not adversely affect the product quality in terms of sensorial aspects.

4. Conclusions

The study's main goal of developing acceptable spreads devoid of hydrogenated palm oil and with greater iron content than conventional chocolate spreads was successfully achieved. The suggested formulae #4 can assist with anemia to meet the daily recommended dietary intake, especially for the most vulnerable individuals, such as children and adult females, because 100 g of this iron-rich source provides ≈20.5 mg iron. Finally, future investigations are encouraged to support our findings by examining the iron bioavailability and digestibility of the proposed formulations.

Data Availability

The data used to support the findings of this study are included in the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Supplementary Materials

Supplementary 1 shows the data illustrated in Figure 2. (*Supplementary Materials*)

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