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Author Affiliation:
Department of Nutrition and Food Sciences, Faculty of Home Economics, Menoufia University, Shibin El Kom, Egypt

Corresponding author:
Doha Abdallah
dohasaid945@gmail.com
Mobile: +2 01030402718

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Nutritional Benefits of Some Children's Food Products Enriched with Blue-Green Algae (*Spirulina*)

Authors
Sahar El Shafai, Doha Abdallah

Abstract:
Spirulina is a type of blue-green algae that humans can consume. This biomass comprises three species: *Arthrospira platensis, A. fusiformis*, and *A. maxima*. It is rich in protein and folic acid, which supports the development and hydration of the developing brain. The researchers created complementary recipe formulas with 0.5 to 2% spirulina for six different products, including gelatin dessert (jelly cola) at 2%, frozen yogurt at 1%, salted biscuits at 0.5%, wafer biscuits at 1%, potato balls at 0.5%, and sushi at 2%. These products' chemical composition and nutritional value, as well as their total phenols and acid value, were determined. The results showed that the wafer biscuits had the highest protein and lipid contents (12.09% and 27.38%, respectively) compared to the other products, while the salted biscuits had the highest total carbohydrate content (76.69%). The salted biscuits were also a rich source of minor elements such as Mg, Fe, Zn, Cu, and Mn. The frozen yogurt had the highest total phenolics value (482.66 µ/g) among the products, while the jelly cola had the lowest acid value (0.33%) compared to the other products. It has been concluded that salted biscuits and jelly cola have high nutritional value and are highly acceptable for children.

Keywords:
Nutrients, Child nutrition, Blue-green algae, Spirulina, Functional foods

Introduction

There are 149 million stunted children and 45 million wasting children in the world [1]. Good nutrition is essential for the growth and development of children. However, many studies have shown that children's diets are often inadequate in terms of essential nutrients, vitamins, and minerals. The lack of proper nutrition can lead to a range of health problems, including stunted growth, impaired cognitive development, weakened immunity, and increased susceptibility to diseases. Additionally, modern-day diets that are high in processed and junk food have been linked to the rising incidence of childhood obesity, diabetes, and other chronic diseases. These issues are particularly relevant in low-income

countries, where access to nutritious food is limited, and in developed countries where unhealthy food options are readily available and heavily marketed to children. Addressing these issues requires a multifaceted approach, including education and awareness campaigns, public health policies, and the development of nutritious and affordable food options that appeal to children.

Inadequate protein and calorie intake throughout childhood is directly linked to stunted growth and is a precursor to a number of psychosocial issues in adulthood. Children who are undernourished also show delayed development and reduced functional ability. Pediatric undernutrition, which is directly linked to diminished cognitive abilities, is defined by a lack of sufficient weight increase, low weight per height, or low weight per length [2].

Spirulina, which is the dried biomass of the cyanobacterium Arthrospira platensis, is a safe and widely used food source in many countries. It has been approved by both the Food and Drug Administration (FDA) and the National Health Surveillance Agency (ANVISA) and is recognized as generally safe for both humans and animals due to its lack of toxicological side effects [3-6]. Although Spirulina is high in protein, it is only permitted as a food additive in limited amounts of 0.5 to 3.0 grams per serving by the FDA, based on the GRAS (generally recognized as safe) designation [7-9]. As a result, specialty snack bars, nutritional drinks, popcorn, beverages, frozen desserts, condiments, and fruit products are all made with Spirulina. Spirulina can be consumed at any age, from infancy to pregnancy and adulthood, but its benefits are most evident in young children during their growth period, especially from ages 1 to 6 [10, 11].

Spirulina's health properties can greatly benefit malnourished children, as it meets their daily dietary needs for beta-carotene, which can help prevent blindness and eye diseases. Spirulina is rich in beta-carotene, which is an effective treatment for eye problems caused by vitamin A deficiency [12-14]. Spirulina has been suggested as a possible food supplement for malnourished children.

The aim of this study is to investigate the nutritional benefits of food products enriched with Spirulina for children, focusing on six different products: gelatin-dessert (jelly cola), frozen yogurt, salted biscuits, wafer biscuits, potato balls, and sushi. The study aims to evaluate the chemical composition and nutritional value of these products, as well as their total phenols and acid value, in order to determine which products have the highest nutritional value and are most suitable for consumption by children. The study aims to provide insight into the potential benefits of Spirulina as a food supplement for children's health and wellbeing.

Materials and methods

Materials:

Spirulina were purchased from National Research Center (NRC), Dokki, Giza, Egypt. Gelatin powder, rice, flour, coconut milk, baking powder, vanilla, powdered sugar, salt, onion, potato, and eggs were purchased from Hyper One souper market. Moreover, milk, butter, and yoghurt were purchased from Almarai Dairy Products Company, New Cairo, Egypt.

Table (1): Preparation of jelly cola

Ingredients	Amount
Spirulina	2.0 g
Gelation Solution	100.0 mL
Gelatin Powder	15.0 g
Vanilla	3.0 g
Honey	80.0 g

As a formulation shown in Table (1), the first step was to fill a medium mixing basin with cups of cold or room temperature (not hot) water. Then, 15 g of plain gelatin powder was added to the water. Add and stir until completely dissolved. This step should be completed first to give the gelatin time to bloom. Two more should be added, and a small pot should be heated to a rolling boil. The gelatin and cold-water mixture ought to be fully bloomed and ready to use at this time. When the water has reached a rolling boil, pour the hot water into the heat-safe mixing bowl containing the water and gelatin. The gelatin powder should completely dissolve into the water after whisked everything together. The jelly mixture should be poured into a shallow glass Pyrex dish, covered with plastic wrap or a lid, and chilled until completely set, which typically takes at least 2-3 hours. Smaller plates might set quicker [15].

Table (2): Preparation of frozen yogurt

Ingredients	Portion (g)
Spirulina	1.0
Yogurt	50.0
Honey	8.0
Vanilla	1.0
Strawberry	11.0
Mango	11.0
Chocolate Chips	7.0
Kiwi	11.0

As a formulation shown in Table (2), yogurt was made from pasteurized milk (2.5% fat), which was boiled at 85°C for 30 minutes before being cooled to 42°C. The manufacturer's recommended amount of yoghurt starter (DVS, YC-11 Kristin Hansen Denmark) was incorporated into the milk (0.2% milk w/w). When the acidity of the fermented milk reached 80°C, it was taken out of the incubator and allowed to cool to refrigerator temperature. In order to make frozen yoghurt, ingredients like honey (8%) are dissolved in water, well combined, and then pasteurized at 85°C for 30 minutes before being cooled to the temperature of a refrigerator.

The above mixture was combined with various types of fruits in the experimental samples, with each fruit constituting 11% of the mixture. Afterward, chocolate chips were mixed with the yogurt, and the resulting mixture was ripened for 15 hours in a refrigerated environment. Once the ripening process was complete, the mixture was frozen in an ice cream maker for

30 minutes. The final product was then packaged in plastic and chilled at -18°C until it hardened [16].

Table (3): Preparation of wafer biscuits rolls

Ingredients	Portion (g)
Spirulina	1.0
Sugar powder	23.0
Egg whites	20.0
White flour	29.0
Butter	27.0

Wheat flour, sugar, butter, salt, and egg powder were used as raw materials in the project (Table 3). Everything was thoroughly combined before going into the oven for 15 minutes. The finished product was then rolled and placed in a freezer, where it was kept at a temperature of -18oC [17].

Table (4): Preparation of salted biscuits

Ingredients	Portion (g)
Spirulina	0.5
Rice flour	45.0
Baking powder	20.0
Salt	1.0
Butter	9.0
Cold Water	4.0
Onion fresh	17.0

To create the mixture, as indicated in Table (4), combine the initial five ingredients in a large bowl. Following that, combine the buttermilk, onion, and butter to the dry ingredients, adding only enough moisture to achieve the desired consistency. Drop heaping teaspoonfuls of the mixture onto baking sheets coated with cooking spray, spacing them 2 inches apart. Finally, spray the tops with butter-flavored spray and bake in a 400-degree oven for 10 to 14 minutes or until golden brown. Serve hot after baking [18].

Table (5): Preparation of potato balls

Ingredients	Portion (g)
Spirulina	0.5.0
Potatoes	50.0
Spices	3.0
Starch	8.0
Baking Powder	2.0
Turmeric	1.0
Salt	0.5
Oil	23.0
Flour/Semolina	12.0

As a formulation shown in Table (5), the potatoes were boiled till tender but not quite done. For deep frying, a bit of salt, a pinch of turmeric, one teaspoon of finely chopped coriander

seeds, and two to three tablespoons of self-rising flour were added. Grate the potatoes and place them in a large bowl. Add the salt, turmeric, coriander powder, fresh coriander, garam masala, and two tablespoons of flour. forming into ping-pong-ball-sized koftas. A little extra flour can be added if the mixture is too sticky. The fried kofta should then be transferred to a paper towel to absorb any extra oil [19].

Table (6): Preparation of sushi

Ingredients	Portion (g)
Boiled white rice	72.0
Filler (tuna, anchovy, lemon juice, soy sauce, sesame oil, mayonnaise & mustard)	28.0
Spirulina	2.0

As a formulation shown in Table (6), follow the rice's cooking directions on the package, but before starting the cooking process, add an additional 4 tbsp of water. Rice becomes stickier as a result. Meanwhile, remove the oil from the tuna in the can and compost it. Combine tuna, salt, and mayonnaise. When the rice is finished cooking, season it with salt and sesame oil. Combine well to spread the seasoning. Allow this to finish cooling. A 1/3 measuring cup should be covered with a thick piece of cling film. Rice that has been seasoning filled the cling film. Spread the rice out into a thick pancake using the cling film [20].

Methods

Chemical composition

Gross composition of samples includes moisture, total solids, fat, protein, carbohydrates and ash contents were determined according to AOAC official methods [19].

Determination of reducing sugars by dinitro salicylic acid (DNSA)

Dinitrosalicylic acid (DNSA) is a common reagent used to measure reducing sugars in a solution. The DNSA assay is a colorimetric method used to quantify the concentration of reducing sugars, such as glucose, fructose, and maltose, in a solution. Glucose was used as a reference for calculating the exact sugar content [22].

Minerals Determination

The samples were digestion at first by H_2SO_4 and H_2O_2 according the methods described by Crompton [21]. Determination of calcium and magnesium by the Versenate (EDTA) method reported by Harley [24]. Determination of potassium and sodium by flame photometer as mentioned by Cheng and Bray [25]. Determination of N, P, Mn, Fe, Cu, and Zn in samples by Inductively Coupled Plasma (ICP) Emission Spectroscopy according to the standard methods of the American Public Health Assocaition (APHA) [26].

Determination of total phenolic compounds (TPC)

In a nutshell, 2 g of material dissolved in 50 mL (95% ethanol). The extract was then diluted with 8 mL of distilled water, 0.5 mL of Folin-Ciocalteu's reagent, and 1 mL of saturated sodium carbonate solution. After being vortexed for 15 seconds and allowed to stand at room temperature for 30 minutes, the mixture's absorbance at 725 nm was measured using a spectrophotometer. The results are given as micrograms of equivalent gallic acid per g of the extract [28].

Determination of acid value

The approach was modified from IUPAC [26]. Using 1% phenolphthalein indicator, 100% ethanol and diethyl ether were properly neutralized with 0.10 N potassium hydroxide solution. In 50 ml of neutralized ethanol-diethyl ether solvent, 5 g of the test materials were dissolved. They were then titrated with 0.10 M potassium hydroxide while being constantly shaken until a pink color remained for 15 seconds. Oleic acid was used to compute free fatty acid content [29].

FFA % as oleic acid = S × 0.0282 × 100 / W

Where: S = titration (ml), W = weight of the test sample (g).

Determination of polyphenols fractions of Spirulina by HPLC

An Agilent 1260 series was used for the HPLC analysis. 4.6 mm x 250 mm i.d., 5 m, C18 column was used for the separation. Water (A) and 0.02% tri-floro-acetic acid in acetonitrile (B) were the components of the mobile phase, which had a flow rate of 1 ml/min. The linear gradient was sequentially programmed into the mobile phase as follows: 12–14 minutes (80% A), 15–16 minutes (80% A), 0–5 minutes (40% A), 8–12 minutes (50% A), and 16–20 minutes (80% A). At 280 nm, the multi-wavelength detector was observed. For every one of the sample solutions, 10 l of injection volume was used. The temperature in the column was kept constant at 35 °C [30].

Sensory evaluation:

The food samples fortified with Spirulina at different concentrations were evaluated, using sensory means by ten panelists of the staff member of Food Industries and Nutrition Division, National Research Centre, using the score sheet from 1 to 9, which “1” is low score and “9” is high score.

Statistical analysis

Statistical Package for the Social Sciences (SPSS) for Windows, version 17.0, was used to analyze the data (SPSS Inc., Chicago, Illinois, USA). Data were expressed as means standard deviations (SD). The TUKEY honesty test was conducted after the one-way analysis of variance (ANOVA) calculation.

Results and Discussion

Spirulina is a type of blue-green algae that is known for its high nutritional content and potential health benefits. Spirulina is a rich source of proteins, containing approximately 55-70% protein by dry weight. The protein in spirulina is considered to be of high quality, as it contains all essential amino acids in appropriate ratios. Spirulina contains a variety of carbohydrates, including glucose, fructose, sucrose, and starch. The carbohydrate content of spirulina is relatively low, accounting for approximately 15-20% of its dry weight. Spirulina contains a small amount of lipids, accounting for approximately 5-10% of its dry weight. The lipid content of spirulina is composed of a variety of fatty acids, including omega-3 and omega-6 fatty acids. Spirulina is a rich source of vitamins, including vitamins A, B1, B2, B3, B6, B9, C, D, and E. Spirulina is particularly high in vitamin B12, which is often lacking in plant-based diets. Spirulina is also a good source of minerals, including calcium, iron, magnesium, phosphorus, potassium, and zinc. Spirulina is particularly high in iron, which is important for maintaining healthy blood [31, 32]

The investigation's identification of the phenol components in Spirulina revealed a high concentration of phenolic acids and a low content of flavonoids (due to the absence of a standard for flavonoids), with wide variations in mg/g concentrations (Table 7). The most prevalent components of which were the gallic, chlorogenic, coumaric, caffeic, vanillic, and ferulic acids. Gallic acid (17.16 mg/g) had the highest concentration of phenolic compounds, followed by chlorogenic acid (10.92 mg/g), catechin (7.0 mg/g), and caffeic acid (5.32 mg/g), while the remaining phenolic and flavonoid components had moderate and low amounts.

Table (7): HPLC polyphenols fractions of Spirulina.

Identified components	Concentration (mg /g) *
Gallic acid	17.16 ± 0.34
Chlorogenic acid	10.92 ± 0.28
Catechin	7.00 ± 0.10
Coffeic acid	5.32 ± 0.25
Syringic acid	0.36 ± 0.02
Rutin	1.39 ± 0.11
Ellagic acid	1.14 ± 0.14
Coumaric acid	2.63± 0.22
Vanillin	3.75 ± 0.17
Ferulic acid	2.54 ± 0.33
Naringenin	3.93 ± 0.84
Propyl Gallate	0.93 ± 0.50
Quercetin	1.31± 0.09
Cinnamic acid	0.94 ± 0.13

**The results were expressed as mean values ± standard deviations.*

Salicylic, trans-cinnamic, synaptic, chlorogenic, and caffeic acids are the primary phenolic fractions identified in Spirulina, according to Miranda et al., [33]. Phenolic acids are a class of polyphenols that are commonly found in plants. Spirulina contains several phenolic acids, including chlorogenic acid, caffeic acid, and ferulic acid. These compounds have been shown to have antioxidant and anti-inflammatory properties and may have potential therapeutic applications for a range of conditions, including cardiovascular disease and cancer [34].

According to the study's findings, which were summarized in a Table (8), a sample of wafer rolls that had been fortified with 1% Spirulina is a decent source of dietary protein and lipids. 12.09% greater than the 0.93 g sample without the addition. Additionally, the proportion of lipids was recorded as 27.38% while it was 5.15g, and it was discovered that it supplied a substantial portion of the nutritional needs when compared to the nutritional recommendations table. This item is regarded as suitable for kids. Building, maintaining, and repairing our body's tissues depend on protein [35]. Children in their prepubescent years may oxidize fatty acids faster than adults. Therefore, compared to adults, children would have larger dietary fat needs.

Table (8): Chemical composition of different types of products fortified with Spirulina.

Items (g/100g)	Jelly Cola	Yoghurt	Salty biscuit	Wafer	Potatoes	Sushi
Total Solids	71.87±2.23	28.38±1.93	99.19±3.66	79.13±2.83	76.00±2.96	62.34±1.68
Moisture	28.13±1.36	71.62±3.36	0.81±0.11	20.87±1.13	24.00±1.14	37.66±1.39
Ash	3.44±0.12	1.43±0.55	4.99±0.63	6.95±1.04	0.80±0.05	4.97±0.73
Total protein	9.47±1.17	4.62±0.83	5.86±0.34	12.09±1.00	6.00±0.77	7.22±0.82
Total carbohydrates	13.75±1.69	20.18±1.39	76.69±2.62	23.94±1.16	63.31±1.18	27.25±0.99
Total lipids	2.21±0.15	2.15±0.22	11.56±0.59	27.38±1.27	5.89±0.84	14.70±1.01
Total Sugars	36.06±2.74	13.70±0.79	5.14±0.20	2.06±0.31	1.47±0.21	1.75±0.55

The data was expressed as mean values ± standard division (SD).

For children aged 4 to 18 years, the recommended dietary fat intake is higher (25 to 35 percent of energy) than it is for adults (20 to 35 percent of energy). In spite of this, many of parents and kids limit dietary fat for health reasons. Both children and adults need healthy fats as part of a balanced diet. Consuming adequate amounts of good fats is crucial for development and growth. They must be consumed in sufficient amounts by young children for healthy brain development. Fats not only provide energy for the body but also aid in the absorption of fat-soluble vitamins (vitamins A, D, E, and K).

The Recommended Dietary Allowances (RDA), according to FDA, for minerals vary depending on age, gender, and other factors such as pregnancy or lactation. Here are the estimated needs of some important minerals for the age group of 4-18 years according to the RDA:

- Calcium: The RDA for calcium for children aged 4-8 years is 1000 mg/day, and for children aged 9-18 years, it is 1300 mg/day.
- Iron: The RDA for iron for children aged 4-8 years is 10 mg/day, and for children aged 9-13 years, it is 8 mg/day. For boys aged 14-18 years, the RDA is 11 mg/day, and for girls aged 14-18 years, it is 15 mg/day.
- Zinc: The RDA for zinc for children aged 4-8 years is 5 mg/day, and for children aged 9-13 years, it is 8 mg/day. For boys aged 14-18 years, the RDA is 11 mg/day, and for girls aged 14-18 years, it is 9 mg/day.
- Magnesium: The RDA for magnesium for children aged 4-8 years is 130 mg/day, and for children aged 9-13 years, it is 240 mg/day. For boys aged 14-18 years, the RDA is 410 mg/day, and for girls aged 14-18 years, it is 360 mg/day.
- Phosphorus: The RDA for phosphorus for children aged 4-8 years is 500 mg/day, and for children aged 9-18 years, it is 1250 mg/day.

The research demonstrated that a sample of a gelatin dessert product fortified with 2% Spirulina (Jelly Cola) is a good source of dietary iron through a Table (9), as the findings were documented as follows: Compared to the sample prior to inclusion, which was 0.13 g, 1.04 gramme Additionally, the percentages of zinc were recorded as 1.21 while it was just 0.01 mg, and it was discovered that it provided a large portion of the nutritional requirements

when compared to the nutritional recommendations table. For kids of school age, this medication is said to help avoid iron deficiency anemia and stimulate memory [30].

Table (9): Major and minor elements of different types of products enriched by Spirulina

Items	Jelly Cola	yoghurt	Salty biscuits	wafer	Potatoes	Sushi
N (%)	1.53	0.75	0.94	1.94	0.97	1.16
P (%)	0.91	0.18	0.43	1.05	0.25	0.74
K (%)	2.11	0.28	0.46	4.21	0.25	4.10
Na (%)	0.02	0.26	0.83	0.04	0.36	1.09
Ca (%)	1.04	1.72	3.19	1.39	0.69	1.07
Mg (ppm)	1.10	1.55	1.92	0.03	0.83	0.97
Fe (ppm)	1.04	14.5	88.00	2.15	29.40	1.03
Zn (ppm)	1.21	12.4	12.8	0.90	28.70	0.80
Mn (ppm)	0.21	1.67	2.14	0.16	5.41	0.14
Cu (ppm)	0.46	38.8	44.4	0.55	17.9	0.47

According to the findings presented in Table (9), adding 1% Spirulina to a frozen yogurt park product sample makes it a valuable source of dietary magnesium, as the sample contained 1550 g of magnesium compared to the original 13 mg. Magnesium is a crucial mineral that the body needs and can only obtain through diet or supplements. It participates in over 300 different chemical reactions within the body and is necessary for the functioning of various vitamins and minerals, as well as metabolism, which enables cells to utilize the energy from carbohydrates consumed by children [31].

Table (9) showed that the addition of 0.5% Spirulina to a sample of salty biscuits resulted in a significant increase in dietary calcium, with 3190 mg present compared to 119 mg in the original sample. The biscuits also contained a slightly lower percentage of carbohydrates after the addition of Spirulina, but still provided a substantial amount of nutrition according to the recommended daily intake. These biscuits are considered safe for children and can help to prevent calcium deficiency, which is crucial for strong bones and proper nerve and muscle function. Carbohydrates are essential for providing energy to the body, and glucose, in particular, serves as the primary fuel for the brain, which is important for children's cognitive function and activity levels [38].

Table (9) of the research showed that a potato kofta product sample is rich in dietary potassium with 253 mg, and a significant amount of magnesium with 830 mg, as opposed to 32 mg prior to supplementation. Comparing the nutritional recommendations table, it was found that the sample provides a substantial portion of the required nutrition. Deficiency of potassium, which is lost through vomiting, diarrhea, or excessive sweating, can lead to hypokalemia, especially in kids. Potassium is crucial for normal cell function, protein synthesis, carbohydrate metabolism, heartbeat regulation, and proper muscle and nerve functioning. Magnesium, another essential mineral, participates in over 300 chemical processes in the body and is only available through diet or supplements. It aids in the metabolism of carbohydrates, facilitates the functions of other vitamins and minerals, and enables cells to extract energy from carbohydrates consumed by children [36].

Table (9) presented research findings that a sample of sushi tuna balls enriched with 2% Spirulina is a valuable source of dietary nitrogen, with 1160 mg detected. Furthermore, the study showed that the sample contained 740 mg of phosphorus, in contrast to the original 431 mg, and it meets a significant portion of the nutritional requirements according to the recommended dietary allowances. The nitrogen is an essential component for the creation of nucleic acids such as DNA and RNA, as well as proteins that form muscles and other tissues. On the other hand, phosphorus is necessary for several processes in the body, such as filtering waste and repairing cells and tissues. It is important to consume protein regularly in your diet to ensure adequate phosphorus levels and overall health. It is considered safe for children to consume this item to help meet their dietary needs.

Micronutrients, such as long-chain polyunsaturated fatty acids (LC-PUFAs), choline, iodine, folate, and B12, are critical for cognitive development, as indicated by research [30]. Iron is essential for the formation of neurological connections in the brain, which affects brain function [31]. Infants and young children grow quickly, increasing their demand for iron and putting them at risk of developing iron deficiency anemia, which can significantly harm overall intelligence and cognitive development if it develops during infancy. Zinc, a crucial trace mineral found in the brain, plays a crucial role in supporting cerebral structure and function [36]. Infantile zinc insufficiency has been linked to delayed motor growth and negative effects on attention and short-term memory [37], while chronic zinc deficiency is associated with stunting [38].

A substantial portion of the nutritional requirements were met by the yoghurt product, which had a high phenol content of 482.66 µg/g when compared to the dietary guidelines (Table 10). The total polyphenols for all samples were significantly ($p \leq 0.05$) varied. This medication is intended to protect kids from phenolic acids' antibacterial and antioxidant effects. Phenolic acids are easily absorbed through the walls of the gastrointestinal tract and are good for human health because they may function as antioxidants and prevent cell damage brought on by free-radical oxidation processes. Phenolic acids support human beings' ability to fight inflammation when consumed regularly.

Table (10): Total phenols and acid value of different types of products enriched with Spirulina.

Items	Jelly cola	Yoghurt	Salty biscuit	Wafer	Potatoes	Sushi
Acid value (mg/g)	0.33±0.03d	14.63±0.25a	1.03±0.11c	0.74±0.02cd	0.48±0.01d	2.18±0.44b
Total phenols (µg/g)	341.92±5.48b	482.66±3.77a	253.52±4.11c	200.04±2.84d	225.36±5.27cd	319.19±6.11bc

The data was expressed as mean values ± standard division (SD); the different letter of the same raw was significant ($p \leq 0.05$).

Total phenolic compounds and acid values are important indicators of the nutritional quality and shelf life of food products. Recent research has investigated the levels of these compounds in various Spirulina-enriched food products, including sushi, potatoes, wafer, salty biscuits, yoghurt, jelly, and cola. The results show that all of these products contain significant amounts of total phenolic compounds, which are known for their antioxidant and anti-inflammatory properties. Additionally, the acid values of these products were found to

be within the acceptable range, indicating that they are safe for consumption and have a reasonable shelf life. These findings suggest that incorporating Spirulina into different food products can not only increase their nutritional value but also improve their overall quality. The need for phenolic compounds in industry is particularly strong since they serve as precursors to other important bioactive compounds [23].

The figure (1) presents the results of evaluating the sensory properties of Spirulina-enriched food products, specifically jelly candies. The evaluation focused on the color, flavor, aroma, and texture of the candies, which were found to be at acceptable levels. The assessment was conducted using a scale of 1 to 10, where 10 indicates a strong preference and 1 indicates a strong dislike. The results indicate that the jelly candies are suitable for all consumer groups and can serve as a healthy treat for children. When compared to other products, the jelly and sushi shapes performed better in terms of all parameters assessed in Figure (1).

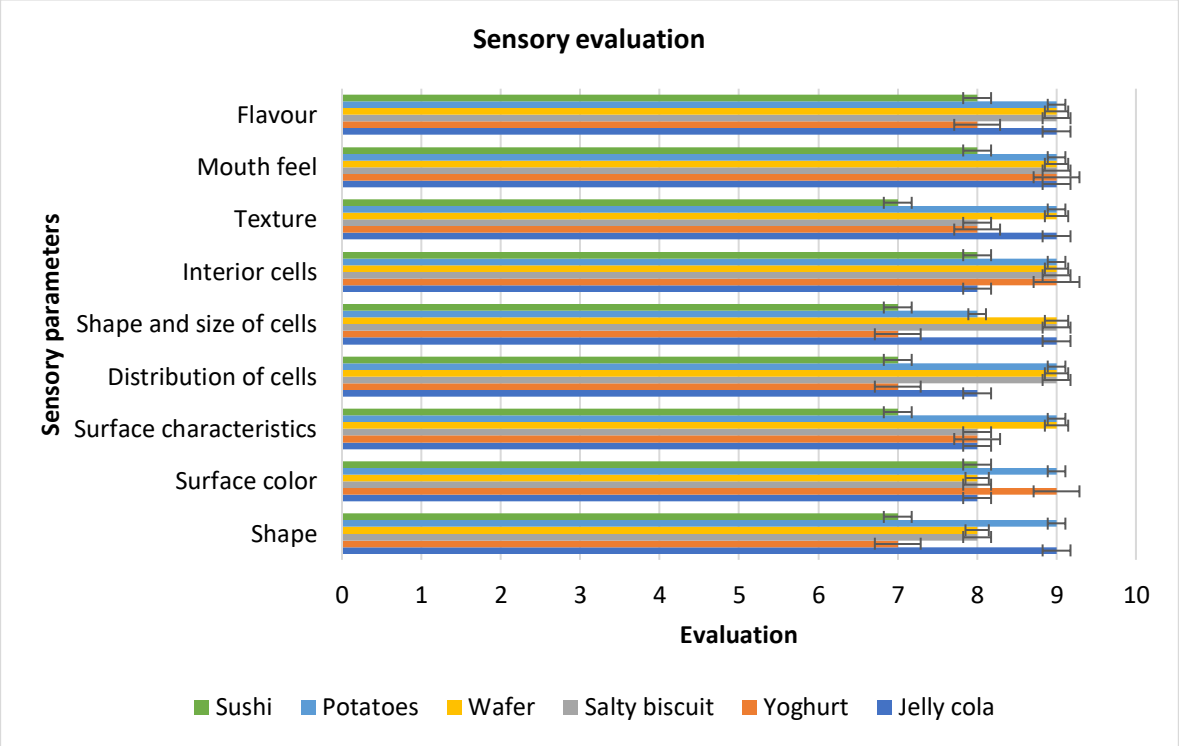

Figure 1: Sensory evaluation of different types of products enriched by Spirulina.

Conclusion

In conclusion, the findings of this research suggest that incorporating blue-green algae, specifically Spirulina, in children's food products can have nutritional benefits. The six products enriched with Spirulina showed variations in their chemical composition and nutritional value, with the salted biscuits and jelly cola having high nutritional value and being highly acceptable for children. Additionally, the frozen yogurt was found to be rich in total phenolics, which are known to have antioxidant properties. These results support the potential of Spirulina-enriched functional foods (at ratio of 0.5 to 2% g) as a means of improving children's nutrition and health. Further research is needed to explore the long-

term effects of consuming Spirulina-enriched products and to determine the optimal concentration of Spirulina in different food products for maximum nutritional benefits.

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الفوائد التغذوية لبعض المنتجات الغذائية للأطفال الغنية بالطحالب الخضراء المزرقة (سبيرولينا)

سحر عثمان الشافعي، ضحى سعيد عبد الله

قسم التغذية وعلوم الأطعمة .كلية الاقتصاد المنزلي .جامعة المنوفية، شبين الكوم، مصر

الملخص العربي:

سبيرولينا هو نوع من الطحالب الخضراء المزرقة التي يمكن أن يستهلكها الأنسان بشكل طبيعي حيث أنها غنية بالبروتينات والمغذيات الأخري. حيث تتكون من ثلاثة أنواع ، وهي أرثروسبيرا بلاتنسيس و أرثروسبيرا ماكسيما وأرثروسبيرا مغزلي ، وهي غنية بالبروتينات وحمض الفوليك مما يدعم نمو وترطيب الدماغ. لذلك كانت خطة الدراسة هي ابتكار وصفات بنسب مختلفة تتراوح من 0.5 إلى 2٪ سبيرولينا لستة منتجات مختلفة ، بما في ذلك حلوى الجيلاتين (جيلي كولا) بنسبة 2٪ ، والزبادي المجمد بنسبة 1٪ ، والبسكويت المملح بنسبة 0.5٪ ، والبسكويت الويفر بنسبة 1٪ ، وكرات البطاطس 0.5٪ و السوشي بنسبة 2٪. تم تقدير التركيب الكيميائي والقيمة الغذائية لهذه المنتجات ، بالإضافة إلى إجمالي الفينولات وقيم الحموضة. حيث أظهرت النتائج أن بسكويت الويفر احتوى على أعلى محتوى من البروتين والدهون (12.09٪ و 27.38٪ على التوالي) مقارنة بالمنتجات الأخرى ، بينما احتوى البسكويت المملح على أعلى نسبة من الكربوهيدرات (76.69٪). وكان البسكويت المملح أيضًا مصدرًا غنيًا للعناصر الصغري مثل الماغنسيوم و الحديد و الزنك و النحاس و المنجنيز. فيما يتعلق بالفينولات الكلية وجد أن الزبادي المجمد الأعلي قيمة للفينولات الكلية (482.66 ميكروغرام / جرام) بين كل المنتجات ، بينما كانت أقل قيمة للحموضة لنفس المنتج (0.33٪) مقارنة بالمنتجات الأخرى. بناءً على هذه النتائج ، يمكننا القول أن البسكويت المملح وحلوي الجيلاتين لهما قيمة غذائية عالية ومقبولان للغاية بالنسبة للأطفال.

الكلمات الأفتتاحية: المغذيات ، تغذية الأطفال ، الطحالب الخضراء المزرقة ، سبيرولينا ، الأغذية الوظيفية