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Development and Sensory Evaluation of *Spirulina* Chocolate Chip Oatmeal Cookies

Abdel Ghaly[1*], Amal Hammouda[1,2] and Mariam Al Hattab[1]

[1]*Deparment of Process Engineering and Applied Science, Faculty of Engineering, Dalhousie University, Halifax, Nova Scotia, Canada*
[2]*Department od Special food and Nutrition, Food Technology Research Institute, Agricultural Research Center, Giza, Egypt*

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ABSTRACT

Spirulina is very rich in protein, omega 3 and omega 6 oils, vitamin and mineral and its incorporation into cookies will enrich their nutritional values. However, adding *spirulina* to cookies may affect their smell, color, appearance, texture and taste. The objectives of this study were to evaluate the acceptability of *spirulina* added chocolate chip oatmeal cookies and to assess the effect of the amount of added *spirulina* on the sensory evaluation parameters (odor, color, texture, taste and shred) using a panel of 10 members. The results showed that all the baked samples had a noticeable smell. The majority of the panel members described the smell of the cookies as pleasant cookies smell, sweet-yeast smell, musty-seawater smell and fishy-seawater smell for the cookies receiving 0, 3, 6 and 9 % s*pirulina*, respectively. Adding and/or increasing the amount of *spirulina* increased the vividness of the color. The panel described the color as yellow, green-yellow, blue-green and green for the cookies that received 0, 3, 6 and 9% *spirulina*, respectively. The color appearance seemed acceptable to the majority of the panel members. The addition of s*pirulina* affected the easiness with which breaking a cookie was made, the fragmentation and the appearance of the break line. However, increasing the *spirulina* content increased the toughness of the cookies but did not affect the fragmentation or appearance of the break line. Small parts and smooth line were observed with the cookies that received no *spirulina* while large parts and irregular line were observed with all the cookies that received *spirulina*, regardless the amount of *spirulina* added. Adding *spirulina* to cookies may help maintain their integrity and reduce breakage during packaging and distributions. The addition of *spirulina* to the cookies affected both the texture and mouth feel. However, the amount of *spirulina* added to the cookies did not have any significant effect on either the texture or the mouth feel. The cookies that received no *spirulina* had a smooth texture and moist-smooth mouth feel whereas those received *spirulina* had grainy texture and dry-chewy mouth feel. The taste of the cookies that received no *spirulina* was rated sweet/delicious whereas the taste of the cookies that received *spirulina* was sweet-sour, sour-fishy and bitter-fishy for the cookies that received 3, 6 and 9% *spirulina*, respectively. Increasing the amount of *spirulina* from 3 to 9% changed the nature of the taste from pleasant (sweet) to unpleasant (bitter-fishy). The results showed that adding 3% s*pirulina* did not affect the odor and taste of the cookies and the addition of a strong aromatic compound to musk the smell of *spirulina or* a flavoring agent to musk the taste of *spirulina* may be required with higher concentrations of *spirulina*.

Keywords: *Spirulina*, Chocolate Chips, Oatmeal, Cookies, Color, Taste, Odor, Texture, Shred.

INTRODUCTION

Algae are great sources of nutrients and natural compounds which could be used as ingredients for new foods and functional food products. They contain protein, fat, carbohydrate, minerals and vitamins (Table 1) [1-10]. Algae have a well-balanced chemical composition and can enhance the nutritional value of foods and food products [11,12]. Among the most nutritious algae species, *Spirulina* has the highest biomass growth and the highest protein yield (Table 2) [3,8,13,14]. For a given area, the harvest yield of *Spirulina* is 10 times that of soy beans, 20 times that of corn and 200 times that of beef cattle [15].

Corresponding author: Professor A. E. Ghaly, Department of Process Engineering and Applied Science, Faculty of Engineering, Dalhousie University, Halifax, Nova Scotia, Canada; Tel:902-494-6014; Email: abdel.ghaly@dal.ca

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Table 1. Nutritional contents of some microalgae species [1-10].

Species	Protein (%)	Carbohydrate (%)	Lipids (%)	Minerals	Vitamins
Botryococcus brauni	18	32	17	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Chlorella protothecides	57	26	31	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Chlorella pyrenoidosa	57	26	2	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Chlorella Saccharophila	25-45	24-35	20-28	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Chlorella srokiniana	45	10-28	27	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Chlorella vulgaris	51-58	12-17	14-22	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Chlorococcum sp.	63	15	11	P, Zn, I, Se, Fe, Mn, Mg, Cu, P, Na, N, Co, Mo, S, Ca	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Scenedesmus obliqus	50-56	10-17	12-14	P, K, Ca, Na, Mg, S, Zn, Fe, Se, Cu, Co, Mn, Mo	A, B1, B2, B3, B6, B9, B12, C, D, E, H, riboflavin, pantothenate, folic acid
Spirulina platensisa	**61-72**	8-14	4-9	Ca, Fe, Zn, Mg, Cu, Na, P, K, Mn, Se	A, B1, B2, B3, B5, B6, B12, E, H, folacin, panthothenic acid, Inositol

Table 2. Biomass, protein yield and environmental growth conditions for some microalgae species [3,8,13,14].

Species	Biomass (g/L)	Protein yield (g/L)	Temperature (°C)	pH
Botryococcus brauni	1.84	0.331	20	7.6
Chlorella protothecides	1.32	0.752	25	6.0
Chlorella pyrenoidosa	2.84	1.619	25	6.0
Chlorella Saccharophila	3.88	1.746	20-24	6-9
Chlorella srokiniana	3.22	1.449	30	7-8
Chlorella vulgaris	1.01	0.580	25-30	7.0
Chlorococcum sp.	3.92	2.470	20-30	8.0
Scenedesmus obliqus	4.35	2.436	20-30	8.0
Spirulina platensisa	**4.30**	**2.709**	30	9.0

Spirulina is a blue-green algae that has a great potential for use in food and food products because of its high nutritional composition (Table 3) [4,12,16,17]. The dark green color of *Spirulina* comes from the high amount of chlorophyll *(plant blood)* which is only one molecule different from the hemoglobin (human blood). No one fruit, vegetable or meat can provide all the nutrition elements the human body demands as *Spirulina*. *Spirulina* contains over 100 nutritional and bioactive compounds, free of cholesterol, has only 4 Cal/g, has a high digestibility (95%) and has an alkali pH which can protect the human body from the diseases resulting from acidic foods such as meat, sea food and cereals. The protein content in S*pirulina* is about 65-71% which is higher than that in the soybean and is easier to digest. *Spirulina* contain all the essential and non-essential amino acids (Table 4) [12,17,18] which are 3-4 times those in fish and meat and 29 times those in soybeans. *Spirulina* also contains more than 2000 enzymes that are beneficial for human health [12,19,20]. The fatty acids (Table 5) contain omega 6 (gamma linolenic, essential linolenic and dihomogamma linolenic) and omega 3 (alpha linolenic, decosahexaenoic, palmitoleic, oleic and euric) oils [18,21-23]. *Spirulina* also contain several vitamins (Table 6) including: beta-carotene or vitamin A, thiamine or vitamin B1, riboflavin or vitamin B2, niacin or vitamin B3, pyridoxine or vitamin B6, cyanocobalamin or vitamin B12, d-a tocopherol or vitamin E, biotin or vitamin H, folic acid, panthothenate and inositol [4,12,16,17,21,22]. The vitamin

Table 3. General composition of dry *spirulina* [4,12,16,17].

Content	Value	Unit
Moisture	4.0-5.0	%
Energy	2.9	Kcal/g
Protein	65.0-71.0	%
Carbohydrates	15.0-25.0	%
Fibers	3.0-7.0	%
Lipids	4.0-7.0	%
Minerals	6.0-12.0	mg/g

Table 4. Amino acids in fresh dried *spirulina* [12,17,18].

Amino Acid	Amount (mg/g)
Alanine	7.7-46.6
Arginine	7.9-47.6
Aspartic Acid	12.1-72.8
Cysteine	0.9-5.6
Glutamic Acid	4.1-84.4
Glycine	5.3-31.9
Histidine	2.5-15.0
Isoleucine	5.4-32.6
Leucine	8.2-48.9
Lysine	4.4-26.2
Methionine	2.2-13.3
Phenylalanine	4.5-26.1
Praline	4.1-24.7
Serine	4.4-26.5
Threonine	4.7-28.1
Tryptophan	1.4-8.5
Tyrosine	4.0-23.8
Valine	6.2-37.4

Table 5. Fatty acids in *spirulina* [18,21-23].

Content	Value	Unit
Omega 6		
Gamma Linolenic	30.00	mg/g
Essential Linolenic	33.00	mg/g
Dihomogamma Linolenic	1.59	mg/g
Omega 3		
Alpha Linolenic	0.04	mg/g
Docosahexaenoic	0.04	mg/g
Palmitoleic	5.90	mg/g
Oleic	0.50	mg/g
Erucic	0.07	mg/g

Table 6. Minerals in *spirulina* [4,12,16,17,21,22].

Mineral	Value	Unit
Calcium	1.68	mg/g
Magnesium	2.55	mg/g
Iron	0.52	mg/g
Phosphorous	9.18	mg/g
Potassium	18.30	mg/g
Sodium	10.98	mg/g
Manganese	0.19	µg/g
Zinc	0.20	µg/g
Boron	0.30	mg/g
Copper	0.30	µg/g
Molybdenum	0.30	µg/g

contents in *spirulina* are higher than those in liver, carrot, spinach and many vegetables [3,5,7]. *Spirulina* is very rich in mineral content (Table 7) including: calcium, phosphorus, iron, sodium, magnesium, potassium, manganese, zinc, boron, copper and molybdenum [16,18]. The mineral contents in *Spirulina* are 28 and 58 fold of those in beef liver and spinach, respectively [8,9,10].

Because of its high content of highly valuable bioactive compounds, *spirulina* has been used to stimulate the immune system by enhancing the production of antibodies and cytokines and, thus, improving the resistance to infections in humans. *Spirulina* preparations have proved to be effective against HIV, herpes virus, cytomegalovirus, and influenza virus. *Spirulina* preparations are also regarded as functional products contributing to the preservation of the resident intestinal micro flora (especially lactic acid *bacilli* and *bifid* bacteria) and decreasing of *Candida albicans* level. Many of the phytonutrients in s*pirulina* function not only as antioxidants but also as anti-inflammatory nutrients working together in synergistic fashion to provide their cardiovascular benefits. Because of this unique combination of antioxidant and anti-inflammatory nutrients, S*pirulina* has several health benefits including: cardiovascular support and prevention of cardiovascular diseases, heart, kidney and liver disease, obesity, neurodegenerative disease, arthritis, allergies, prevention of breast, cervical, colon and esophageal cancers, cholesterol control and improved regulation of blood sugar [24-26].

In recent years, novel attractive healthy foods have been prepared from s*pirulina* [11]. Traditional foods such as salad dressings, dips, puddings, gelled desserts, biscuits, cookies, bread, noodles, pasta, smoothies, ice cream and health drinks such as microalgal sour milk and microalgal green tea were supplemented with s*pirulina* to add coloring and functional

Table 7. Vitamins in *spirulina* [16,18].

Item	Amount
Water soluble vitamins	
B-complex vitamins	
Vitamin B1 (Thiamine)	238.00 mg/g
Vitamin B2 (Riboflavin)	99,00 mg/g
Vitamin B3 (Niacin)	3.67 mg/g
Vitamin B5 (Pantothenic Acid)	3.4mg/g
Vitamin B6 (Pyridoxine)	13.20 mg/g
Vitamin B9 (Folate)	94.00 µg/g
Vitamin B12 (Cyanocobalamin)	6.60 µg/g
Vitamin H (Biotin)	1.00 mg/g
Choline	66.00 mg/g
Vitamin C	58.80 mg/g
Fat soluble vitamins	
Vitamin A (as Beta Carotene)	29.00 µg/g
Vitamin E (D-atocopherol)	5.0 mg/g
Vitamin K	25.20 µg/g
Alpha Carotene	7.50 µg/g
Beta Carotene	1900.00 µg/g
Lutein and Zeaxanthin	126.00 µg/g

attributes, making the products more sensorial attractive with health benefits due to the high content of carotenoids, polyunsaturated fatty acids, antioxidant and anti-inflammatory compounds [12,27-32].

OBJECTIVES

The main aim of this study was to evaluate the acceptability of *spirulina* added chocolate chip oatmeal cookies. The specific objectives were: (a) to assess the effect of the amount of added *spirulina* on the sensory evaluation parameters (odor, color, texture, shred and taste) and (b) to establish the most acceptable amount of *spirulina* that can be added to the cookies.

MATERIALS AND METHODS

Ingredients

The following ingredients were used: 1 cup soft butter (250 ml), 1 ½ cups brown sugar (375 ml), 1 1/3 cups wheat flower (325 ml), 2 cups cooking oats (500 ml), 2 cups chocolate chips (500 ml), 3 eggs, 1 tablespoon baking soda (5 ml), ½ tablespoon salt (5 ml), ½ teaspoon vanilla and the desired amount of *spirulina* (0, 3, 6 and 9% by weight or 0, 15, 30 and 45 g).

Preparation of Cookies

The butter and brown sugar were placed in a large bowl and beaten until became fluffy. The eggs and vanilla were added to the butter mixture. The wheat flower, cooking oats, baking soda and salt were place in a medium bowl and mixed with the required amount of *spirulina*. This mixture was then added to the butter mixture in the large bowl with continuous stirring. The chocolate chips were added while stirring. The total mixture of 2000g was divided into 4 portions (500g each). No *spirulina* was added to the first portion (control), 15g *spirulina* were added to the second portion (3%), 30g s*pirulina* were added to the third portion (6%) and 45g *spirulina* were added to the forth portion (9%).

The oven was heated to 180^{o}C (350^{o}F). From each portion, a teaspoon full was dropped onto lightly greased cooking sheet. Each portion made about 40 cookies. The cooking sheets were place in the oven and the cookies were baked for 15 min.

Sensory Evaluation

Sensory evaluations were carried out on the baked cookies to investigate the effect of the amount of added s*pirulina* to the cookies on the odor, color, texture, shred and taste. A panel of 10 evaluators was formed from among graduate students and professors in the Biological Engineering and Food Science Programs of Dalhousie University. The sensory evaluation sheets used in this study are shown in Figures 1-5.

Nutritional Value

The nutritional contents of the cookies were analyzed. The analyses include the determination of energy, protein, carbohydrate, fat, vitamins and mineral contents. These analysis were performed according to the procedures described Official Methods of Analysis of the Association of the Official Chemists [33].

Name_____ Date: _____

Oder is the property of substance that activates the sensory smell. Odor intensity is the perceived strength of odor sensation. Hedonic assessment is the process of rating on a scale ranging from extremely unpleasant to extremely pleasant. The characters of the odor are the ability to distinguish odor.

A-Please rate the samples as to the presence of odor (color intensity) and the odor hedonic tone using the following scale

Intensity		Hedonic Tone	
No odor	0	No Smell	0
Very Faint	1-2	Extremely Pleasant	1-2
Faint	3-4	Pleasant	3-4
Week	5-7	Neutral	5-7
Strong	8-9	Unpleasant	8-9
Very Strong	10	Intolerable	10

B- Please describe the characters of each sample by giving an appropriate descriptive term. Possible terms that might be used are given in the list below. You may use a term of your choice which you feel properly describes the odor.

Mold	Yeast
Musty	Ammonia
Fish	Animal feed
Stagnant water	Sour
Sea water	Rotten cabbage
Earthy	Other (Please specify)

RATING

Sample	Presence Rating	Hedonic Tone Rating	Odor Description
1			
2			
3			
4			

Thank you for your time

Figure 1. Odor evaluation sheet.

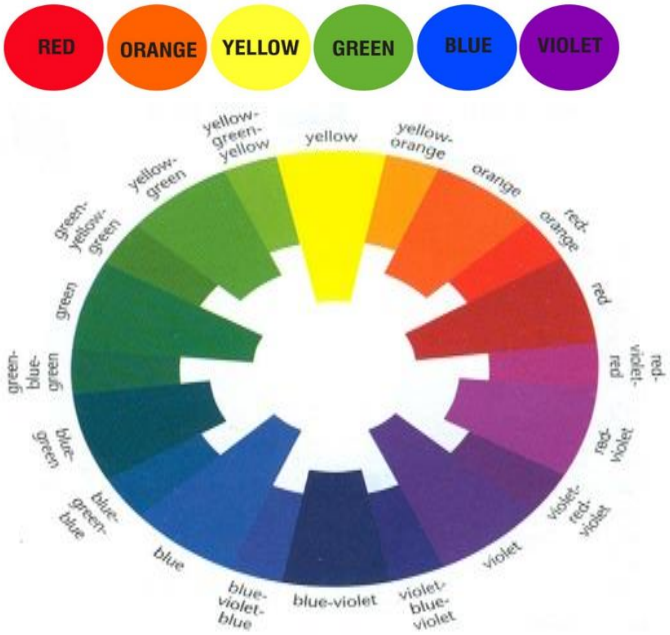
RESULTS AND DISCUSSION

Odor

The odor rating is shown in Table 8. All the baked samples had a noticeable smell. The odor intensity measured on a scale of 0: 10 (0= no odor and 10= very strong odor) was 4.89, 5.06, 5.28 and 6.00 for the cookies that received 0, 3, 6 and 9 % *spirulina*, respectively. The results indicated that the odor intensity ranged from faint for the cookie that received no *spirulina* to weak for the cookies that received *spirulina*. Increasing the amount of *spirulina* from 3 to 9% (3 fold) only increased the odor intensity by 18.5 %.

Name: _____ Date: _____

The color is the property of reflecting light of a particular wavelength. The distinct colors of the spectrum are red, orange, yellow, green, blue, indigo, and violet, each of these is shading into the next as shown in the diagram.



Please identify the color of the samples according to the above diagram and rate the saturation of the color using scale of 1:10 (dull=1 and vivid=10).

RATING

Sample	Color	Saturation
1		
2		
3		
4		

Thank you for your time

Figure 2. Color evaluation sheet.

Name: _____ Date: _____

Shredding/breaking is a method of cutting or breaking food into small pieces.

Please describe the easiness with which breaking is made and the appearance of the broken parts and the breaking line of the samples using the following examples

Toughness	Fragments	Breaking Line
Firm and hard to break	Beaks into granules	Uniform
Soft and easy to break	Breaks into large parts	Smooth
Sticky and hard to separate	Breaks into irregular parts	Irregular
Sticky and separate to clumps	Breaks into sticky parts/clumps	Continuous
Other (Specify)	Other (Specify)	Other (Specify)

RATING

Sample	Toughness	Fragmentation	Break Line
1			
2			
3			
4			

Thank you for your time

Figure 3. Shred/break evaluation sheet.

Name: _____ Date: _____

The texture is the appearance, finish or consistency of a surface of a substance. It is the characteristic physical structure given to an object by the size, shape, arrangement and proportions of its parts. It could also be defined as the way that a food or drink feels in the mouth.

A-Please describe the surface appearance and mouth feel of the samples using the following examples

Appearance	Mouth Feel
Coarse	Heavy
Clumpy	Rough
Grating	Dry
Gritty	Firm
Grainy	Chewy
Granular	Sticky
Sandy	Sandy
Smooth	Grainy
Fuzzy	Smooth
Slimy	Moist
Other (Specify)	Other (Specify)

RATING

Sample	Appearance	Mouth Feel
1		
2		
3		
4		

Thank you for your time

Figure 4. Texture evaluation sheet.

Name: _____ Date: _____

Taste is the sensation of a flavor perceived in the mouth and throat on contact with a substance. The characters of the taste are the ability to distinguish flavors. The hedonic tone is the process of rating the taste on a scale ranging from nasty to delicious

A-Please rate the samples as to the characters and the hedonic tone of flavor.

Characters	Hedonic Tone	
Sweet	Nasty	1
Vinegar	Bad	2-3
Sour	Unpleasant	4-5
Bitter	Tasteless	6-7
Salty	Pleasant	8-9
Coffee	Delicious	10
Pumpkin		
Others (Specially)		

RATING

Sample	Taste	Hedonic Tone
1		
2		
3		
4		

Thank you for your time

Figure 5. Taste evaluation sheet.

The nature of the smell (hedonic tone) was also rated on a scale of 1:10 with a score of 1-2 considered as pleasant odor and a score of 10 considered as intolerable odor. The sensory panel rating for the hedonic tone was 4.06, 4.63, 5.78 and 6.33 for the cookies that received 0, 3, 6 and 9 % *spirulina*, respectively. The nature of the smell of the cookies that received 0 and 3% *spirulina* was pleasant while that of the cookies that revived 6 and 9% *spirulina* was natural. Increasing the amount of *spirulina* from 3 to 9% (3 fold) increased the hedonic tone by 36.7 %.

The majority of the panel members described the smell of the cookies as cookies smell, sweet-yeast smell, musty-seawater smell and fishy-seawater smell for the cookies receiving 0, 3, 6 and 9 % s*pirulina*, respectively. The results showed that adding 3% s*pirulina* did not affect the odor and the addition of a strong aromatic compound to musk the smell of *spirulina* may be required with higher concentrations of *spirulina*.

Sharma and Dunkwal [34] found that the addition of 10% *spirulina* into biscuits did not significantly alter the smell of the biscuit as compared with the biscuits without *spirulina.* Lemes et al. [35] noted no difference in the odor of pasta containing 5 and 10 % *spirulina.* Vijayarani et al. [36] found no significant differences in the odor of extruded products containing 5, 10 and 15% *spirulina.*

Color

The color of the baked cookies is shown in Figure 6. The color rating results are presented in Table 9. The sensory panel also described the color as yellow, green-yellow, blue-green and green for the cookies that received 0, 3, 6 and 9% *spirulina*, respectively. The color appearance seemed acceptable to the majority of the panel members. The intensity or saturation of the color was rated in scale of 1:10 with 1 considered dull color and 10 considered vivid color. The intensity rating of the color by the sensory panel was 3.78, 4.56, 6.22 and 7.54 for the cookies that received 0, 3, 6 and 9% *spirulina*, respectively. The results obtained from the sensory panel showed that adding and/or increasing the amount of *spirulina* increased the vividness of the color.

Salehifar et al. [37] reported that the addition of 0.5-1.5% *spirulina* into traditional Iranian cookies did not alter the color compared to that of the original cookies. Morsy et al. [38] reported that the addition of 2.5% *spirulina* did not significantly change the color of extruded products, but the addition of 5- 12.5% significantly altered the color of the product. Lemes et al. (2012) noted that the addition of 5% *spirulina* to pasta did not change the color significantly from the original pasta, but the addition of 10% significantly altered the color of the pasta. Vijayarani et al. (2012) noticed slight decreases in the color rating of extruded products on the hedonic scale when the *spirulina* content was increased from 5 to 15% (5.0, 4.7 and 4.3 for the 5, 10 and 15%,

Table 8. Odor rating

Cookie Sample	*Spirulina* Content (%)	Odor Intensity	Hedonic Tone	Description
1	0	4.89±0.16	4.06±0.12	Cookie
2	3	5.06±0.24	4.83±0.11	Sweet-yeast
3	6	5.28±0.22	5.78±0.15	Musty-seawater
4	9	6.00±0.19	6.33±0.09	Fishy-seawater

Odor intensity is the perceived strength of odor sensation.
Hedonic tone is rating odor on a scale of 1 (extremely unpleasant): 10 (extremely pleasant.)

0% 3% 6% 9%

Figure 6. Baked cookies with varying amounts of *spirulina*.

Table 9. Color rating.

Cookie Sample	*Spirulina* (%)	Saturation Rating	Color
1	0	3.78±0.17	Yellow
2	3	4.56±0.23	Green-yellow
3	6	6.22±0.27	Blue-green
4	9	7.54±0.21	green

The saturation of the color is the intensity of the color in a scale of 1 (dull): 10 (vivid).

respectively). However, Sharma and Dunkwal [34] found that the change in the color of the biscuits due to the addition of 10% *spirulina* was not statistically significant. Lyer et al. [29] found that increasing the addition of *spirulina* from 1 g to 5 g (2-10%) in 22 Indian recipes (including biscuits), decreased the color/appearance acceptance and concluded that addition of 1.0-2.5 g (2-5%) of *spirulina* was acceptable.

Shred/Break

The toughness or easiness with which breaking cookies is made, fragmentation or appearance of the broken parts and the appearance of the break line were evaluated for cookies receiving different amounts of *spirulina*. The shred/beak rating results are presented in Table 10. The addition of s*pirulina* affected the easiness with which breaking a cookie was made, the fragmentation and the appearance of the break line. However, increasing the *spirulina* content affected the easiness with which breaking a cookie was made but did not affect the fragmentation or the appearance of the break line. The panel reported a toughness rating of soft-easy to beak, firm-easy to beak, firm-hard to break and very firm-hard to break for the cookies that received 0, 3, 6 and 9% *spirulina*, respectively. However, small parts and smooth line were observed with the cookies that received no *spirulina* while large parts and irregular line were observed with all the cookies that received *spirulina*, regardless the amount of *spirulina* added. The results showed that adding *spirulina* to cookies may help maintain their integrity and reduce breakage during packaging and distributions

Morsy et al. [38] reported that the addition of 2.5-7.5 *spirulina* did not significantly alter the brittleness and the firmness of the extruded products but concentrations above 7.5% significantly altered the firmness and the brittleness of the extruded products.

Texture

The results of the texture appearance and mouth feel of the cookies are presented in Table 11. The addition of *spirulina* to the cookies affected both the texture and mouth feel. However, the amount of *spirulina* added to the cookies did not have any significant effect on either the texture or the mouth feel. The cookies that received no *spirulina* had a smooth texture and moist-smooth mouth feel whereas those received *spirulina* had grainy texture and dry-chewy mouth feel.

Lemes et al. [35] noted that there was no difference in the texture of pasta containing *spirulina* at concentrations of 0, 5 and 10%. Sharma and Dunkwal [34] reported that the incorporation of 10% *spirulina* into biscuits did not have any significant effect on the texture. Salehifar et al. [37] noted that the addition of 0.5-1.5% *spirulina* into traditional Iranian cookies did not alter the texture of the cookies. Morsy et al. [38] reported that the addition of 2.5-7.5 *spirulina* did not significantly alter the texture of the extruded products but concentrations above 7.5 % had a significant effect on the texture of the extruded products. Lyer et al. [39] found that

Table 10. Shred/break rating

Cookie Sample	*Spirulina* (%)	Toughness	Fragmentation	Break line
1	0	Soft & easy to break	Small parts	Smooth
2	3	Firm & easy to break	Large parts	Irregular
3	6	Firm & hard to break	Large parts	Irregular
4	9	Very firm & hard to break	Large parts	Irregular

Toughness is the easiness with which breaking of a cookie is made
Fragmentation is the appearance of the broken parts of a cookie
Break line is the appearance of the breaking line of a cookie

Table 11. Texture rating

Cookie Sample	*Spirulina* (%)	Texture Appearance	Mouth Feel
1	0	Smooth	Moist and Smooth
2	3	Grainy	Dry and Chewy
3	6	Grainy	Dry and Chewy
4	9	Grainy	Dry and Chewy

Texture is appearance, finish or consistency of a surface of a cookie
Mouth feel is the feeling of moistness and dryness or chewiness and smoothness of a substance in the mouth.

Table 12. Taste rating

Cookie Sample	*Spirulina* (%)	Taste	Hedonic Tone
1	0	Sweet/Delicious	8.33±0.35
2	3	Sweet	7.06±0.34
3	6	Sour/Fishy	5.11±0.26
4	9	Bitter/Fishy	5.00±0.18

Taste is the sensation of flavor perceived in the mouth and throat on contact with a substance.
The hedonic tone is the rating of taste on a scale of 1 (nasty): 10 (delicious)

increasing *spirulina* content from 1 g to 5 g (2-10%) did not significantly alter the texture of Parathas bread and biscuits. Vijayarani et al. [36] noticed slight differences in the texture of extruded products when the *spirulina* content was increased from 5% to 15%. However, Sharma and Dunkwal [34] found that the change in the texture of the biscuits due to the addition of 10% *spirulina* was not statistically significant.

Taste

The sensation of flavor perceived in the mouth and throat on contact with pieces of cookies was evaluated by the panel. The nature of the taste or hedonic tone was also rated on a scale of 1 (nasty): 10 (delicious). The results are presented in Table 12. The addition and/or increasing the amount of *spirulina* affected both the taste and the hedonic tone. The taste of the cookies that received no *spirulina* was rated sweet/delicious with a hedonic score of 8.33 which is in the pleasant taste range of 8-9. The taste of the cookies that received *spirulina* was sweet-sour, sour-fishy and bitter fishy and the hedonic tone was 7.06, 5.11 and 5.00 for the cookies that received 3, 6 and 9% *spirulina*, respectively. Increasing the amount of *spirulina* from 3 to 9% changed the nature of the taste from pleasant (sweet) to unpleasant (bitter-fishy). The results showed that adding 3% s*pirulina* did not affect the taste and the addition of a flavoring agent to musk the taste of *spirulina* may be required with higher concentrations of *spirulina*.

Lemes et al. [35] noted differences in the taste of pasta containing 5% *spirulina* and the pasta containing no *spirulina*. Morsy et al. [38] reported that the addition of 2.5% *spirulina* did not significantly alter the taste of the extruded products, but higher concentrations of 5 to 12.5% resulted in an undesirable taste. Lyer et al. [39] found that with increasing *spirulina* content from 1 to 5 g (2-10%) the taste of Parathas bread and biscuits changed but remained acceptable. However, Sharma and Dunkwal [34] found that the addition of 10% *spirulina* into biscuits did not result in any significant change in the taste.

Nutritional Facts

The nutritional values are shown in Table 13. The addition of *spirulina* has enhanced the nutritional value of the cookies by increasing the protein, vitamin and mineral contents and adding omega 3 and omega 6 oils. *Spirulina* is much better source of protein (65%) than milk (4.3%), eggs (13.3%), pulses (24%) and soybean (43.2%). The beta carotene in *spiruina* (1900 µg/g) is much higher than that in carrots (18.9 µg/g), spinach (55.8 µg/g) and mango (27.4 µg/g). The iron content in *spirulin*a (0.522 mg/g) is also higher than spinach (0.109 mg/g) and soy bean (0.115 mg/g).

CONCLUSION

The incorporation of *spirulina* into cookies will enrich their nutritional values by increasing the protein, vitamin and mineral contents and the addition of omega 3 and omega 6 oils. *Spirulina* is a good source of protein, beta carotene and iron. The protein content in *spirulina* (65%) is much higher than that in milk (4.3%), eggs (13.3%), pulses (24%) and soybean (43.2%). The beta carotene in *spiruina* (1900 µg/g) is much higher than that in carrots (18.9 µg/g), spinach (55.8 µg/g) and mango (27.4 µg/g). The iron content in *spirulin*a (0.522 mg/g) is also higher than spinach (0.109 mg/g) and soy bean (0.115 mg/g). However, adding spirulina to cookies affected their smell, color, appearance, texture and taste.

All the baked samples had a noticeable smell. The odor intensity ranged from faint for the cookie that received no *spirulina* to weak for the cookies that received *spirulina*. The smell of the cookies that received 0 and 3% *spirulina* was pleasant while that of the cookies that revived 6 and 9% *spirulina* was natural. Increasing the amount of *spirulina* from 3 to 9% (3 fold) increased the odor intensity by 18.5 %

Table 13. Nutritional facts for a cookie.

Amount per serving	*Spirulina* (%)			
	0	3	6	9
Calories (Cal)	175.000	177.610	180.220	182.830
Fat (g)	3.750	3.795	3.840	3.890
Omega 3 (mg)		6.543	13.086	19.629
Omega 6 (mg)		58.131	116.262	174.393
Carbohydrate (g)	24.750	24.990	25.110	25.290
Fiber (g)	0.750	0.750	0.750	0.750
Sugar (g)	1.500	1.500	1.500	1.500
Protein (g)	1.500	2.083	2.670	3.255
Vitamin				
A (mg)		0.270	0.540	0.810
B1 (mg)		0.306	0.612	0.918
B2 (mg)		297.000	594.000	891.000
B3 (µg)		18.630	37.260	55.890
B6 (µg)		0.396	0.792	1.188
B9 (µg)		0.360	0.720	1.080
B12 (µg)		0.198	0.396	0.594
C (mg)		1.764	3.528	5.292
E (µg)		13.500	27.000	40.500
H (mg)		0.030	0.060	0.090
K (µg)		0.066	0.132	0.198
Alpha Carotene (µg)		0.225	0.450	0.675
Beta Carotene (µg)		0.225	0.450	0.675
Lutein and Zeaxanthin (µg)		3.780	7.560	11.340
Choline (µg)		0.171	0.342	0.513
Folic Acid (µg)		0.027	0.054	0.081
Pantothenic Acid (µg)		0.004	0.007	0.0108
Minerals				
Calcium (mg)		0.360	0.720	1.080
Magnesium (mg)		0.432	0.864	1.296
Iron (mg)		0.095	0.1908	0.286
Phosphorous (mg)		0.936	1.872	2.808
Potassium (mg)		1.368	2.736	4.104
Sodium (mg)	120.000	120.657	121.314	121.971
Manganese (µg)		2.340	4.680	7.020
Zinc (µg)		1.080	2.160	3.240
Boron (µg)		0.900	1.800	2.700
Copper (µg)		0.090	0.180	0.270
Molybdenum (µg)		0.090	0.180	0.270

Cookie Size = 30 g

and increased the hedonic tone by 36.7 %. The majority of the panel members described the smell of the cookies as cookies smell, sweet-yeast smell, musty-seawater smell and fishy-seawater smell for the cookies receiving 0, 3, 6 and 9 % s*pirulina*, respectively.

The results obtained from the sensory panel showed that adding and/or increasing the amount of *spirulina* increased the vividness of the color. The panel described the color as yellow, green-yellow, blue-green and green for the cookies that received 0, 3, 6 and 9% *spirulina*, respectively. The color appearance seemed acceptable to the majority of the panel members.

The addition of s*pirulina* affected the easiness with which breaking a cookie was made, the fragmentation and the appearance of the break line. However, increasing the *spirulina* content affected the easiness with which breaking a cookie was made but did not affect the fragmentation and the appearance of the break line. The toughness was reported as soft-easy to beak, firm-easy to beak, firm-hard to break and very firm-hard to break for the cookies that received 0, 3, 6 and 9% *spirulina*, respectively. Small parts and smooth break line were observed with the cookies that received no *spirulina* while large parts and irregular break line were observed with all the cookies that received *spirulina*, regardless the amount of *spirulina* added.

The addition of *spirulina* to the cookies affected both the texture and mouth feel. However, the amount of *spirulina* added to the cookies did not have any significant effect on either the texture or the mouth feel. The cookies that received no *spirulina* had a smooth texture and moist-smooth feel whereas those received *spirulina* had grainy texture and dry-chewy mouth feel.

The taste of the cookies that received no *spirulina* was rated sweet/delicious whereas the taste of the cookies that received *spirulina* was rated sweet-sour, sour-fishy and bitter-fishy for the cookies that received 3, 6 and 9% *spirulina*, respectively. Increasing the amount of *spirulina* from 3 to 9% changed the nature of the taste from pleasant (sweet) to unpleasant (bitter-fishy).

The results showed that adding 3% s*pirulina* did not affect the odor and taste of the cookies and the addition of a strong aromatic compound to musk the smell of *spirulina or* a flavoring agent to musk the taste of *spirulina* may be required with higher concentrations of *spirulina*. Adding s*pirulina* to cookies may help maintain their integrity and reduce breakage during packaging and distributions.

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REFERENCE

1. Ashokkumar, V. and R. Rengasamy. 2012. Mass culture of *Botryococcus braunii* Kutz. under open raceway pond for biofuel production. Journal of Bioresource Technology, 104:394-399. doi:10.1016/j.biortech.2011.10.093
2. Liu, J., J. Huang, Z. Sun, Y. Zhong, Y.Jiang and F. Chen. 2011. Differential lipid and fatty acid profiles of photoautotrophic and heterotrophic *Chlorella zofngiensis*: assessment of algal oil for biodiesel production. Journal of Bioresource Technology, 102:106-110. doi:10.1016/j.biortech.2010.06.017
3. Demirbas, M.F. 2011. Biofuels from algae for sustainable development. Applied Energy, 88: 3473-3480. doi:10.1016/j.apenergy.2011.01.059
4. Becker, E.W. 2004. Microalgae in human and animal nutrition. In A. Richmond (Ed), Handbook of microalgal culture (pp. 312-351). Oxford: Blackwell. DOI: 10.1002/9780470995280.ch18
5. Sydney, E.B., W. Sturm, J.C. Carvalho, V. Thomaz-Soccol, C. Larroche, A. Pandey and C.R. Socool. 2010. Potential carbon dioxide fixation by industrially important microalgae. Bioresource Technology, 101: 5892-5896. doi:10.1016/j.biortech.2010.02.088.
6. Ravishankar, G.A., R. Sarada, B. Sandesh Kamath and K.K. Namitha, 2008. Food application of algae. In: Pometto, A., K. Shetty, G. Paliyath and R.E. Levin (2nd Eds.) Food biotechnology (pp. 491). CRC Press. ISBN: 1420027972
7. El-Sayed, A.B. and A.A. Abdel-Maguid. 2010. Immobilized-microalga *Scenedesmus* sp. for biological desalination of red sea water: II. Effect on macronutrients removal. Journal of American Science, 6(9): 637-643. ISSN: 1545-1003
8. Spolaore, P., C. Joannis-cassan and E. Duran. 2006. Commercial applications of microalgae. Journal of Bioscience and Bioengineering, 101(2): 87-96. doi:10.1263/jbb.101.87
9. Priyadarshani, I. and B. Rath, 2012. Commercial and industrial applications of microalgae- A review. Journal of Algal Biomass Utilization, 3(4):89-100. ISSN: 2229-6905
10. Singh, B., A. Guldhe, P. Singh, A. Singh, I. Rawat and F. Bux. 2015. Sustainable production of biofuels from microalgae using a biorefinary approach. In: Kaushik, G. Editor (Eds.), Applied environmental biotechnology: present scenario and future trends (pp. 115). Springer. ISBN: 8132221230
11. Gouveia, L., A.E. Marques, J.M. Sousa, P. Moura and N. M. Bandara. 2010. Microalgae source of natural bioactive molecules as functional ingredients. Food Science & Technology Bulletin: Functional Foods 7: 21–37. ISSN: 1476-2137.
12. Batista, A.P., L. Gouveia, N.M. Bandarra, J.M. Franco and A.A. Raymundo. 2013. Comparison of microalgal biomass profiles as novel functional ingredient for food products. Algal Research, 2:164–173. doi:10.1016/j.algal.2013.01.004
13. Velichkova, K., I. Sirakov and G. Georgiev. 2012. Cultivation of *Botryococcus braunii* strain in relation of its use for biodiesel production. Journal of Bioscience and Biotechnology, National Youth Conference "Biological Sciences for a better future", Plovdiv, October 19-20: 157-162. ISSN: 1314-6246.
14. Becker, E. W. 2007. Micro algae as a source of protein. Journal of Biotechnology Advances, 25: 207-210. doi:10.1016/j.biotechadv.2006.11.002
15. Vidyadhar, V. 2015. Spirulina-a potent antioxidant. Accessed on April 13, 2015 at htt://drvidyadhar.hubpages.com/hub/spirulina-a-potent-antioxidant.
16. Brown, M.R., M. Mular, I., Miller, C., Farmer and Trenerry. 1999. The vitamin content of microalgae used in aquaculture. Journal of Applied Phycology, 11, 247-255. ISSN: 1573-5176
17. Gami, B., A. Naik and B. Patel. 2011. Cultivation of *Spirulina* species in different liquid media. Journal of Algal Biomass Utilization, 2(3): 15– 26. ISSN: 2229 – 6905
18. Liue, X.M. and S.Z. Liang. 1999. Pharmacological effects of *Chlorella* and its use as a health care supplement.

Chinese Traditional and Herbal Drugs 30:383-386. ISSN: 02532670

19. Khan, Z., O. bhadouria and P. Bisan. 2005. Nutrition and therapeutic potential of *spirulina*. Current pharmaceutical biotechnology, 6(3):373-379
20. McCarty, F.M. 2007. Clinical potential of *spirulina*: A source of phycocyanobilin. Journal of Medical Food, 10(4):566-570. doi: 10.1089/jmf.2007.621
21. Bandarra, N.M., P.A. Pereira, I., atista and M.H. Vilela. 2003. Fatty acids, sterol α-tocopherol in Isochrysis galbana. Journal of Food Lipids, 18: 25-34. DOI: 10.1111/j.1745-4522.2003.tb00003.x
22. Donato, M., M.H. Vilela, and N.M. Bandarra. 2003. Fatty acids, sterols, α-tocopherol and total carotenoids composition of Diacronema vlkianum. Journal of Food Lipids, 10:267276. DOI: 10.1111/j.1745-4522.2003.tb00020.x
23. Molina Grima, E., E.H. Belarbi, F.G. Acien-Fernandez, A. Robles-Medina and C. Yusuf. 2003. Recovery of microalgal biomass and metabolites: process options and economics. Biotechnology Advances, 20(7–8):491–515. doi:10.1016/S0734-9750(02)00050-2
24. Meyers, K.J., C.B. Watkins, M.P. Pritts and R.H. Liu, 2003. Antioxidant and ant proliferative activities of strawberries. Journal of Agricultural and Food Chemistry 51: 6887- 6892. doi: 10.1021/jf034506n
25. Olsson, M.E., C.S. Andersson, S. Oredsson, R.H. Berglund and K. Gustavsson. 2006. Antioxidant levels and inhibition of cancer cell proliferation in vitro by extracts from organically and conventionally cultivated strawberries. Journal of Agricultural and Food Chemistry 54: 1248 - 1255. doi: 10.1021/jf0524776
26. Heneman, K. and S. Zidenberg-Cherr. 2008. Some facts about catechins. Nutrition and Health Info-sheet, UC Cooperative Extension Center for Health and Nutrition, University of California Davis, Sacramento, California.
27. Chen, Y.Z. and Y.M. Li. 1999. Development of nutritious *Spirulina* noodle. Zhongguo Liangyou Xuebao, 14(4): 13-15. ISSN:1003-0174
28. Gouveia, L., A. Raymundo, A.P. Batista, I. Sousa and J. Empis. 2006. *Chlorella vulgaris* and *Haematococcus pluvialis* biomass as colouring and antioxidant in food emulsions. European Food Research Technology, 222: 362-367. ISSN: 1438-2385
29. Gouveia, L., C. Coutinho, E. Mendonça, A. P. Batista, I. Sousa, A. Bandarra, N. M. Raymundo. 2008. Functional biscuits with PUFA-ω3 from *Isochrysis galbana*. Journal of the Science of Food and Agriculture, 88(5): 891–896. ISSN:0022-5142
30. Fradique, M., A. Batista, M. Nunes, L. Gouveia, N. Bandarra and A. Raymundo. 2010. Incorporation of Chlorella culgaris and Spirulina maxima biomass on pasta products. Part 1: preparation and evaluation. Journal of Science Food Agriculture, 90: 1656-1664. doi: 10.1002/jsfa.3999
31. Feng, C.F. and S.P. Peng. 1991. Production method of blue0bacteria- *Spirulina* drink. Chinese Patent CN1035425A.
32. Adiba, B.D., B. Salem, S. Nabil and M. Abdelkim. 2011. Preliminary characterization of food tablets from date phoenix dactylifera and *Spirulina* (*Spirulina* sp.) powders. Powder Technology, 208:725-730. doi:10.1016/j.powtec.2011.01.016
33. AOAC, 2012. Official Methods of Analysis. Association of Analytical Chemists, Rockville, Maryland.
34. Sharma, V. and V. Dunkwal. 2012. Development of *Spirulina* based "biscuits": a potential method of value addition. Ethno Med, 6(1):31-34. ISSN: 0973-5070
35. Lemes, A.C., K.P. Takeuchi, J.C.M. de Varvalho and E.D.G. Danesi. 2012. Fresh pasta production enriched with *Spirulina platensis* biomass. Brazilian Archives of Biology and Technology, 55(5): 741-750. ISSN: 1516-8913
36. Vijayarani, V, S. Ponnalaghu and J. rajathivya. 2012. Development of value added product using *spirulina*. International Journal of Health Science and Research, 2(4):42-47. ISSN: 2249-9571
37. Salehifar, M., S. Shahbazizadeh, K. Khosravi Darani, H. Behmadi, R. Ferdowsi. 2013. Possibility of using microalgae *Spirulina Platensis* powder in industrial production of Iranian traditional cookies. Iranian Journal of Nutrition Sciences & Food Technology, 7: 63-72. ISSN:1735-7756
38. Morsy, O.M., A.M. Sharoba, A.I. El-Desouky, H.E.M. Bahlol and E.M. Abd El Mawla, 2014. Production and evaluation of some extruded food products using *spirulina* algae. Annals of Agricultural Science, Moshtohor Journal, 54(4): 329-342. ISSN: 1110-0419
39. Lyer, U.M., S.A. Dhruv and I.U. Mani. 2007. *Spirulina* and its therapeutic implications as a food product. In: Gershwin, M.E. and A. Belay. *Spirulina* in human nutrition and health (pp.51). CRC Press. ISBN: 1420052578