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Nutritional Value, Amino Acids of Biscuits and Cakes Fortified with Spirulina (*Arthrospira platensis*) Powder

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Abstract

Ancient cultures have long employed the blue-green microalga Spirulina (Arthrospira platensis) as a food source. The current study aims to assess the nutritive content and sensory characteristics of biscuits and cakes fortified with Spirulina powder at levels (2.5%, 5%, and 7.5%). The study included determining the chemical composition and phenolic compounds of raw Spirulina powder (Sp) and determining amino acids. Likewise, the physical and sensory characteristics of the studied biscuits and cakes were assessed. The data revealed that the chemical composition of raw (Sp) was (56.20%) protein, (10.50%) fat, (5.01%) crude fiber, (11.27%) ash, and (17.02%) total carbohydrates with a (387.38 Kcal/100 g). Raw (Sp) recorded increased phenolic compounds in ellagic acid and catechin and decreased cinnamic acid and vanillin. Furthermore, biscuits and cakes supplemented with 2.5%, 5%, and 7.5% (Sp) of essential amino acids and non-essential amino acids showed significant differences at ($p \leq 0.05$). Essential and non-essential amino acids recorded an increase in threonine, leucine, aspartic acid, glutamic, and proline, respectively, in biscuits and cakes supplemented with 5% and 7.5% compared with raw (Sp). Therefore, the results showed significant differences in all biscuits and cakes' sensory and physical characteristics. Moreover, biscuits and cakes fortified with 2.5% (Sp) had the best scores of all studied sensory characteristics. So, we recommend using (Sp) in children's formulas to enhance the nutritional values.

Key words: Spirulina, amino acids, phenolic compounds, bakery products.

Introduction

Spirulina (*Arthrospira platensis*) is a bluegreen microalga, that has been a common dietary substance around the world since ancient times [1]. It is widely used in many nations, is GRAS (generally recognized as safe), has no toxicological side-effects, and has FDA and ANVISA approval [2,3]. It is also referred to as the perfect food for mankind

and the World Health Organization views it as the best food going forward due to its extremely high nutritional value and designation as a superfood [4]. For the past 3.5 billion years or so, Spirulina has been one of the most ancient life forms to develop in alkaline volcanic warm water lakes. This alga's cells are arranged in a spiral pattern, like a basic prokaryote. Despite having more than 60 species, Spirulina platensis (S. platensis) and Spirulina maxima are the two most often utilized varieties for dietary supplements [5].
Additionally, Spirulina species have anti-viral, anti-bacterial, anti-fungal, and anti-parasitic properties, and their preparations help preserve the natural gut microbial flora, particularly Lactobacillus and Bifidus. Because of this, opportunistic infections like Candida albicans and E. coli pose less of a threat when consumed with Spirulina [6]. Spirulina is utilized as a feed additive for many animal species, including fish and birds, as well as a food supplement for mankind because it is also known for excreting significant anti-inflammatory and antioxidant activity [7,8]. S. Platensis is the meal with the highest protein content currently available, with a protein level of (65%) [9]. As a result, it is the food that has the most protein. It has more than three times as much protein as meat or fish and twice as much protein as soybeans [7]. It has methionine, which is typically missing in other algae, 47% of the essential amino acids, 15–25% of carbohydrates, 8–13% of minerals, 3-7% of fat, and 8–10% of fiber. Also, it includes minerals, vitamins, vital fatty acids, carotenoids, phycocyanin, chlorophyll, and other bioactive elements [10]. As a result, it is crucial for baby growth, ideal for kids, especially during the growth phase, and quite beneficial for the elderly as well [4]. These days, this organism is marketed as a food supplement and used to fortify a variety of foods and beverages, ranging from noodles, health drinks, smoothies, confectionary, food bars, baked desserts, doughnuts, muffins, pasta, salad dressing, frozen desserts, snack foods, popcorn, corn chips, crackers, breakfast cereals, and soups [11]. To prevent or remedy a proven nutrient shortage in the general population or a particular population group, food fortification is the addition of one or more critical nutrients to food [12]. It has contributed to a significant transformation of baking as we know it today. One of the world's largest and fastest-growing food industries is the bakery sector. Both kids and adults can benefit from their products as healthy snacks [13]. Additionally, we can increase the nutritional value of our regular diet by fortifying these snacks with (Sp), notably biscuits and cakes. Cakes are a crucial baked product in the human diet and are typically consumed with soft beverages, juice, or tea. Biscuits are the most widely consumed serial-based baked morning food [14] and cakes are an important baked product in the human diet and are usually eaten with soft drinks, juice, or tea and are also used as weaning foods for infants [15]. But, just like any other algae, the regular intake of (Sp), as a dietary supplement, demands closer monitoring of potentially harmful constituents [4].

The objective of this study is to assess the nutritional value and sensory characteristics of biscuits and cakes fortified with Spirulina powder at levels (2.5%, 5% and 7.5%) and test their acceptability with consumers.

Materials & Methods

Materials

Spirulina (Arthrospira platensis) algae powder was obtained from the Faculty of Science, Al-Azhar University, Cairo Branch, Egypt. Wheat flour 72% extraction was provided from the south Assiut mills company, Assiut government, Egypt, Sugar powder, milk, butter, egg, Salt (sodium chloride), baking powder, oil and vanilla was purchased from a local market (Khair Zaman) in Assiut city, Egypt.

Technological Process

Biscuit formulae

Biscuit dough was prepared according to [16]. The ingredients of the formulae are presented in Table (1).

Table (1): Biscuit formula

Ingredients	control	Treatment		
		T1	T2	T3
Wheat flour (72% extraction) (g)	100	97.5	95	92.5
Spirulina (g)	--	2.5	5	7.5
Sugar powder (g)	47	47	47	47
Milk (ml)	5	5	5	5
Butter (g)	3.13	3.13	3.13	3.13
Egg (n)	1	1	1	1
Sodium chloride (g)	0.75	0.75	0.75	0.75
Baking powder (g)	1	1	1	1

control = biscuit without Spirulina powder. T_1 = biscuit with 2.5% Spirulina powder. T_2 = biscuit with 5% Spirulina powder. T_3 = biscuit with 7.5% Spirulina powder.

Dough preparation

Biscuits samples have been organized through changing components of wheat flour with Spirulina powder (Sp) at chances of 2.5%, 5%, 7.5% and (20g) darkish chocolate powder with inside the fundamental method of biscuits. Powdered sugar and fats have been creamed in Braun Mixer (Molunix, AL-Araby Company, Banha, Egypt) with a flat beater for 2 minutes. Egg and milk have been brought to the cream and combined for 5 minutes. Then baking powder turned into delivered to the blended combination of wheat flour with darkish chocolate, (Sp) and salt (sodium chloride) which had been combined for 2 minutes to acquire biscuits dough [16].

Preparation of biscuits

The dough turned into sheeted to a thickness of approximately 3 mm the use of Atlas Brand rolling machine. The sheeted dough changed into reduce right into a rounded form

the usage of a 45 mm diameter cutter and baked on an aluminum tray in an electric powered oven at 180°C for 6 minutes. The biscuit turned into cooled for 30 minutes, packed in polyethylene luggage and saved beneath Neath desiccation [17,18].

Cake formula

The cake batter was made according to [19]. The formula's components listed in Table (2).

Table (2): Cake formula

		Treatment		
Ingredients	control	T1	T2	T3
Wheat flour (72% extraction) (g)	100	97.5	95	92.5
Spirulina (g)	--	2.5	5	7.5
Sugar (g)	90	90	90	90
Oil (ml)	60	60	60	60
Butter (g)	20	20	20	20
Baking powder (g)	4	4	4	4
Milk (ml)	25	25	25	25
Salt (g)	2	2	2	2
Egg (g)	120	120	120	120
Vanilla essence (dops)	2	2	2	2

control = cake without Spirulina powder. T_1 = cake with 2.5% Spirulina powder. T_2 = cake with 5% Spirulina powder. T_3 = cake with 7.5% Spirulina powder.

Dough Preparation

In the basic cake recipe, portions of the wheat flour were swapped out with (Sp) with percentages of 2.5%, 5%, 7.5%, and (20 g) dark chocolate powder to create cake samples. Each cake sample's wheat flour and other ingredients were precisely weighed using the ratios shown in Table (2). Then, to create cream, sugar, oil, and butter were combined in a mixer for 20 minutes. Wheat flour was combined well for 10 minutes at low speed (150 rpm) with 60g of egg, milk, baking powder, and salt added to make sure the ingredients were spread evenly. Then, the mixture received an additional 60g of egg and two drops of vanilla essence, and it was mixed for two minutes at medium speed (250 rpm).

Preparation of cakes

The batter was then poured into cake pans (greased with vegetable oil) to approximately 2/3 volume. All pans were baked in the oven at 170o C for 45 min. after baking, the cakes were cooled for 1-2 h. at room temperature (25o C) in a sealed plastic bag. The cakes were then cut into 2×3×5 cm. slices using a bread knife for sensory evaluation [19].

Methods

Determination of the chemical composition of raw Spirulina powder

According to the AOAC methodology [20], moisture, crude protein, fat, crude fiber, and crude ash were measured. According to [21], the total carbohydrates were computed using the difference. The method of [22] is used to calculate the caloric value.

Total calories = fat × 9 + protein × 4 + total carbohydrates × 4

Physical evaluation of biscuits

The dimensions of biscuits were measured in cm3 for height, width, spread ratio, and spread factor. For each of the three biscuits under study, three were used to evaluate, and averages were kept. The following equations were used to compute the spread ratio and spread factor in accordance with [18].

$$Spread\ ratio = \frac{Width}{Height}$$

$$Spread\ factor = \frac{Spread\ ratio\ of\ sample}{Spread\ ratio\ of\ control} \times 100$$

Physical evaluation of cakes

Different prepared cakes were measured in weight, volume and specific volume as follows: the weight of different cakes was recorded by using a sensitive balance (0.1 g). The volume of the prepared samples was determined by the clover seeds displacement method. Specific volume was calculated according to the method of [23] using the following equation:

$$Specific\ volume\ (cm^3/g) = \frac{Volume\ (cm^3)}{Weight\ (g)}$$

Sensory evaluation of biscuits

Consumer approval was assessed using sensory evaluation for the color, odor, sweetness, flavor, texture, and overall acceptability. For sensory evaluation, a numerical hedonic scale from 1 to 10 (where 10 represents good performance) was utilized [16]. The proposed biscuits are tested by ten seasoned individuals.

Sensory evaluation of cakes

Consumer acceptability was assessed using sensory evaluation for the color (crust and crumb), graining, texture, taste, odor, and overall acceptability. For sensory evaluation, a numerical hedonic scale from 1 to 10 (where 10 represents good performance) was utilized [24]. The proposed cakes are tested by ten seasoned individuals.

Identification of phenolic active compounds of raw Spirulina powder

The injection quantity become 10 µl. wave lengths of 280 nm (for flavan-3-oils and derivatives of benzoic acid) and 360 nm (for flavonols and derivatives of cinnamic acid) had been decided on for detection; quantification of the compounds turned into found out

the use of calibration curves received through HPLC of natural standards. The HPLC technique become used in accordance to [25].

Amino acids composition of Spirulina powder

The amino acid composition of raw (Sp) and samples (biscuits and cakes) were determined using HPLC methods [26].

Ethical Approval

This study was approved by the ethics committee of the Faculty of Specific Education, Assiut University.

Statistical analysis

According to the MSTAT-C Statistical program, the data were subjected to statistical analysis of variance, and treatment means were compared for significant differences using Duncan's Multiple Range Test significant differences at $P< 0.05$ [27]. All variance analyses were carried out using the computer program in accordance with the process described by [28].

Results and discussion

Chemical composition of raw Spirulina powder

The chemical composition of raw Spirulina powder (Sp) is presented in Table (3). The data revealed that (Sp) contains protein (56.20%), fat (10.50%), crude fiber (5.01%), ash (11.27%), total carbohydrates (17.02%) and caloric value (387.38 Kcal/100 g). These results agree with [29] who claimed that because S. platensis has such high nutritional benefits, its biochemical components provide it its marketing worth, making it one of the most promising microalgae for culture. Being a rich source of vitamins, including vitamin B12 and pro-vitamin A, minerals, particularly iron, and γ-linolenic acid, an essential fatty acid precursor for prostaglandins, it is also widely known as a source of protein (60–70 g/100 g) of high biological value. The physiochemical analysis of S. Platensis was reported by [30,31] and disagrees with [32] who reported that the physiochemical analysis of S. Platensis was 60.32% protein, 7.28% lipid, carbohydrate content 17.63%, ash 6.88% and caloric value 369.28 Kcal. Those variations may be due to the environmental condition of water, climate and salinity.

Table (3): Chemical composition of raw Spirulina powder (g/100g)*

Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Total carbohydrate (%)	Caloric value (Kcal/100g)
6.45±0.6	56.20±1.3	10.5±0.8	5.0±0.05	11.3±0.6	17.02±1.1	387.4±4.6

* *Mean of three replicates*

Identification of phenolic active compounds of Spirulina powder

Data in Table (4) shows the identification of phenolic active compounds of raw Spirulina powder (Sp). The obtained results indicated that the highest phenolic compounds

identified in (Sp) were recorded for ellagic acid and catechin. The values were (12000 and 7500) mg/100g. On the other hand, the lowest phenolic compounds identified in (Sp) were recorded for cinnamic acid and vanillin. The values were (1000 and 1.290) mg/100g. These data agree with [1] who reported that Spirulina has high total antioxidant activity (39.2%). Furthermore, extensive research has been done on the possible health advantages of algae bio-active substances like phenolics. They are potent antioxidants in humans and may reduce oxidative damage to proteins, lipids, and biomolecules that are involved in chronic illnesses like cancer and brain dysfunction [32].

Table (4): Identification of phenolic active compounds of raw Spirulina powder*

Phenolic active compounds of Spirulina powder	Values (mg/100g)
Gallic acid	1500±6.2
Chlorogenic acid	5000±7.6
Catechin	7500±15.1
Caffeic acid	1800±6.7
Quercetin	4000±8.6
Ferulic acid	2000±4.5
Vanillin	1.290±0.03
Methyl gallate	1500±4.3
Syringic acid	1.720±0.04
Pyro catechol	4000±7.6
Rutin	6100±6.5
Ellagic acid	1200±6.1
Coumaric acid	2000±3.8
Naringenin	3000±4.6
Daidzein	3500±5.6
Cinnamic acid	1000±3.2
Apigenin	5000±7.8
Kaempferol	3000±6.4
Hesperetin	2000±3.1

* *Mean of three replicates.*

Additionally, [33,34,35] stated that Spirulina is taken into consideration as highlighting antioxidant, anti-inflammatory, antibacterial sports and sluggish the development of sure cancers and decrease the dangers of cardiovascular disease, diabetes and neurological illnesses. While [8,36] suggested that spirulina platensis is a microalga belonging to the elegance of cyanobacteria with a unique system of energetic products, which includes minerals, nutrients and proteins, beta-carotene, tocopherols, and phenolic acids.

Spirulina powder serves as the richest source of phenolic compounds that's utilized in antioxidant, antimicrobial and antifungal because of its free-radical scavenging activity.

Amino acids of Spirulina powder and supplemented biscuits & cakes

Results regarding amino acids of Spirulina Powder (Sp) are given in Table (5). The results for essential amino acids in Spirulina Powder recorded that leucine was of the highest value (4.02 g/100g) followed by threonine (1.96 g/100g), isoleucine (1.92 g/100g), phenylalanine (1.81 g/100g), lysine (1.39 g/100g) and valine (1.24 g/100g); respectively while the lowest values (0.60 g/100g and 0.83 g/100g) were noted for histidine and methionine. The results for non-essential amino acids in (Sp) indicated glutamic acid as the major amino acid followed by proline and aspartic acid whereas the lowest content was noticed for tyrosine.

These data are in agreement with [37-39] they reported that leucine was found to be present in high proportions followed by valine in the results for essential amino acids in Spirulina and spirulina protein isolates, whereas tryptophan was found to have the lowest value. Leucine and valine were also two of the most important necessary amino acids in Spirulina. Although glutamic acid and aspartic acid were the two most prevalent non-essential amino acids in Spirulina and Spirulina protein isolates, cysteine was found to have the lowest concentration. Aspartic acid and glutamic acid were also present in significant levels.

Through reverse-phase HPLC, the naturally dried Spirulina of Cuban provenance was examined for its amino acid composition.

On a dry weight basis, it was found that the levels of valine and leucine were in a high proportion (6.1 and 6.0 g/100g); respectively. Additionally, the examination of the amino acids revealed that glutamic acid had the greatest value (101 mg/g) [38]. Most of the algae include lysine and sulfur-containing amino acids methionine and cysteine [30]. Numerous seaweed species also contain significant amounts of arginine, aspartic acid, and glutamic acid [40]. The chemical substances known as the essential amino acids are required for biological functions. They make up the majority of all bodily tissues. The body cannot naturally generate the essential amino acids, so they must be consumed regularly through the diet. The use of (Sp) as a supplement food can fulfil the daily requirement for essential amino acids based on the essential amino acid content [41]. All enzymes, membrane carriers, blood transport molecules, intracellular matrices, hair, fingernails, serum albumin, keratin, collagen, several hormones, and a sizable portion of membranes are examples of proteins, which are also the primary functional and structural component of all body cells. Also, the amino acids that make up proteins serve as the building blocks for a variety of coenzymes, hormones, nucleic acids, and other compounds vital to life. Thus, maintaining cellular integrity and function, as well as for health and reproduction, requires an adequate intake of dietary protein. Because (Sp) includes a large level of protein due to the high content of necessary and non-essential amino acids, it was

discovered that the blends' essential and non-essential amino acid contents (found in cookies and cakes) had good values.

Table (5): Amino acids of Spirulina powder and supplemented biscuits & cakes (g/100g)

Amino acids		Raw	Biscuits				Cakes			
		(Sp)	control	2.5%	5%	7.5%	control	2.5%	5%	7.5%
Essential amino acids	Phenylalanine	1.81c ±0.03	1.2d ±0.01	1.8c ±0.03	2.3b ±0.3	2.8a ±0.04	1.3e ±0.02	2.4c ±0.02	3.1b ±0.2	4.2a ±0.3
	Methionine	0.83c ±0.01	0.4d ±0.01	0.9c ±0.01	1.5b ±0.01	2.0a ±0.03	0.5e ±0.02	1.2c ±0.02	1.9b ±0.03	2.5a ±0.03
	Threonine	1.96d ±0.04	1.3e ±0.03	2.6c ±0.1	4.0b ±0.4	5.3a ±0.3	1.6e ±0.02	2.4c ±0.04	4.3b ±0.2	6.8a ±0.1
	Valine	1.24a ±0.02	0.9b ±0.01	0.5c ±0.01	0.4c ±0.01	0.2cd ±0.01	0.8d ±0.01	1.30c ±0.03	1.9b ±0.04	2.5a ±0.05
	Isoleucine	1.92b ±0.02	1.0d ±0.02	1.4c ±0.01	1.9b ±0.1	3.3a ±0.03	1.3e ±0.04	1.6d ±0.03	2.5b ±0.02	2.9a ±0.1
	Leucine	4.02c ±0.4	3.3e ±0.1	3.9d ±0.2	4.8b ±0.6	5.6a ±0.05	3.5d ±0.1	4.1c ±0.1	4.8b ±0.3	5.5a ±0.4
	Lysine	1.39c ±0.02	0.7e ±0.02	1.0d ±0.01	2.3b ±0.2	3.5a ±0.03	1.1e ±0.02	1.5c ±0.03	2.5b ±0.04	3.1a ±0.02
	Histidine	0.6b ±0.01	0.4b ±0.03	0.6b ±0.01	0.03c ±0.001	1.2a ±0.02	0.50c ±0.02	0.9c ±0.03	1.3b ±0.03	2.2a ±0.01
	Alanine	3.25a ±0.4	2.0d ±0.06	3.4a ±0.3	3.0b ±0.2	2.5c ±0.04	2.3e ±0.04	4.1c ±0.2	5.2b ±0.3	6.1a ±0.2
	Arginine	2.91c ±0.2	2.0d ±0.1	3.5b ±0.2	3.8b ±0.3	4.3a ±0.2	1.5d ±0.01	3.1c ±0.1	4.6b ±0.1	5.8a ±0.2
Non-essential amino acids	Aspartic acid	4.66c ±0.3	4.0d ±0.2	5.1bc ±0.6	5.6b ±0.4	6.7a ±0.6	3.1d ±0.4	4.5c ±0.4	6.3b ±0.6	7.8a ±0.5
	Glutamic acid	7.59c ±0.7	5.0e ±0.2	6.5d ±0.7	8.4b ±0.7	9.7a ±0.7	6.3d ±0.6	7.1c ±0.6	8.5b ±0.7	10.2a ±0.6
	Glycine	2.08d ±0.2	1.0e ±0.01	3.2c ±0.4	4.6b ±0.2	5.7a ±0.1	1.5e ±0.01	2.9c ±0.2	5.5b ±0.3	7.8a ±0.4
	Proline	4.88c ±0.5	3.5d ±0.4	4.7c ±0.4	5.5b ±0.5	6.9a ±0.7	3.3e ±0.1	5.4c ±0.3	6.3b ±0.4	7.8a ±0.4
	Cysteine	2.69c ±0.02	2.0d ±0.04	2.6c ±0.02	3.5b ±0.4	4.6a ±0.1	2.3d ±0.1	2.6c ±0.03	3.9b ±0.1	4.8a ±0.2
	Tyrosine	1.76a ±0.03	1.0c ±0.01	1.3b ±0.01	0.9c ±0.04	0.5d ±0.02	1.3d ±0.04	1.7c ±0.04	2.6b ±0.1	3.5a ±0.1
	Serine	2.31c ±0.1	1.4d ±0.03	2.0c ±0.03	3.5b ±0.3	4.4a ±0.2	1.1d ±0.02	2.3c ±0.1	4.1b ±0.2	5.6a ±0.3

Each value represent mean± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Sensory evaluation of wheat biscuits and biscuits supplemented with Spirulina powder

Table (6) shows the sensory evaluation result of the biscuit 100% (control sample) and samples supplemented with 2.5%, 5% and 7.5% (Sp). The data in Table (6) mentioned that there was a highly significant difference between wheat flour biscuit (control) and supplemented biscuit with 2.5% and 5% (Sp) in all sensory attributes and overall acceptability. The best score for sensory attributes, color, odor, sweetness, flavor, texture and overall acceptability was recorded 49.43 in biscuits supplemented with 2.5% (Sp). These data are disagreement with [42] who mentioned that the pasta with a 3% Spirulina additive received the lowest ratings for colour, texture, and overall look. While a prior study found that adding S. platensis microalga to Manico-based bread items increased their protein content [43]. The protein ingredient picked for inclusion in cookies needs to have a good flavour and be very protein-efficient without materially altering the flexibility and consistency of the dough [44]. Carotenoids, chlorophyll, and phycocyanin are the three main pigments found in spirulina microalgae and account for 0.4, 1.0, and 14% dry weight, respectively. Therefore, substituting microalgae powder with green chlorophyll and green-blue phycocyanin pigments for some of the flour's yellow Xanthophyll pigment results in a drop in L* and negative values for a* and b* [10].

Table (6): Sensory evaluation of wheat biscuits and biscuits supplemented with Spirulina powder

Sensory evaluation	Color	Odor	Sweetness	Flavor	Texture	Overall acceptability
Samples	(10)	(10)	(10)	(10)	(10)	(50)
Wheat biscuits 72% extraction (control)	8.92c ±0.6	8.9c ±0.8	8.91c ±0.8	8.80c ±0.6	8.93c ±0.6	44.49c ±1.6
Biscuits with 2.5% Spirulina Powder	9.85a ±0.4	9.9a ±0.7	9.90a ±0.7	9.88a ±0.7	9.88a ±0.7	49.43a ±1.7
Biscuits with 5% Spirulina Powder	9.23b ±0.6	9.3b ±0.6	9.32b ±0.2	9.24b ±0.8	9.32b ±0.9	46.46b ±2.1
Biscuits with 7.5% Spirulina Powder	8.78cd ±0.7	8.6d ±0.4	8.86c ±0.3	8.67d ±0.9	8.92c ±0.6	43.86c ±1.6

Each value represent mean± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Sensory evaluation of wheat cakes and cakes supplemented with Spirulina powder

Table (7) shows the sensory evaluation result of the cakes 100% (control sample) and samples supplemented with 2.5%, 5% and 7.5% Spirulina powder. The data in Table (7) revealed that there was a highly significant difference between wheat flour cake (control) and supplemented cake with 2.5% and 5% (Sp) in all sensory attributes and overall

acceptability. The lowest score was recorded for cake supplemented with 7.5% (Sp). While the best score of all studied sensory evaluations was recorded for cake supplemented with 2.5% (Sp). These results agree with [45] who reported that the large particles of Spirulina microalgae could imprint discontinuities in the dough network, resulting in a softer structure. Also, [46] showed that Spirulina is cyanobacteria that lack a rigid cell wall which leads to higher water absorption rates (by its cellular components mainly proteinaceous structure). In fact, Spirulina protein molecules due to having a hydrophilic property, compete for water binding sites with starch molecules, destabilizing and delaying gelation of starch, leading to a more fragile gel structure.

Table (7): Sensory evaluation of wheat cakes and cakes supplemented with Spirulina powder

Sensory evaluation	Crust color	Crumb color	Graining	Texture	Taste	Odor	Overall acceptability
Samples	(10)	(10)	(10)	(10)	(10)	(10)	(60)
Wheat cake 72%	8.97d	8.61c	8.89c	8.66d	9.08c	8.77d	54.87c
extraction (control)	±0.3	±0.5	±0.7	±0.6	±0.7	±0.6	±1.3
Cake with 2.5%	9.91a	9.89a	9.97a	9.89a	9.88a	9.94a	59.25a
Spirulina Powder	±0.4	±0.8	±0.6	±0.4	±0.8	±0.7	±2.2
Cake with 5%	9.33b	9.34b	9.23b	9.39b	9.36b	9.41b	57.12b
Spirulina Powder	±0.7	±0.9	±0.4	±0.5	±0.9	±0.8	±3.1
cake with 7.5%	9.16c	8.72c	9.17b	8.88c	9.17c	9.07c	54.75c
Spirulina Powder	±0.8	±1.1	±0.3	±0.6	±0.6	±0.9	±1.6

Each value represent mean± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

Physical evaluation of wheat biscuits and biscuits supplemented with Spirulina powder

The mean values of physical evaluation of wheat biscuits and biscuits supplemented with (Sp) at 2.5%, 5% and 7.5% (Sp) are presented in Table (8) and Figures (1a-d). The data recorded a gradual increment in spread ratio from 94.56 to 119.5 in processed biscuits. The Spread ratio increased with increasing (Sp) in wheat flour. The reason is that the continuous formation of the gluten network is affected by the protein of flour, which in turn increases the dough's viscosity. The spread ratio is an important quality parameter that correlates with mouthfeel, texture and fineness of biscuits. Furthermore, this addition changes the baking properties which may be due to the changes in the quality and quantity of protein with the added ingredients which also affects the gas retention of dough during the baking process.

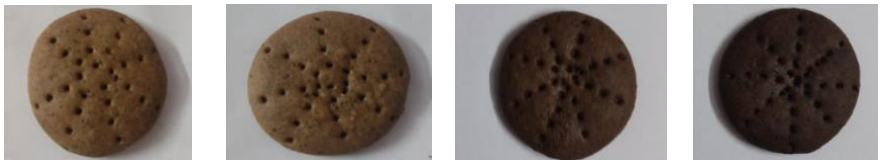
Table (8): Physical evaluation of wheat biscuits and biscuits supplemented with Spirulina powder

Physical evaluation Samples	Width Cm	Height Cm (a)	Spread ratio (b)	Spread factor% (c)
Wheat biscuits 72% extraction (control)	5.81c±0.4	0.81b±0.01	7.17bc±0.6	100.0bc±0.7
Biscuits with 2.5% Spirulina Powder	6.10a±0.5	0.90a±0.02	6.78c±0.5	94.56c±0.5
Biscuits with 5% Spirulina Powder	6.00b±0.3	0.80b±0.01	7.50b±0.9	104.6b±0.8
Biscuits with 7.5% Spirulina Powder	6.00b±0.2	0.70c±0.02	8.57a±0.7	119.5a±0.6
F-Test	**	**	**	**

Each value represent mean± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

a = Thickness of three biscuits in series $b = \frac{\text{Width}}{\text{Height}}$

$c = \frac{\text{Spread ratio of sample}}{\text{Spread ratio of control}} \times 100$



(a) **(b)** **(c)** **(d)**

Figure (1a-d).

(a) biscuit without Spirulina powder (control).
(b) biscuit with 2.5% Spirulina powder.
(c) biscuit with 5% Spirulina powder.
(d) biscuit with 7.5% Spirulina powder.

Physical evaluation of wheat cakes and cakes supplemented with Spirulina powder

The mean values of physical evaluation of wheat cakes and cakes supplemented with (Sp) at 2.5%, 5% and 7.5% are presented in Table (9) and Figures (2a-d). The data in Table (9) outlined significant differences between weight (g) and volume (cm3) of cake supplemented with 2.5%, 5% and 7.5% (Sp). The data showed that the highest value of weight in cake supplemented with 7.5% (Sp) was (322 g). While the larger volume and specific volume was in cake supplemented with 2.5% (Sp) when compared with other treatments.

Table (9): Physical evaluation of wheat cakes and cakes supplemented with Spirulina powder

Physical evaluation / Samples	Weight (g)	Volume (Cm^3)	Specific volume (cm^3/g)
Wheat cake 72% extraction (control)	324a±3.2	404a±4.6	1.25a±0.03
cake with 2.5% Spirulina Powder	317a±4.1	384b±3.2	1.21ab±0.02
cake with 5% Spirulina Powder	320a±2.7	363c±4.2	1.13b±0.01
cake with 7.5% Spirulina Powder	322a±3.4	342d±5.6	1.06c±0.03
F-Test	N.S	**	**

Each value represent mean± standard deviation. Mean under the same column bearing different superscript letters are different significantly ($p \leq 0.05$).

$$\text{Specific volume} = \frac{\text{Volume } (cm^3)}{\text{Weight (g)}}$$

(a) **(b)** **(c)** **(d)**

Figure (2a-d).
(a) cake without Spirulina powder (control).
(b) cake with 2.5% Spirulina powder.
(c) cake with 5% Spirulina powder.
(d) cake with 7.5% Spirulina powder.

Conclusion

The present study showed that the chemical composition and phenolic compounds of (Sp) recorded the highest values in protein, crude fat, crude fiber, ellagic, and catechin. So, it can be considered very nutritious and rich in antioxidants. Besides, (Sp) is used as a high source of amino acids. Correspondingly, sensory evaluation scores revealed that biscuits are recommended for children's formulas, especially in the growth phase.

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القيمة الغذائية والأحماض الأمينية للبسكويت والكيك المدعم بمسحوق طحلب الاسبيرولينا

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استخدمت الحضارات القديمة الاسبيرولينا "طحلب أخضر مزرق" كمصدر للغذاء. تهدف الدراسة الحالية إلى تقدير القيمة الغذائية والخصائص الحسية للبسكويت والكيك المدعم بمسحوق الاسبيرولينا بنسب (2,5%، 5% و7,5%). واشتملت الدراسة على تقدير التركيب الكيميائي والمركبات الفينولية لمسحوق الأسبيرولينا الخام وكذلك تقدير الأحماض الأمينية بالاضافة إلى الخصائص الفيزيائية والحسية للبسكويت والكيك. وأظهرت النتائج أن التركيب الكيميائي لمسحوق الأسبيرولينا الخام (56,20%) بروتين، (10,50%) دهون، (5,01%) ألياف خام، (11,27%) رماد، (17,02%) كربوهيدرات كلية، وسعرات حرارية (387,38 كيلوكالوري/100جم). كما سجلت الاسبيرولينا الخام ارتفاع بالمركبات الفينولية في حمض الأليجيك والكاتشين وانخفاض في حمض السينامك والفالين. بالإضافة إلى أن هناك فروق ذات دلالة معنويه بين الاحماض الأمينية الأساسية والغير اساسية عند ($p\leq0.05$) في البسكويت والكيك المدعمين بـ 2,5%، 5%، 7,5% فالأحماض الأمينية الأساسية والغير أساسية سجلت ارتفاعاً في الثريونين والليسين وحمض الاسبارتيك والجلوتاميك والبرولين على التوالي في البسكويت والكيك المدعمين بـ 5% و 7,5% عند مقارنتهم بمسحوق الاسبيرولينا الخام. لذا أظهرت النتائج أن هناك فروق ذات دلالة معنويه في الخصائص الحسية والفيزيائية لكل من البسكويت والكيك محل الدراسة. علاوة على ذلك سجل البسكويت والكيك المدعمين بـ 2,5% مسحوق الاسبيرولينا أفضل الدرجات لجميع الخصائص الحسية المدروسة. لذلك نوصي باستخدام مسحوق الاسبيرولينا في فورميولات الأطفال لرفع القيمة الغذائية.

الكلمات المفتاحية: الاسبيرولينا، الأحماض الأمينية ، المركبات الفينولية، منتجات المخابز.