

1 | **Incorporation of *Arthrospira platensis*/*Spirulina Platensis* in Traditional Egyptian Cookies as a**
2 | **Source of Natural Bioactive Molecules and Functional Ingredients:**
3 | **Development and Sensory Evaluation of Nutrition Snack for School Children**
4 |

Formatted: Font: Bold

5 | **ABSTRACT**

6 | *Arthrospira platensis* (formerly *Spirulina platensis*) is very rich in protein, amino acids, omega 3,
7 | 6, 7 and 9 oils, vitamins and minerals and its incorporation into cookies will enrich their nutritional
8 | values. The objectives of this study were to evaluate the acceptability of adding "*spirulina*" to traditional
9 | Egyptian cookies as a source of natural bioactive molecules and to assess the effect of the amount of
10 | added "*spirulina*" *spirulina* on the sensory evaluation parameters (texture, shred, color, odor and taste)
11 | using a panel of 10 members. The results indicated that addition of *spirulina* to the cookies affected the
12 | texture, the mouth feel, the easiness with which breaking a cookie was made, the fragmentation and the
13 | appearance of the break line. The cookies that received no *spirulina* had smoother texture and moist-
14 | smooth mouth feel whereas those received "*spirulina*" *spirulina* had more sandy-course texture and
15 | heavy-chewy mouth feel. Increasing the *spirulina* content from 5 to 15% made the cookies more firm and
16 | harder to break. Irregular large parts and continuous break lines were observed with the cookies that
17 | received no "*spirulina*" *spirulina* while more granules and smaller parts with irregular line were observed
18 | with all the cookies that received *spirulina*. The results showed that adding "*spirulina*" *spirulina* to
19 | cookies may help maintain their integrity and reduce breakage during packaging and distributions. The
20 | color of the control sample (0% *spirulina*) was yellow to yellow-orange and that of the samples that
21 | received 5 and 10% "*spirulina*" *spirulina* was tallow-green to green-yellow-green while that of the
22 | sample that received 15% "*spirulina*" *spirulina* was green-yellow-green to green-blue-green. All the
23 | baked cookies had a noticeable smell and the odor intensity ranged from faint (4.06-4.89) to strong (8.19-
24 | 8.69). The weighted average for the odor intensity was 6.11, 5.53, 6.02 and 6.63 for cookies receiving 0,
25 | 5, 10 and 15% *spirulina*, respectively; all of which are within the odor intensity range of weak odor.
26 | Increasing the amount of "*spirulina*" *spirulina* from 5 to 15% (3 fold) only increased the odor intensity by
27 | 19.6 % (from 5.33 to 6.63). The nature of the smell of the cookies that received 0 and 5% "*spirulina*"
28 | *spirulina* was pleasant while that of the cookies that received 10 and 15% "*spirulina*" *spirulina* was
29 | musty-seawater and fishy-seawater, respectively. Adding 5% "*spirulina*" *spirulina* did not affect the odor
30 | but with higher concentrations (10-15%) of "*spirulina*"*spirulina*, the addition of a strong aromatic
31 | compound to the cookies may be required to mask the smell of "*spirulina*"*spirulina*. The addition and/or
32 | increasing the amount of "*spirulina*" *spirulina* affected both the taste and the degree of acceptance. The
33 | taste of the cookies that received no *spirulina* was rated sweet-delicious with a high degree of acceptance
34 | while the taste of the cookies that received "*spirulina*" *spirulina* varied from sweet-sour to bitter-fishy
35 | with lower degree of acceptance. Adding 5% "*spirulina*" *spirulina* did not affect the taste. However,
36 | addition of a flavoring agent to cookies receiving higher concentrations of "*spirulina*" *spirulina* (10-15%)
37 | may be required to mask the taste of "*spirulina*"*spirulina*. The results showed that addition of "*spirulina*"
38 | *spirulina* enhanced the nutritional value of the cookies by increasing the protein content of the cookies
39 | and enriching them with vitamins, mineral, omega 3, 6, 7 and 9 fatty acids and amino acids, all of which
40 | have significant health benefits to school children. Therefore, a further work should be directed towards
41 | improving the smell and the taste.

Formatted: Font: Not Italic

Formatted: Font: Not Italic

42 |
43 | **Keywords:** Anemia, Obesity, Stunting, "*Spirulina*", Cookies, Nutrition, Amino Acids, Omega 3 and 6
44 | Oils, Vitamin, Minerals Sensory Evaluation, Cookies, Texture, Shred, Color, Odor, Taste

46 | **INTRODICTION**

47
48 Egypt has about 12.5 million school children in the age range of 5-18 [1]. A significant number of
49 these children suffer from malnutrition specially those of low socioeconomic standard which resulted in
50 several diseases including anemia, obesity and stunting.

51 Anemia is a condition in which the amount of red blood cells in the body is decreased below
52 normal and it can make the child appear pale in color and feel cranky, tired and weak. Studies have
53 indicated that anemia is a major public health problem among Egyptian school children [2- 4]. Iron
54 deficiency anemia was found to be the most common cause of anemia among Egyptian children affecting
55 30-43% of children under 6 years of age [5] whereas the prevalence of anemia among children in the age
56 group of 6-12 years was found to be 12% [6-7].

57 Obesity is an excessive accumulation of fat that adversely affects well-being and health [8].
58 Obesity is a major public health problem that affects nearly 35 % of adults and 18% of teenagers in Egypt
59 [9- 11], the highest in the world. Obesity is more prevalent in children between 6 and 9 years of age and is
60 more prevalent in girls than in boys [12-14]. Egypt is a country where most citizens receive enough food
61 to silence their hunger but not enough to nourish their bodies, a phenomenon that would negatively affect
62 the country's development. There is an urgent need to spread awareness about obesity, its consequences
63 and find ways of prevention, especially among young children [15].

64 Stunting is the impaired growth and development (low height-for-age) that children experience
65 from poor nutrition and inadequate psychosocial stimulation. Children are defined as stunted if their
66 height-for-age is more than two standard deviations below the WHO Child Growth Standards Median
67 [16]. Stunting remains a very important problem in Egypt, as one-third of children under 5 years of age
68 are affected [16-17]. According to the United Nations Children's Fund (UNICEF), the largest number of
69 stunted children (about 2.7 million) in the Middle East was in Egypt due to the socioeconomic conditions
70 of a country [17]. Stunting in early life of child has adverse functional consequences on the child
71 including: (a) poor cognition and poor school performance, (b) when stunting is accompanied by
72 excessive weight gain later in childhood, it results in increased risk of nutrition-related chronic diseases in
73 adult life such as diabetes, hypertension, and obesity and (c) lost productivity and reduced earnings later
74 in life [18-19].

75 Household food security in Egypt is very fragile and fluctuating food prices can cause severe
76 shocks resulting in malnutrition among the low-income families. Hunger and malnutrition can drive
77 children away from schools. Malnutrition among Egyptian children results in: (a) 11% of children deaths,
78 (b) 33% stunted children (age 6-18 years.) and their ability to comprehend and concentrate during class
79 are impacted, (c) 2% of these children are likely to fail in education and (d) 6 % repetition rate in primary
80 governmental schools [19]. Therefore, the current Government of Egypt invests USD 110 million per year

81 on the National School Feeding Programme which reaches 12.5 million pupils. The goals of this program
82 are: (a) enhancing students' health by providing nutritious meals on a daily basis to increase
83 their concentration in class, (b) educating the students and parents about the importance of the healthy
84 nutritious meals and (c) motivating students to attend their classes and decrease school dropout rates
85 and absences. However, the nutritional composition of these meals must be enhanced [20].

86 Arthrospira (formerly Spirulina) is a blue-green alga (Cyanobacteria) that has a great potential
87 for use in food and food products because of its high nutritional composition (Table 1). The dark green
88 color of ArthrospiraSpirulina comes from the high amount of chlorophyll (“plant blood”) which is only
89 one molecule different from the hemoglobin (human blood). No one fruit, vegetable or meat can provide
90 all the nutrition elements the human body demands as ArthrospiraSpirulina. ArthrospiraSpirulina
91 contains over 100 nutritional and bioactive compounds, is free of cholesterol, has only 2-4 cal/g, has a
92 high digestibility (95%) and has an alkali pH which can protect the human body from the diseases
93 resulting from acidic foods such as meat, sea food and cereals. The protein content in
94 ArthrospiraSpirulina is about 65-72% which is higher than that in the soybean and is easier to digest.
95 ArthrospiraSpirulina contain all the essential and non-essential amino acids (Table 2) which are 3-4
96 times those in fish and meat and 29 times those in soybeans. ArthrospiraSpirulina contains more than
97 2000 enzymes that are beneficial for human health [25, 29-30]. The fatty acids (Table 3) contain omega 3
98 (alpha linolenic and docosahexaenoic) omega 6 (linolenic, gamma linolenic and dihomo-gamma
99 linolenic), omega 7 (palmitoleic) and omega 9 (oleic and auric) oils [22, 28, 30]. ArthrospiraSpirulina is
100 very rich in mineral content (Table 4) including: calcium, phosphorus, iron, sodium, magnesium,
101 potassium, manganese, zinc, boron, copper and molybdenum [23, 28]. The mineral contents in
102 ArthrospiraSpirulina are 28 and 58-fold of those in beef liver and spinach, respectively [31,32].
103 ArthrospiraSpirulina contain several vitamins (Table 5) including: beta-carotene (vitamin A), thiamine
104 (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), pyridoxine (vitamin B6), cyanocobalamin
105 (vitamin B12), Da-tocopherol (vitamin E), biotin (vitamin H), folic acid, pantothenate and inositol [21-
106 23,25-26]. The vitamin contents in Arthrospiraspirulina are higher than those in liver, carrot, spinach and
107 many vegetables [33].

108 The common name "spirulina" refers to the dried biomass of A. platensis, which belongs to the
109 oxygenic photosynthetic bacteria that cover the phylum Cyanobacteria (ref.

110 Gershwin, ME; Belay, A (2007). Spirulina in human nutrition and health. CRC Press, USA.)

111 In recent years, novel attractive healthy foods have been prepared from “spirulina”spirulina
112 [30,33-35]. Traditional foods such as salad dressings, dips, puddings, gelled desserts, biscuits, cookies,
113 bread, noodles, pasta, smoothies, ice cream and health drinks such as micro-algal sour milk and micro-
114 algal green tea were supplemented with “spirulina”Spirulina to add coloring and functional attributes,

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Formatted: Font: Italic

Formatted: Font: Italic

Formatted: Font: Italic

115 making the products more sensorial attractive with health benefits due to the high content of carotenoids,
116 polyunsaturated fatty acids, antioxidant and anti-inflammatory compounds [22,30, 34-37].

117 *ArthrospiraSpirulina* is a fast-growing microorganism and has high biomass growth and high
118 protein yield (Table 6). For a given area, the harvest yield of *ArthrospiraSpirulina* is 10 times that of
119 soybeans, 20 times that of corn and 200 times that of beef cattle [37]. It can be grown to produce protein
120 and bioactive and function compounds.

121 Table 1. General composition of fresh dried "*spirulina*"*spirulina* [21-27].

122

Content	Value
Energy (Cal/g)	2.90
Moisture (%)	4 -5
Protein (%)	65 -72
Carbohydrate (%)	15 -25
Fibers (%)	3 -7
Lipids (%)	4 -7
Minerals (mg/g)	6 -12

123

124

125 Table 2. Amino acids in fresh dried "*spirulina*"*spirulina* [22, 24, 28].

Amino Acids	Value (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

126

127

128

129

130

131

132

133

134 | Table 3. Fatty acids in fresh dried "*spirulina*"*spirulina* [22, 28, 30].

Fatty Acids	Value
Omega 3	
Alpha Linolenic	0.04 mg/g
Docosahexaenoic	0.04 mg/g
Omega 6	
Linolenic	33.0 mg/g
Gamma Linolenic	30.0 mg/g
Dihomo-gamma Linolenic	1.59 mg/g
Omega 7	
Palmitoleic	5.90 mg/g
Omega 9	
Oleic	0.50 mg/g
Erucic	0.07 mg/g

135

136

137

138

139 | Table 4. Minerals in fresh dried "*spirulina*"*spirulina* [23,28].

Minerals	Value
Calcium	168.00 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	19.00 µg/g
Zinc	2.00 µg/g
Boron	30.00 µg/g
Copper	3.00 µg/g
Molybdenum	30.00 µg/g
Selenium	5.00 µg/g

140

141

142

143
144
145
146
147

148 | Table 5. Vitamins in fresh dried "*spirulina*"*spirulina* [21-23,25-26] .

Vitamins	Value
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 (Da-tocopherol)	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

149
150
151

152 | Table 6. Biomass and protein yields and environmental growth conditions of "*spirulina*"*Spirulina* [31-
153 36].

Parameter	Value
Biomass yield (g/L)	4.30
Protein yield (g/L)	2.71
Temperature (C°)	30.00
pH	9.00

155
156
157
158
159
160
161

162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194

OBJECTIVES

The main aim of this study was to evaluate the acceptability of traditional Egyptian cookies containing *spirulina* as a source of natural bioactive molecules.. The specific objectives were: (a) to determine the cookies characteristics (odor/smell, taste, color, texture and shred) using sensory evaluations, (b) to establish the most acceptable amount of *spirulina* that can be added to the cookies and (c) determine the nutritional value of the cookies.

MATERIALS AND METHODS

Preparation of Cookies

The following ingredients were used: soft butter (100 g), sugar (100 g), wheat flower (280 g), 2 eggs (109 g), baking powder (10 g), salt (1 g), vanilla (1 g) and desired amount of *spirulina* (0, 5, 10 and 15% by weight of the wheat flower or 0, 14, 28 and 42 g of *spirulina* as replacements for wheat flower).

The butter and sugar were placed in the large bowl of a bowl-lift stand mixer (Model No. 4KV25HOXER, Kitchen Aid, Mississauga, Ontario, Canada) and beaten until became fluffy. The eggs and vanilla were added to the butter-sugar mixture. The wheat flower, baking powder, salt and the desired amount of *spirulina* were first mixed together and then added to the butter-sugar-eggs-vanilla mixture and mixed with continuous stirring. Four portions of 601g each were made. No "*spirulina*"*spirulina* was added to the first portion (control), 14 g "*spirulina*"*spirulina* were added to the second portion (5%), 28 g s"*spirulina*"*pirulina* were added to the third portion (10%) and 42 g *spirulina* were added to the fourth portion (15%).

The oven was heated to 180°C (350°F). From each portion, cookies were made, each was about 5 cm in diameter and 0.5 cm in height. The cookies were placed on a cooking sheet placed in a baking tray. The baking trays were place in a convention countertop oven (Model No. TO4211SKT, Black & Dekker,

195 Rayovac, Argentina) and the cookies were baked for 14 min. Each backed cookie weighed approximately
196 30 g.

197

198 **Sensory Evaluation**

199 Sensory evaluations were carried out on the baked cookies to determine some of the physical
200 properties (texture and shredding/breaking) and to evaluate the acceptability of color, smell and taste of
201 the cookies. The procedure described by Ghaly et al. [38] was followed. A panel of 10 evaluators was
202 formed from among technicians, undergraduate and graduate students and professors in the Agricultural
203 Engineering Department, Faculty of Agriculture, Cairo University. The panel included males and females
204 who varied in age from 18 to 55 years. The sensory evaluation sheets used in this study (Figures S-1-5) in
205 appendix were those developed by Ghaly et al. [38].

206

207 **Nutritional Value**

208 The nutritional contents of the cookies were analyzed. The analyses include the determination of
209 energy, protein, amino acids_carbohydrate, fat, vitamins and mineral contents. These analyses were
210 performed according to the procedures described in Official Methods of Analyses of the Association of
211 the Official Chemists [39].

212

213

213 **RESULTS AND DISCUSSION**

214 **Texture**

215 The results of the texture appearance and mouth feel of the cookies are presented in Table
216 7. The addition of "spirulina"*spirulina* to the cookies affected both the texture and mouth feel
217 compared to the control (0% spirulina). The cookies that received no "spirulina"*spirulina* (control
218 samples) had smoother texture and moist-smooth mouth feel whereas those received
219 "spirulina"*spirulina* had sandy-courses texture and heavy-chewy mouth feel. Increasing the
220 percentage of spirulina made the surface of the cookies more sandy-courses and made the mouth
221 feel more firmer and chewier.

222 Salehifar et al. [40] reported that the addition of 0.5-1.5% *spirulina* into traditional Iranian cookies
223 did not alter the texture of the cookies. Lyer et al. [41] found that increasing *spirulina* content from 2
224 to 10% did not significantly alter the texture of biscuits. Sharma and Dunkwal [42] reported that the
225 incorporation of 10% "spirulina"*spirulina* into biscuits did not have any significant effect on the biscuits
226 texture. Lemes et al. [43] noted no statistical differences in the textures of pasta samples containing
227 "spirulina"*spirulina* at concentrations of 0, 5 and 10%. However, Morsy et al. [44] reported that the

228 | addition of 2.5-7.5% "spirulina"*spirulina* to several extruded products did not significantly alter the
 229 | texture of products but concentrations above 7.5 % had a significant effect on the texture of these
 230 | products. Vijayarani et al. [44] noticed slight differences in the texture of extruded products when the
 231 | "spirulina"*spirulina* content was increased from 5% to 15%. trey. Ghaly et al. [38] reported that the
 232 | addition of spirulina to chocolate chip oatmeal cookies affected their texture and mouth feel as compared
 233 | to the original cookies (no spirulina added) but increasing the percentage of spirulina from 3 to 9% did
 234 | not show any significant differences.

235
 236
 237

238 |
 239 | Table 7. Effect of "spirulina"*spirulina* on the texture and mouth feel of cookies.
 240 |

<u>"spirulina"</u> <i>Spirulin</i> <i>a</i> (%)	Texture Appearance	Panelists	Mouth Feel	Panelists
0	Smooth	6	Moist and Smooth	10
	Sandy	2		
	Course	2		
5	Smooth	4	Moist and Smooth	6
	Sandy	2		
	Course	4	Heavy and Chewy	4
10	Smooth	3	Heavy and Chewy	7
	Sandy	3		
	Course	4	Firm & Chewy	3
15	Smooth	2	Firm & Chewy	8
	Sandy	3		
	Course	5	Rough and Chewy	2

241 | Texture is appearance, finish or consistency of the surface of a cookie
 242 | Mouth fell is the feeling of moistness and dryness or chewiness and smoothness of a substance in the mouth.
 243 |

244
 245
 246
 247
 248
 249 | **Shred/Fragmentation/Beak Line**

250 The toughness (the degree of easiness with which breaking cookies is made), fragmentation
251 (appearance of the broken parts) and the appearance of the break line were evaluated for the cookies
252 receiving different amounts of "spirulina"*spirulina*. The results are presented in Table 8. The addition of
253 "spirulina"*spirulina* affected the easiness with which breaking a cookie was made, the fragmentation and
254 the appearance of the break line. Increasing the "spirulina"*spirulina* content made the cookies more firm
255 and harder to beak. However, the addition of 5% spirulina did not affect the toughness of the cookies. The
256 panel reported a toughness rating of soft-easy to beak for both 0 and 5% "spirulina"*spirulina* and firm-
257 easy to beak to firm-hard to break for the cookies that received 10 and 15% "spirulina"*spirulina*,
258 respectively

259 Also, higher content of spirulina affected the fragmentation and the appearance of the break line.
260 However, irregular large parts and continuous beak lines were observed with the cookies that received no
261 "spirulina"*spirulina* while more granules and smaller parts with irregular line were observed with all the
262 cookies that received "spirulina"*spirulina*. Increasing the percentage of *spirulina* made the parts firmer
263 and stickier. The results showed that adding "spirulina"*spirulina* to cookies may help maintain their
264 integrity and reduce breakage during packaging and distributions.

265 Salehifar et al. [40] reported that the addition of 0.5-1.5% "spirulina"*spirulina* into cookies did
266 not alter their brittleness. Morsy et al. [44] reported that the addition of 2.5-7.5 "spirulina"*spirulina* did
267 not significantly alter the brittleness and the firmness of the extruded products but concentrations above
268 7.5% significantly altered the firmness and the brittleness of these products. Ghaly et al. [38] reported that
269 the addition of 3- 9% spirulina to chocolate chip oatmeal cookies affected the easiness with which the
270 cookies were broken but did not affect their fragmentation nor the appearance of the break line.

271

272 **Color**

273 The color of the baked cookies is shown in Figure 1 and the color rating results are presented in
274 Table 9. The sensory panel members described the color of the control sample (0% "spirulina"*spirulina*)
275 as yellow and yellow-orange and the samples that received the 5 and 10% spirulina as green, tallow-
276 green and green-yellow-green while the sample that received 15% spirulina as green, tallow-green, green-
277 yellow-green and Green-blue-green. The color shifted from dark green to bluish green with the increase
278 of spirulina content.

279 The intensity or saturation of the color was rated in scale of 1:10 with 1 considered dull color and 10
280 considered vivid color. The intensity rating of the color by the sensory panel varied from 6.88±0.89 for
281 the yellow-orange color to 10.00±0.00 for the green-yellow-green color. The results obtained from the
282 sensory panel showed that increasing the amount of "spirulina"*spirulina* in the cookies increased the
283 vividness of their color.

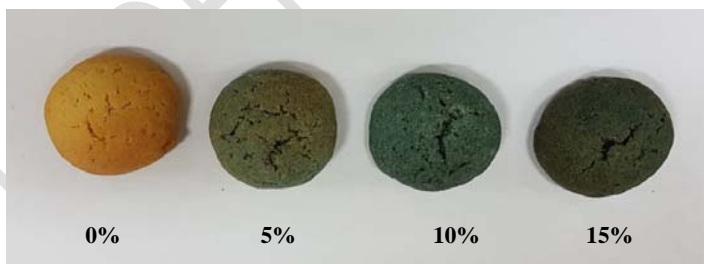
284
285
286
287

Table 8. Effect of "spirulina"*spirulina* on the toughness, fragmentations and breaking line of cookies.

<u>"spirulina"</u> <i>Spirulin</i> α Content (%)	Toughness		Fragment		Breaking Line	
	Description	Panelists	Type	Panelists	Description	Panelists
0	Soft and easy to break	10	Irregular parts	4	Continuous	6
			Large parts	6	Irregular	4
5	Soft and easy to break	10	Granules	5	Continuous	3
			Large parts	5	Irregular	7
10	Firm and easy to break	8	Granules	4	Continuous	3
	Firm and hard to break	2	Large parts Sticky parts	4 2	Irregular	7
15	Firm and easy to break	7	Granules	4	Continuous	3
	Firm and hard to break	3	Large parts Sticky parts	3 3	Irregular	7

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

291
292
293
294
295
296
297
298
299
300
301
302
303
304



305 Figure 1. Samples of baked cookies with varying amounts of "spirulina"*spirulina*.
306

307

308

309 | Table 9. Effect of "spirulina"*spirulina* on the color of cookies.

<u>spirulina</u> " <i>Spirulina</i> (%)	Saturation Rating	Color	Panelists
0	7.00±0.00	Yellow	2
	6.88±0.89	Yellow-Orange	8
5	7.00±0.00	Green	1
	7.66±0.67	Yellow-Green	2
	8.37±0.38	Green-Yellow-Green	7
10	7.86±0.87	Green	4
	7.33±0.33	Yellow-Green	3
	7.83±0.87	Green-Yellow-Green	3
15	9.50±0.21	Green	4
	8.00±0.00	Yellow-Green	1
	10.00±0.0	Green-Yellow-Green	1
	9.10±0.29	Green-Blue-Green	4

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

311

312

313

314

315

316

317 | Salehifar et al. [40] reported that the addition of 0.5-1.5% "spirulina"*spirulina* into traditional
318 | Iranian cookies did not alter their color compared to that of the original cookies. Morsy et al. [44]
319 | reported that the addition of 2.5% "spirulina"*spirulina* to several extruded products did not change their
320 | color, but the addition of 5- 12.5% spirulina to these products significantly altered their color. Lemes et
321 | al. [43] noted that the addition of 5% "spirulina"*spirulina* to pasta did not change its color from that of
322 | the original pasta, but the addition of 10% altered the color of the pasta. Vijayarani et al. [45] noticed
323 | slight change of the color of extruded products when the "spirulina"*spirulina* content was increased from
324 | 5 to 15%. Sharma and Dunkwal [42] found change in the color of biscuits due to the addition of 10%
325 | "spirulina"*spirulina*. Lyer et al. [41] found that increasing the content of "spirulina"*spirulina* from 2 to
326 | 10% in Indian biscuits decreased the color appearance acceptance and concluded that addition of up to
327 | 5% of "spirulina"*spirulina* may be acceptable. Ghaly et al. [38] reported a change of the color of
328 | chocolate chip oatmeal cookies when spirulina was added to the cookies and increasing the spirulina

329 content from 3 to 9% increased the vividness of the color. They stated that the color of the cookies was
 330 acceptable as reported by the members of the sensory panel.

331

332 **Odor**

333 All the baked samples had a noticeable smell. The odor intensity was measured on a scale of 0:
 334 10 (0= no odor and 10= very strong odor) and the results are shown in Table 10. The results indicated
 335 that the odor intensity ranged from faint (4.06-4.89) to strong (8.19-8.69) for the all cookies. However,
 336 the number of panelists who reported strong odor increased with increasing the spirulina content. The
 337 weighted average for the odor intensity was 6.11, 5.53, 6.02 and 6.63 for the cookies receiving 0, 5, 10
 338 and 15% spirulina, all of which are rated weak odors. Increasing the amount of "spirulina"spirulina from
 339 5 to 15% (3 fold) only increased the odor intensity by 19.6 % (from 5.33 to 6.63).

340 The nature of the smell (Hedonic Tone) was also rated on a scale of 1:10 with a score of 1-2
 341 considered as extremely pleasant odor and a score of 10 considered as intolerable odor. The sensory panel
 342 rating for the Hedonic Tone was 4.06, 4.63, 5.78 and 6.33 for the cookies that received 0, 5, 10 and 15 %
 343 "spirulina"spirulina, respectively. The nature of the smell of the cookies that received 0 and 5%
 344 "spirulina"spirulina was pleasant (cookies smell and sweat-yeast smell, respectively) while that of the
 345 cookies that received 10 and 15% "spirulina"spirulina was must-seawater and fishy-seawater,
 346 respectively. The weighted average for the Hedonic Tone was 2.97, 3.88, 4.69 and 4.74 for the cookies
 347 receiving 0, 5, 10 and 15% "spirulina"spirulina, all of which are within the pleasant odor range.
 348 Increasing the amount of "spirulina"spirulina from 5 to 15% (3 fold) increased the Hedonic Tone by
 349 18.14 % (from 3.88 to 4.74). The results showed that adding 5% "spirulina"spirulina did not affect the
 350 odor and the addition of a strong aromatic compound to mask the smell of "spirulina"spirulina may be
 351 required with higher concentrations (10-15%) of "spirulina"spirulina.

352

353 Table 10. Effect of spirulina on the odor of cookies.

<u>spirulina</u> "Spirulina" a Content (%)	Odor Intensity	Panelists	Hedonic Tone	Panelists	Odor Description
0	4.89±0.16 (Faint)	4	2.66±0.32 (Extremely Pleasant)	8	Cookie
	6.57±0.76 (Weak)	5	4.06±0.12 (Pleasant)	2	
	8.69±0.00 Strong)	1			
5	4.06±0.24 (Faint)	4	2.43±0.11 (Extremely Pleasant)	6	Sweet-Yeast
	6.17±0.56 (Weak)	5	4.05±0.22 (Pleasant)	2	
	8.19±0.00 Strong)	1	8.06±0.18 (Unpleasant)	2	
10	4.28±0.22 (Faint)	3	2.18±0.15 (Extremely Pleasant)	4	Musty-

	6.32±0.56 (Weak)	5	Pleasant)	3	Seawater
	8.29±0.32 (Strong)	2	4.06±0.19 (Pleasant)	3	
			8.66±0.14 (Unpleasant)		
15	4.38±0.19 (Faint)	2	2.33±0.09 (Extremely	3	Fishy-Seawater
	6.47±0.56 (Weak)	5	Pleasant)	3	
	8.41±0.32 (Strong)	3	4.41±0.12 (Pleasant)	4	
			9.06±0.32 (Unpleasant)		

354 Odor intensity is the perceived strength of odor sensation on a scale of 0 (no odor) :10 (very strong odor)

355 Hedonic Tone is the rating odor on a scale of 1 (no smell); 10 (intolerable smell.)

356

357

358

359

360

361

362

363

364 Sharma and Dunkwal [42] found that the addition of 10% "spirulina"*spirulina* into biscuits did
 365 not significantly alter the smell of the biscuit as compared with the biscuits without *spirulina*. Lemes et al.
 366 [43] noted no difference in the odor of pasta containing 5- 10 % "spirulina"*spirulina*. Vijayarani et al.
 367 [44] found no significant differences in the odor of extruded products containing 5- 15%
 368 "spirulina"*spirulina*. Ghaly et al. [38] reported no change of the smell of chocolate chip oatmeal cookies
 369 when "spirulina"*spirulina* was added to the cookies at 3% and increasing the "spirulina"*spirulina*
 370 content from 3 to 9% increased the smell of spirulina and stated that a strong aromatic compound may be
 371 require to musk the smell of spirulina.

372

373 Taste

374 The sensation of flavor perceived in the mouth and throat on contact with pieces of cookies was
 375 evaluated by the sensory panel. The degree of acceptance of the taste was also rated on a scale of 1
 376 (nasty): 10 (delicious). The results are presented in Table 11. The addition and/or increasing the amount
 377 of "spirulina"*spirulina* affected both the taste and the degree of acceptance. The taste of the cookies that
 378 received no "spirulina"*spirulina* was rated sweet/delicious with a degree of acceptance between 8.33 and
 379 10.00 (sweet and delicious). The taste of the cookies that received "spirulina"*spirulina* varied from sweet
 380 to sour or sour-fishy or bitter-fishy and the degree of acceptance also varied from 8.06 (Sweet) to 4.16
 381 (unpleasant) for the cookies receiving 5% spirulina to from 8.09 (Sweet) to 2.38 (bad) for the cookies
 382 receiving 15% spirulina. The results showed that adding 5% "spirulina"*spirulina* did not affect the taste

383 | but addition of a flavoring agent to the cookies to musk the taste of "spirulina"*spirulina* may be required
 384 | with higher concentrations of "spirulina"*spirulina* (10-15%).

385 | Lyer et al. [41] reported that increasing "spirulina"*spirulina* content in Parathas bread and
 386 | biscuits from 2 to 10%) changed the taste but remained acceptable. Sharma and Dunkwal [42] found that
 387 | the addition of 10% "spirulina"*spirulina* into biscuits did not result in any significant change in the taste.
 388 | Lemes et al. [43] noted differences in the taste of pasta containing 5% "spirulina"*spirulina* compared to
 389 | the pasta containing no "spirulina"*spirulina*. Morsy et al. [44] reported that the addition of 2.5%
 390 | "spirulina"*spirulina* did not significantly alter the taste of the extruded products, but higher
 391 | concentrations of 5-12.5% resulted in an undesirable taste. Ghaly et al. [38] reported the addition of 3%
 392 | spirulina to chocolate chip oatmeal cookies did not change their taste but increasing the spirulina content
 393 | in the cookies from 6 to 9% may require a strong aromatic compound to musk the smell of spirulina.

394

395 | **Nutritional Content**

396 | The nutritional values of 30 g cookies containing different amounts of "spirulina"*spirulina* are
 397 | shown in Table 12. The addition of "spirulina"*spirulina* has enhanced the nutritional value of the cookies
 398 | by increasing the protein and adding vitamins, mineral, omega 3, 6, 7 and 9 fatty acids and amino acids.
 399 | "spirulina"*Spirulina* is much better

400

401 | Table 11. Effect of "spirulina"*Spirulina* on the taste of the cookies.

<u>spirulina</u> " <i>Spirulin</i> a (%)	Taste	Degree of Acceptance	Panelists
	Sweet	8.33±0.35 (Pleasant)	6
	Delicious	10.00±0.00 Delicious	4
5	Sweet	8.06±0.34 (pleasant)	6
	Sour	6.66±0.14 (Tasteless)	2
	Bitter	4.16±0.38 (Unpleasant)	2
10	Sweet	8.11±0.26 (Pleasant)	5
	Sour and Fishy	4±0.34 (Unpleasant)	2
	Bitter and Fishy	2±0.44 (Bad)	3
15	Sweet	8.09±0.18 (Pleasant)	4
	Sour and Fishy	4±0.54 (Unpleasant)	3
	Bitter and Fishy	2±0.38 (Bad)	3

402 | Taste is the sensation of flavor perceived in the mouth and throat on contact with a substance.

403 The degree of acceptance is the rating of taste on a scale of 1 (nasty): 10 (delicious)
404
405

UNDER PEER REVIEW

406 | Table 12. Nutritional facts for cookies with different “*spirulina*”*Spirulina* contents.

Amount per serving	“ <i>spirulina</i> ” <i>Spirulina</i> (%)			
	0	3	6	9
Calories (Cal)	145.000	147.100	149.200	151.300
Carbohydrate (g)	19.400	19.540	19.680	19.820
Fat (g)	4.990	5.039	5.088	5.137
Omega 3 (mg)		6.550	13.100	19.650
Omega 6 (mg)		45.213	90.426	135.639
Protein (g)	5.440	5.930	6.420	6.910
Alanine (mg)		21.700	43.400	68.100
Arginine (mg)		21.000	42.000	63.000
Aspartic Acid (mg)		29.400	58.800	88.200
Cysteine (mg)		2.100	4.200	6.300
Glutamic Acid (mg)		30.100	60.200	90.300
Glycine (mg)		13.300	26.600	39.900
Histidine (mg)		14.000	28.000	42.000
Isoleucine (mg)		15.400	30.800	46.200
Leucine (mg)		25.000	50.000	75.000
Lysine (mg)		11.200	22.400	33.600
Methionine (mg)		3.600	7.200	10.800
Phenylalanine (mg)		7.000	14.000	21.000
Proline (mg)		10.500	21.000	31.500
Serine (mg)		11.900	23.800	35.700
Threonine (mg)		12.600	25.200	37.800
Tryptophan (mg)		3.500	7.000	10.500
Tyrosine (mg)		8.400	16.800	25.200
Valine (mg)		16.100	32.200	48.300
Vitamin				
A (µg)		20.300	40.600	60.900
B1 (mg)		166.600	333.200	499.800
B2 (mg)		69.300	138.600	207.900
B3 (mg)		2.569	5.138	7.707
B5 (mg)		2.380	4.760	7.140
B6 (mg)		9.240	18.480	27.720
B9 (µg)		65.800	131.600	197.400
B12 (µg)		4.620	9.240	13.860
C (mg)		41.160	82.320	123.480
E (mg)		3.500	7.000	10.500
H (mg)		0.700	1.400	2.100
K (µg)		17.640	35.280	52.920
Alpha Carotene (µg)		5.250	10.500	15.750
Beta Carotene (mg)		1.330	2.660	3.990
Lutein and Zeaxanthin (µg)		88.200	176.400	264.600
Choline (mg)		46.200	92.400	138.600
Folic Acid (µg)		0.027	0.054	0.081
Pantothenic Acid (µg)		0.004	0.007	0.010
Minerals				
Calcium (mg)		117.600	235.200	352.800
Magnesium (mg)		1.785	3.570	5.355
Iron (mg)		0.364	0.728	1.092
Phosphorous (mg)		6.426	12.852	19.278
Potassium (mg)		12.810	25.620	38.430
Sodium (mg)	157.363	165.049	172.735	180.421
Manganese (µg)		1.400	2.800	4.200
Zinc (µg)		13.300	26.600	39.900
Boron (µg)		27.300	54.600	81.900
Copper (µg)		2.100	4.200	6.300
Molybdenum (µg)		21.000	42.000	63.000
Selenium (µg)		3.500	7.000	10.500

407 | Cookie Weight = 30 g

408 | Cookie Size = 5 cm diameter x 0,5 cm height

409

410

411

412 source of protein (65%) than milk (4.3%), eggs (13.3%), pulses (24%) and soybean (43.2%). The beta
413 carotene in "spirulina"*spirulina* (1900 µg/g) is much higher than that in carrots (18.9 µg/g), spinach (55.8
414 µg/g) and
415 mango (27.4 µg/g). The iron content in "spirulina"*spirulina* (0.522 mg/g) is also higher than spinach
416 (0.109 mg/g) and soybean (0.115 mg/g). Table 13-17 show the health benefits of amino acids, water
417 soluble and fat-soluble fatty acids, minerals and vitamins found in "spirulina"*spirulina*.

418 Because of its high contents of highly valuable bioactive compounds, "spirulina"*spirulina* has
419 been used to stimulate the immune system by enhancing the production of antibodies and cytokines and,
420 thus, improving the resistance to infections in humans. "Spirulina"*Spirulina* preparations have proved to
421 be effective against HIV, herpes virus, cytomegalovirus and influenza virus as well as preservation of the
422 resident intestinal micro flora (especially lactic acid *bacilli* and *bifid* bacteria) and decreasing of *Candida*
423 *albicans* level. Many of the phytonutrients in *spirulina* function as antioxidants and anti-inflammatory
424 nutrients (Table 18) working together in synergistic fashion to provide cardiovascular benefits. Because
425 of this unique combination of antioxidant and anti-inflammatory nutrients, "spirulina"*Spirulina* has
426 several health benefits including: cardiovascular support and prevention of cardiovascular diseases, heart,
427 kidney and liver disease, obesity, neurodegenerative disease, arthritis, allergies, prevention of breast,
428 cervical, colon and esophageal cancers, cholesterol control and improved regulation of blood sugar [21-
429 25,28-30,34,46,61-63].

430

431

CONCULOSION

432

433 The incorporation of "spirulina"*spirulina* into cookies will enrich their nutritional values by
434 increasing the protein content and adding vitamins, minerals, omega 3 and omega 6 oils and amino acids.
435 "Spirulina"*Spirulina* is a good source of protein, beta carotene and iron. The protein content in
436 "spirulina"*spirulina* (65%) is much higher than that in milk (4.3%), eggs (13.3%), pulses (24%) and
437 soybean (43.2%). The beta carotene in "spirulina"*spirulina* (1900 µg/g) is much higher than that in carrots
438 (18.9 µg/g), spinach (55.8 µg/g) and mango (27.4 µg/g). The iron content in "spirulina"*spirulina* (0.522
439 mg/g) is also higher than spinach (0.109 mg/g) and soy bean (0.115 mg/g). However, adding
440 "spirulina"*spirulina* to cookies affected their smell, color, appearance, texture and taste.

441

442 The addition of "spirulina"*spirulina* to the cookies affected both the texture and mouth
443 feel compared to the control (0% spirulina). The cookies that received no "spirulina"*spirulina* had
444 smoother texture and moist-smooth mouth feel whereas those received "spirulina"*spirulina* had
sandy-courses texture and heavy-chewy mouth feel. Increasing the percentage of

445 | “*spirulina*”**spirulina** made the surface of the cookies more sandy-courses and made the mouth
 446 | feel firmer and chewier.

447
 448
 449

450 | Table 13. Health benefits of amino acids in “*spirulina*”**spirulina** [46-49].

452

Amino Acid	Health Benefits
Alanine	Is a critical player in the body’s “protein biosynthesis” and has certain regulatory functionality, the liver absorbs alanine from the blood and converts it into pyruvate to enable a faster and more effective supply of energy to the body. It supports the immune system and prevents kidney stones which are produced by the body as insoluble toxic compounds, stimulates the production of glucagon when blood sugar is too low and supports the generation of glucose from other amino acids, protects the prostate gland from an irregular enlargement which cause severe pain during urination, reacts with glucose which leads to an increased production and excretion of insulin, increases physical fitness when combined with exercise and protects from cardiovascular illnesses.
Arginine	Reduces blood pressure and improves blood flow, reduces risk of heart disease and type 2 diabetes, helps increase insulin levels and decrease blood glucose levels in diabetes, stimulates the immune system to act on and destroy pathogens, reduces anxiety, increases stamina, improves wound healing, maintains memory during aging, increases fertility and fights Aging.
Aspartic acid	Improves muscle strength, increases lean body mass and boosts energy levels, increases natural testosterone production which is needed for building muscles, increases endurance and improves performance, regulates hormone production, boosts growth hormones and positively affects insulin-like growth factors, enhances the level of nitric oxide which helps increase muscular pumps and vascularity and plays a major role in enhancing memory enhancers and preventing depressants.
Cysteine	Neutralizes free radicals that can damage cells and tissues, prevents kidney and liver damage, prevents side effects of drugs and environmental toxins, improves psychiatric disorders and decreases withdrawal symptoms, prevents relapse in cocaine addicts, relieves symptoms of respiratory conditions and reduces inflammation in bronchial tubes and lung tissues, improves cystic fibrosis, asthma, pulmonary fibrosis and nasal and sinus congestion, boosts brain health and slows the loss of cognitive ability in people with Alzheimer’s, improves fertility in men and women, stabilizes blood sugar, reduces heart disease and improves immune function.
Glutamic acid	Improves gastrointestinal health such as irritable bowel syndrome, ulcerative colitis, diverticulosis, diverticulitis, leaky gut, joint pain, autoimmune response, Hashimoto’s disease, arthritis and skin issues like psoriasis, boosts brain health, improves diarrhea by balancing mucus production, promotes muscle growth and decreases muscle wasting, cleanses the body from high levels of ammonia, burns fat, helps suppress insulin levels and stabilizes blood glucose.
Histidine	Protects heart, reduces blood pressure, reduces oxidative stress, reduces inflammation, decreases insulin resistance, prevents obesity, protects skin from UV radiation, improves brain function, prevents blood clots, suppresses seizures, protects eyes from inflammation and prevents oxidative stress.
Isoleucine	Is antiaging and anti-inflammation and is important for synthesis of hemoglobin and other proteins. It increases muscle mass, prevents essential amino acid deficiency in individuals on protein-restricted diets, treats hot flushes in postmenopausal women, improves vision disturbance, dermatitis and diarrhea, detoxifies nitrogen wastes, heals wound, treats erectile dysfunction, diabetes, hair losses, inflammation, osteoarthritis, rectal diseases, insomnia, weight loss and cancer, improves blood circulation, reduces cholesterol, boosts the immune system and muscle growth and improves fertility.
Lucien	Helps in weight loss, protects against liver and colorectal cancer, manages blood glucose levels and prevents complications of diabetes, keeps blood pressure and cholesterol within target ranges, prevents heart disease and stroke, helps maintain strong bones and teeth, improves mood

Formatted: Font: Not Italic

453
454
455

	and memory, improves gut health and helps getting a good night's sleep.
Lysine	Is important for normal growth and muscle turnover. It protects against and treats cold sores by blocking arginine, reduces anxiety by blocking stress response receptors, improves calcium, iron, and zinc absorption and retention, reduces blood pressure, promotes wound healing by helping create collagen, helps produce enzymes, antibodies and hormones, supports the immune system, treats herpes virus, treats poor concentration, irritability, nausea and red eyes problems, treats hair losses and supports hair growth, treats anorexia, prevents bone loss, promotes healthy growth of skin, prevents plaque buildup in arteries and treats shingles.

Table 13. Continued (Health benefits of amino acids in "*spirulina*"*spirulina*).

Amino Acid	Health Benefits
Methionine	Provides an important role relating to the growth of new blood vessels, heals wounds, treats drug withdrawal, schizophrenia, radiation, copper poisoning, asthma, allergies, alcoholism and depression, supports the proper function of the immune system, reduces risk of colorectal cancer, lowers tremors in Parkinson's patients, builds bone strength and helps treat the effects of liver disease.
Phenylalanine	Is direct precursor of tyrosine in the human body and is used as a marker for Parkinson's Disease. It treats depression and pain, treats vitiligo which is a skin condition where the skin loses its colorist, increases natural opioids in the body by inhibiting the enzyme carboxypeptidase which degrades endogenous opioids in the body, alleviates alcohol withdrawal symptoms, enhances the effectiveness of acupuncture anesthesia and improves ADHD symptoms in the short term.
Praline	Is vital for nerve conduction and brain function, improves improves digestion, helps with weight loss , reduces the risk of certain cancer, provides anti-Inflammatory and anti-aging benefits, prevents skin problems, stimulates hair growth and prevents hair loss, reduces the risk of coronary heart disease and minimizes the risk of stroke, reduces the risk of breast cancer, promotes colon health and facilitates regular bowel movements, improves bone and teeth health, reduces blood pressure, strengthens the immune system, plays an important role in maintaining good skin, aids in the elimination of toxins and waste from the body and prevents the occurrence of wrinkles and pigmentation
Serine	Is a precursor to other amino acids like glycine and cysteine and is important in cell communication within the brain. It assists assists in production of immunoglobulins and antibodies for a healthy immune system, helps in the absorption of creatine that helps build and maintain the muscles, treats brain diseases such as amyotrophic lateral sclerosis (ALS), chronic fatigue syndrome and Alzheimer disease, plays a role in forming of all four bases of DNA and RNA (adenine, guanine, cytosine, thymine, and uracil, assists in production of antibodies (immunoglobulins), plays a central role in information processing, assists in stimulating the nervous system, produces serotonin which ultimately affects mood, digestion and sleep, increases levels of creatine which promotes muscle mass in the body, reduces symptoms of the brain disease (HSAN1) that causes loss of sensation in the legs and feet, treats seizures, increases blood flow to the brain, improves Huntington's disease, slows the appearance of wrinkles and decreased the presence of pre-existing wrinkles, combats depression and schizophrenia and helps relieve anxiety.
Threonine	Treats various nervous system disorders including spinal spasticity, multiple sclerosis, familial spastic paraparesis and amyotrophic lateral sclerosis, treats different types of depression, makes up elastin, collagen and enamel protein, promotes the proper fat metabolism in the liver, aids the digestive and intestinal tracts to function more smoothly and helps in metabolism in the upper reaches of the small intestine (ileum), produces the mucus gel layer that covers the digestive tract which is a barrier to digestive enzymes that can damage the intestines, produces antibodies to boost the immune system, supports the liver and treats amyotrophic lateral sclerosis (Lou Gherigs Disease),
Tryptophan	Is a precursor to the brain neurotransmitter serotonin (low serotonin production in the brain leads to depression, anxiety, mood disorders, insomnia, poor cognition). It improve sleep quality and lifts mood, reduces depression and anxiety, helps with recovery from addictions, reduces

Formatted: Font: Not Bold, Not Italic

headaches and migraines, maintain a healthy weight, contributes to the therapy of autism, cardiovascular disease, cognitive function, chronic kidney disease, depression, inflammatory bowel disease, multiple sclerosis, sleep, social function and microbial infections, facilitates the diagnosis of certain conditions such as human cataracts, colon neoplasms, renal cell carcinoma and prognosis of diabetic nephropathy, brings on natural calming effects, induces sleep, fights anxiety, helps burn more body fat, stimulates the release of growth hormones and reduces food cravings for carbohydrates and works in the brain and central nervous system to boost feelings of well-being, connection and safety

456
457
458
459
460
461

Table 13. Continued (Health benefits of amino acids in *spirulina*).

Amino Acid	Health Benefits
Tyrosine	Is a precursor for three important neurotransmitters (dopamine regulates reward and pleasure centers and memory and motor skills, norepinephrine and adrenaline which are responsible for the fight-or-flight response to stressful situations as they prepare the body to “fight” or “flee” from a perceived attack or harm, thyroid hormones which are produced by the thyroid gland and primarily responsible for regulating metabolism, melanin which is the pigment that gives skin, hair and eyes their color, improves mood and addresses mental health disorders like depression, bipolar or obsessive-compulsive disorder. It improves brain function, mood and stress response, helps with regulating mood swings caused by premenstrual syndrome (PMS) or premenstrual dysphoric disorder (PMDD), increases good cholesterol levels and reduces bad cholesterol levels, maintains optimal health of the digestive system, skin, hair and eyes, treats sleep-related conditions like insomnia, sleep apnea and bruxism (teeth grinding), helps relieve facial pain, assists in quitting smoking, aids with attention deficit-hyperactivity disorder (ADHD) and Tourette's syndrome, aids with brain maturation of the infant and plays key roles in the neurobehavioral regulations of food intake, satiation and sleep-wake rhythm.
Valine	Is needed for proper mental functioning and is vital for the muscle metabolism and the growth of muscle tissues as it assists in maintaining the proper amount of nitrogen in the body, plays an important role in building muscle and helps to decrease muscle soreness, helps in stress management, boosts immune system and healthy growth, improves mental focus during exercise which is thought to result from the fatigue, prevents muscle wasting by supplying the muscles with extra glucose for energy production during intense physical activity, helps with liver and gallbladder diseases as well as damage to these organs caused by alcoholism and drug abuse, treats or even reverses hepatic encephalopathy or alcohol-related brain damage, helps remove potentially toxic excess nitrogen from the liver by transporting nitrogen to other tissues throughout the body as required, promotes normal growth, repairs tissues, regulates blood sugar and provide the body with energy and helps stimulate the central nervous system.

462
463

464
465
466
467
468
469
470
471
472
473
474

475
 476
 477
 478
 479
 480
 481
 482
 483
 484
 485
 486
 487
 488
 489

Table 14. Health benefits of fatty acids in *spirulina* [25-26,50-52].

Fatty Acid	Health Benefits
Alpha Linolenic	Is an extremely important nutrient for muscles and body growth and is responsible for the production of red blood cells. It improves cognitive function, treats anemia, circulates oxygen, prevents chronic diseases, boosts immune system, treats fatigue and helps reverse insomnia.
Docosahexaenoic	Important for bone formation, maintenance of bone health and prevention of osteoporosis. It prevents diabetes, maintains heart health, prevents migraine headaches, relieves anxiety and helps with premenstrual syndrome.
Linolenic	Builds and maintains strong bones, helps alleviate back pain, keeps bones in their proper shape, helps muscles function properly, protects against cancer and diabetes, prevents arthritis and osteoporosis, helps in maintaining optimal body weight in both males and females, helps the nervous system maintain a proper pressure in arteries, suppresses the growth of polyps which has the potential to lead to cancer, protects against premenstrual depression, prevents kidney stones, controls alkaline pH level, regulates blood pressure and protects teeth by keeping the jaw bone strong and sturdy throughout your life..
Gamma Linolenic	Improves brain function, reduces osteoarthritis symptoms, prevents and treats yeast infections, helps metabolize insulin, helps with kidney stones, supports metabolic processes, protects against oxidative stress and prevents vitamin D deficiency.
Dihomo-gamma Linolenic	Enables the body to form red blood cells, helps maintain healthy bones, blood vessels, nerves and immune function, contributes to iron absorption, prevents cardiovascular disease and osteoporosis, lowers cholesterol and high blood pressure, maintains proper level of white blood cells or neutrophils which fight off infection, maintains proper level of bone mineral density and avoids risk of osteoporosis, plays an important role in maintaining collagen, helps prevent or delay arthritis and helps reduce the production of free radicals.
Palmitoleic	Promotes good bone health and is good for thyroid health, regulates blood sugar level, kick-starts metabolism, protects against diseases, relieves inflammation, combats PMS Syndrome., prevents epileptic seizures, boosts vitamin absorption, supports digestion, improves cognitive function and serves as a co-enzyme to assist metabolic activities in the human body.
Oleic	Is a good antimicrobial agent and trading allergy. It prevents cardiovascular diseases, ischemic stroke and osteoporosis, maintains good bone density and prevents cancer.
Erucic	Prevents cardiovascular diseases and prostate cancer, maintains normal blood pressure, prevents and treats dermatitis and photosensitivity, lung swelling and airway narrowing, allergies, asthma and common cold.

490
 491

492
493
494
495
496
497
498 |
499

Table 15. Health benefits of minerals in "*spirulina*"*spirulina* [21,28,53-55].

Mineral	Health Benefits
Boron	Improves brain function, reduces osteoarthritis symptoms, prevents and treats yeast infections, helps metabolize insulin, helps with kidney stones, supports metabolic processes, protects against oxidative stress and prevents vitamin D deficiency.
Calcium	Is beneficial to postmenopausal women with an increased risk of low bone density and is responsible for building the bone structure, strong teeth and fetal development, strengthens the jawbones that keep the teeth in position, ensures teeth are strong and less exposed to damage from bacteria and tartar, promotes calcium bone levels in children and adolescents, promotes the maintenance of bone mass in adults, decreases the risk of bone fracture in elderly adults, slows the rate of bone loss, keeps muscles strong, maintains the circulatory system, manages the digestive process, encourages bone growth., treats sarcoidosis, treats kidney failure and lactose intolerance.
Copper	Helps maintain healthy bones, blood vessels, nerves and immune function, contributes to iron absorption, prevents cardiovascular disease and osteoporosis, lowers cholesterol and high blood pressure, maintains proper level of white blood cells or neutrophils which fight off infection, maintains proper level of bone mineral density and avoids risk of osteoporosis, plays an important role in maintaining collagen, helps prevent or delay arthritis and helps reduce the production of free radicals.
Iron	Is an extremely important nutrient for muscles and body growth and is responsible for the production of red blood cells, treats anemia, circulates oxygen, prevents chronic diseases, improves cognitive function, boosts immune system, treats fatigue and helps reverse insomnia.
Magnesium	Is important for bone formation, maintenance of bone health and prevention of osteoporosis. It prevents diabetes, maintains heart health, prevents migraine headaches, relieves anxiety and helps with premenstrual syndrome.
Manganese	Is good for thyroid health and is crucial for promoting good bone health, regulates blood sugar level, kick-starts metabolism, protects against diseases, relieves inflammation, combats PMS Syndrome., prevents epileptic seizures, boosts vitamin absorption, supports digestion, improves cognitive function and serves as a co-enzyme to assist metabolic activities in the human body.
Molybdenum	Is a good antimicrobial and trading allergy. It prevents cardiovascular diseases, ischemic stroke and osteoporosis, maintains good bone density and prevents cancer.
Phosphorus	Is important for preventing cardiovascular diseases and prostate cancer, maintains normal blood pressure, prevents and treats dermatitis and photosensitivity, lung swelling and airway narrowing, allergies, asthma and common cold.

Potassium	Is good for improving cognitive function and is a gastro protective. It prevents and treats Cohn's disease, heart disease, prostate and colon cancer, leukemia, respiratory disease, oxidative stress, helps in cancer cell prevention and glucose metabolism, modulates antiaging, lowers cholesterol and treats obesity.
Zinc	Protects against breast and colon cancer, leukemia, neural degradation, heart disease, liver fibrosis, obesity, diabetes, antiaging and skin sun damage

500

501

502

503

504 | Table 16. Health benefits of water-soluble vitamins in "spirulina"spirulina [21,23,28,53-60].

505

Vitamin	Health Benefits
Thiamine (B1)	Boosts energy production, safeguards the nerves system, slows the body aging process, stimulates digestion and enhances memory, helps to prevent Alzheimer's disease, improves appetite, boosts body immunity, treats alcoholism and improves mood
Riboflavin (B2)	Helps body growth and overall good health, helps the body break down carbohydrates, proteins and fats to produce energy, allows oxygen to be used by the body.
Niacin (B3)	Reduces risk of heart diseases, improves mental health, treats diabetes, alleviates symptoms of arthritis, lowers levels of triglycerides, improves skin function and treats impotency, lowers bad cholesterol and regulates digestion.
Pantothenic acid (B5)	Stimulates hormone production, relieves stress, keeps the heart healthy, reduces fatigue and provides stamina to the body, assists in skin and hair care, helps the body generate more hemoglobin, heals wounds and prevents rheumatoid arthritis
Pyridoxine (B6)	Supports healthy skin, detoxifies the liver, enhances the health of blood vessels, improves cognitive function, assists in relieving mood swings, cures anemia, supports eye health, assist in relieving the symptoms of rheumatoid arthritis, prevents diabetes, assist in relieving carpal tunnel syndrome, treats pregnancy related nausea and treats hair loss.
Folate (B9)	Prevents birth defects, premature aging and heart attacks, improves the working of the human heart by removing homocysteine which is one of the major causes of heart attacks at early ages, controls the cholesterol level in the heart and ensures that the cardiovascular system is saved from various disorders, cures mental disorder, helps the body produce more red blood cells, combats depression, acts as a coenzyme, supports muscle build-up, combats free radicals, prevents cancer and aids fertility.
Cobalamin (B12)	Supports the normal function of nerve cells, assists in red blood cell formation and DNA synthesis, benefits the body by boosting energy, improves memory, helps prevent heart disease, improves heart health by decreasing homocysteine, prevents major birth defects, supports bone health and prevents osteoporosis, reduces risk of macular degeneration, improves mood and symptoms of depression, prevents the loss of neurons and supports healthy hair, skin and nails
Ascorbic acid (C)	Reduces the risk of chronic diseases, helps battle high blood pressure, fights heart disease risk factors, reduces blood uric acid levels, prevents gout attacks, prevents iron deficiencies by improving iron absorption and boosts immunity by helping white blood cells function better
Biotin	Helps maintain proper metabolic function, controls the level of sugar in the

(H)	bloodstream, enhances the condition of skin, maintains strong and beautiful nails and healthy hair, treats multiple sclerosis and diabetics, relieves muscle cramps, balances cholesterol levels and assists in obesity, antiaging and ulcer healing
Choline	Prevents breast and colon cancer, leukemia, neural degradation, heart disease, liver fibrosis, obesity, diabetes and skin sun damage.

506

507

508

509

510

511

512 Table 17. Health benefits of fat-soluble vitamins in Spirulina [21,23,28,53-60].

513

Vitamin	Health Benefits
A	Maintains healthy vision, protects eyes from night blindness and age-related decline, ensures normal function of immune system and organs, aids the proper growth and development of babies in the womb, lowers risk of Hodgkin's lymphoma, cervical, lung and bladder cancers, supports a healthy immune system, reduces the risk of acne, supports bone health and reduces the risk of fractures.
E	Balances cholesterol, fights free radicals, prevents disease development, repairs damaged skin, protects against skin cancer from ultraviolet rays, treats scars, acne and wrinkles, helps scalp from becoming dry and flakey, makes hair look healthier and fresher, balances hormones, maintains a healthy weight, keeps a regular menstrual cycle and reduces the cramping, anxiety and cravings, reduces menstrual blood loss, decreases the risk of age-related macular degeneration, protects against Alzheimer's disease, lowers cancer risk and improve growth and development of infants and children.
K	Prevents the calcification of the arteries, maintains the integrity of the bone structure, promotes absorption and utilization of calcium, slows down the bone density loss, regulates menstrual cycle and bleeding, reduces inflammation related to cancer, helps stabilize patients suffering from liver cancer, helps brain function fully, improves cognitive function, prevents tooth decay, prevents arthritis and osteoporosis, heals wounds and keeps digestion and cardiovascular systems up and running.
Alpha carotene	Removes destructive free radicals from the body before they cause the tissue damage that can lead to chronic diseases like heart disease and cancer, prevents cancer by stimulating cell-to-cell communication and promotes a strong component of a longevity and healthy mined.
Beta carotene	Assist in maintaining longevity or healthy mined, helps immune systems, protects against free radicals, lowers the risk of developing cancer and heart diseases, prevents the deterioration of cognition and compensates for some of the damage to the lungs caused by oxygen free radicals.
Lutein	Prevents eye diseases including age-related macular degeneration (AMD), cataracts and retinitis, prevents colon cancer, breast cancer, type 2 diabetes and heart disease, reduces inflammation, preserves skin health and filters high-energy wavelengths of visible light which slows down the rate of oxidative stress.
Zeaxanthin	Filters harmful high-energy blue wavelengths of light resulting in the protection and

maintaining healthy cells in the eyes, improves the contrast in the eyes and stimulates a faster recovery process from light damage, increases macular pigment density resulting in significant improvements in visual processing speed, supports aging eyes, maintains healthy skin growth, improves cognitive functioning and supports brain health in older adults,

514
515
516
517
518
519
520
521
522
523
524
525
526
527

Table 18. Health benefits of "spirulina" *spirulina* antioxidant/anti-inflammatory compounds [21-25,28-30,34,46,61-63].

Group	Compound	Health Benefits
Anthocyanins	Cyanidins	Help in treating and preventing liver disease, various types of cancer, diabetes and arthritis, assists in cholesterol modulation and cartilage protection
	Pelargonidins	Help in treating and preventing colon and liver cancer, neurodegenerative disorder, parkinsonism, meal induced postprandial inflammation, hepatitis B and gastrointestinal digestion
Flavonols	Procyanidins	Help in treating and preventing cardiovascular disease, coronary heart disease, assists in stabilization of collagen in joints, blood vessels and muscles inflammation, provides nutritional support to reduce capillary permeability and antiplatelet aggregation
	Catechins	Prevents and assists in treating obesity, cardiovascular disease, various types of cancer, myocardial infection, assist in cholesterol modulation, atherosclerosis and antiplatelet aggregation
	Gallo-catechins	Prevents skin cancer and treats HIV, helps bone metabolism, protect against neurodegenerative disease, UV-B damage, diabetes, melanoma, acts as antimicrobial and antimetastatic
	Epicatechins	Prevents cardiovascular diseases, periodontal diseases, various types of cancer, hepatitis C and blastocyst. It modulates testosterone secretion, improves insulin resistance and glucose tolerance.
	Kaempferol	Prevents cardiovascular diseases, ischemic stroke, cancer and osteoporosis. Helps maintain good bone density, acts as an antimicrobial and assists with allergy.
	Quercetin	Prevents cardiovascular diseases and prostate cancer. It modulates blood pressure, treats dermatitis, lung swelling and airway narrowing, assists and improves allergies and asthma and treats common cold.
Hydroxy-benzoic acids	Ellagic acid	Prevents Cahn's disease, heart disease, prostate and colon cancer, leukemia, respiratory disease and oxidative stress. Improves glucose metabolism, antiaging, modulates cholesterol, prevent and treats obesity, is a gastroprotective and assists in ulcer healing
	Gallic acid	Prevents and treats breast and colon cancer, leukemia, neural degradation, heart disease, liver fibrosis and obesity. Treats diabetes and skin sun damage and modulates aging.
	Vanillic acid	Protects against ulcerative colitis, oxidative brain damage, colorectal cancer and HIV. Assists with immune system regulation, malaria and ant sickling, and is an effective antimicrobial.
	Salicylic acid	Protects and treats colorectal cancer and blood thinning, reduces pain, helps with skin cleansing, removal of warts and corns, <u>curscur's</u> acne, calluses and dandruff.

	Cinnamic acid	Protects against lung adenocarcinoma and breast cancer, improves diabetes, assist with obesity, gastrointestinal hormone secretion and mycobacterium tuberculosis, improves mood and cognition, assists with allergy and antimalarial activity, is an effective antifungal.
Hydroxy-cinnamic acids	Coumaric acid	Prevents heart disease, liver disease, stomach cancer and renal toxicity. Improves diabetes, assists with immune system regulation and cholesterol modulation.
	Caffeic acid	Prevents liver cancer, HIV, AIDS, neurodegenerative disease, chlamydia pneumonia infection. Assists with hypertension, male fertility and immune system regulation.
	Ferulic acid	Prevents kidney disease, bone degenerative disease, breast and liver cancer, colon and prostate cancer, tongue and lung cancer. Protects skin from photo damage, prevents and treats diabetes, slows aging, assists with cholesterol modulation and menopausal symptoms
Tannins	Ellagitannins	Prevents heart disease, prostate cancer, inhibits cancer growth, reduces gastric inflammation, lowers blood sugar, assists with obesity and modulates aging.
	Gallo-tannins	Prevents colorectal cancer, eye disease, diabetes, assists with abdominal pain, diarrhea, antimicrobial activities
Stilbenes	Resveratrol	Prevents cardiovascular disease, Alzheimer, inhibits cancer growth, helps with obesity and diabetes, lowers high blood pressure and lowers cholesterol.

528

529

530 The addition of "spirulina"*spirulina* affected the easiness with which breaking a cookie was
531 made, the fragmentation and the appearance of the break line. Increasing the "spirulina"*spirulina* content
532 made the cookies more firm and harder to beak. However, the addition of 5% "spirulina"*spirulina* did not
533 affect the toughness of the cookies. The panel reported a toughness rating of soft-easy to beak for the
534 cookies that received 0 and 5% spirulina and firm-easy to beak to firm-hard to break for the cookies that
535 received 10 and 15% "spirulina"*spirulina*, respectively. Also, higher content of spirulina affected the
536 fragmentation and the appearance of the break line. Irregular large parts and continuous lines were
537 observed with the cookies that received no "spirulina"*spirulina* while more granules and smaller parts
538 with irregular line were observed with all the cookies that received "spirulina"*spirulina*. Increasing the
539 percentage of "spirulina"*spirulina* made the parts firmer and stickier. The results showed that adding
540 "spirulina"*spirulina* to cookies may help maintain their integrity and reduce breakage during packaging
541 and distributions.

542 The sensory panel members described the color of the control sample (0% "spirulina"*spirulina*)
543 as yellow and yellow-orange and the samples that received the 5 and 10% spirulina green as yellow-
544 green and green-yellow-green while the sample that received 15% spirulina as green, yellow-green,
545 green-yellow-green and Green-blue-green. The color shifted from dark green to bluish green with the
546 increase of spirulina content. The intensity rating of the color by the sensory panel varied from 6.88 ± 0.89
547 for the yellow-orange color to 10.00 ± 0.00 for the green-yellow-green color. Increasing the amount of
548 "spirulina"*spirulina* increased the vividness of the color

549 All the baked samples had a noticeable smell. The odor intensity ranged from faint (4.06-4.89) to
550 strong (8.19-8.69). The weighted average for the odor intensity was 6.11, 5.53, 6.02 and 6.63 for the
551 cookies receiving 0, 5, 10 and 15% spirulina, all of which are within the weak odor range. Increasing the
552 amount of "spirulina"*spirulina* from 5 to 15% (3 fold) only increased the odor intensity by 19.6 % (from
553 5.33 to 6.63). The sensory panel rating for the Hedonic Tone was 4.06, 4.63, 5.78 and 6.33 for the cookies
554 that received 0, 5, 10 and 15 % "spirulina"*spirulina*, respectively. The nature of the smell of the cookies
555 that received 0 and 5% "spirulina"*spirulina* was pleasant while that of the cookies that received 10 and
556 15% "spirulina"*spirulina* was must-seawater and fishy-seawater, respectively. The weighted average for
557 the Hedonic Tone was 2.97, 3.88, 4.69 and 4.74 for the cookies receiving 0, 5, 10 and 15% spirulina, all
558 of which are within the pleasant odor range. Increasing the amount of "spirulina"*spirulina* from 5 to 15%
559 (3 fold) increased the Hedonic Tone by 18.14 % (from 3.88 to 4.74). The results showed that adding 5%
560 "spirulina"*spirulina* did not affect the odor and the addition of a strong aromatic compound to the cookies
561 to mask the smell of "spirulina"*spirulina* may be required with higher concentrations (10-15%) of
562 "spirulina"*spirulina*.

563 | The addition and/or increasing the amount of "spirulina"*spirulina* affected both the taste and the
564 | degree of acceptance. The taste of the cookies that received no "spirulina"*spirulina* was rated
565 | sweet/delicious with a degree of acceptance between 8.33 and 10 while the taste of the cookies that
566 | received "spirulina"*spirulina* varied from sweet-sour to bitter-fishy and the degree of acceptance also
567 | varied from 8.06 (Sweet) to 4.16 (unpleasant) for the cookies receiving 5% "spirulina"*spirulina* to from
568 | 8.09 (Sweet) to 2.38 (bad) for the cookies receiving 15% spirulina. The results showed that adding 5%
569 | "spirulina"*spirulina* did not affect the taste and the addition of a flavoring agent to mask the taste of
570 | spirulina may be required with higher concentrations of "spirulina"*spirulina* (10-15%).
571 |

572 | REFERENCES

- 573 | 1. CAPMAS. 2019. Number of students enrolled in schools under the Ministry of education. Central
574 | Agency for Public Mobilization and Statistics, Ministry of Education, Egypt.
- 575 | 2. Soliman, G., M. Azmi and S. El Said. 2007. Prevalence of anemia in Egypt (Al-Gharbia
576 | Governorate). Egyptian Journal of Hospital Medicine, 28(2) :395-305.
- 577 | 3. El Sayed, N. A., A. Gad and A. Nofal. 1999. Assessment of the prevalence and potential
578 | determinants of nutritional anemia in Upper Egypt. Food Nutrition Bulletin, 20(2) :417-421.
- 579 | 4. Elalfy, M. S., M. Hamdy and S. Abdel Maksoud. 2012. Pattern of milk feeding and family size as
580 | risk factors for iron deficiency anemia among poor Egyptian infants 6 to 24 months old. Nutrition
581 | Research, 32(1) :93-99.
- 582 | 5. Mansour, P., A. S. Barduagni and F. Ahmed. 2004. Anemia among schoolchildren in Qena
583 | Governorate, Upper Egypt East Mediterranean Health Journal, 10(8) :916-920.
- 584 | 6. Mohamed, A., and A. Abo-donia. 2011. Contributing factors of iron deficiency anemia among
585 | children under two years attending family health centers in Alexandria. New York Science
586 | Journal, 4(1):35.
- 587 | 7. Selmi, A. S. and A. Al-Hindi. 2011. Anemia among school children aged 6-11 years old in Gaza
588 | Strip, Palestine. Annals of Al-Quds Medicine, 7(1) :27-32.
- 589 | 8. Kanagalingam, M. G., N. G. Forouhi and I. A. Greer. 2005. Changes in booking body mass index
590 | over a decade: retrospective analysis from a Glasgow Maternity Hospital. British Journal of
591 | Obstetrics and Gynaecology, 112(12) :1431-1433.
- 592 | 9. Ogden, C. L., M. D. Carroll, L. R. Curtin, M. M. Lamb and K. M. Flegal. 2010. Prevalence of
593 | high body mass index in US children and adolescents, 2007-2008. Journal of the American
594 | Medical Association, 303(2) :242-249.
- 595 | 10. El-Masry, S. A. 2007. Nutritional assessment of Egyptian children. Egyptian Medical Journal,
596 | 6(1) :40-49.
- 597 | 11. Shaaban, S. Y., S. A. El-Masry, N. T. Younis and H. H. Mohamed. 2008. Malnutrition among
598 | preschool children in Cairo. Egyptian Pediatric Association Gazette, 56(1) :26-34.
- 599 | 12. El-Shafie, M. A., M. H. Bahbah and A. M. Randa. 2011. Recent advances in pathophysiology and
600 | management of childhood obesity. Master essay, Menoufia: Faculty of Medicine Menoufia
601 | University, Menoufia, Egypt.
- 602 | 13. Hafez, A. S., M. Y. El-Awady and N. E. Hassan. 2000. Obesity profile among primary school
603 | children in Cairo. Egypt Journal of Community Medicine, 18(1) :99-119.
- 604 | 14. El-Shafie, A. M. and A. A. Sleem. 2013. Prevalence of obesity in primary school children living
605 | in Mit-Ghamr State, Dakahlia Governorate. Master Tesis in Pediatrics, Menoufia: Faculty of
606 | Medicine, Menoufia University, Menoufia, Egypt.
- 607 | 15. Ismail, G. 1998. Study of the problem of obesity among primary school children in Alexandria.
608 | High Institute of Public Health, Alexandria, Egypt.

- 609 16. Giroux, S. 2008. An evaluation of infant growth: the use and interpretation of anthropometry in
610 infants. WHO Working Group on Infant Growth. Bulletin of the World Health Organization,
611 73:165–174.
- 612 17. UNICEF. 2003. Child rights report, United Nation Children's Fund, New York, New York, USA.
613 Accessed March 2019 from : <http://www.unicef.org.uk/>
- 614 18. El-Zanaty, F. and A. Way. 2009. Egypt demographic and health survey. National Population
615 Council, Ministry of Health and Population, Cairo, Egypt, pp: 12–13.
- 616 19. El-Gillany, A., A. El-Wehady and M. El-Wasify. 2012. Updating and validation of the
617 socioeconomic status scale for health research in Egypt. East Mediterranean Health Journal,
618 18(9):962–968.
- 619 20. UNWFP. 2109. World Food program Report, United Nations, Rome, Italy. Accessed March
620 2019 from : <https://sustainabledevelopment.un.org/partnership/partners/?id=75>.
- 621 21. Becker, E. W. 2004. Microalgae in human and animal nutrition. In Handbook of microalgal
622 culture, A. Richmond (Ed), Oxford: Blackwell), pp: 312-351.
- 623 22. Batista, A. P., L. Gouveia, N. M. Bandarra, J. M. Franco and A. A. Raymundo. 2013.
624 Comparison of microalgal biomass profiles as novel functional ingredient for food products.
625 Algal Research, 2(2):164–173.
- 626 23. Brown, M., R. Mular, M. Miller, I. Farmer and C. Trenerry. 1999. The vitamin content of
627 microalgae used in aquaculture. Journal of Applied Phycology, 11(2): 247-255.
- 628 24. Gami, B., A. Naik and B. Patel. 2011. Cultivation of *Spirulina* species in different liquid media.
629 Journal of Algal Biomass Utilization, 2(1): 15– 26.
- 630 25. Bandarra, N. M., P. A. Pereira, I. Atista and M. H. Vilela. 2003. Fatty acids, sterol α -tocopherol
631 in *Isochrysis galbana*. Journal of Food Lipids, 18(1): 25-34.
- 632 26. Donato, M., M. H. Vilela, and N. M. Bandarra. 2003. Fatty acids, sterols, α -tocopherol and total
633 carotenoids composition of *Diacronema vlkianum*. Journal of Food Lipids, 10(2):267-276.
- 634 27. Molina-Grima, E., E. H. Belarbi, F. G. Acien-Fernandez, A. Robles-Medina and C. Yusuf. 2003.
635 Recovery of microalgal biomass and metabolites: process options and economics. Biotechnology
636 Advances, 20(7–8):491–515.
- 637 28. Khan, Z., O. bhadouria and P. Bisan. 2005. Nutrition and therapeutic potential of *spirulina*.
638 Current Pharmaceutical Biotechnology, 6(3):373-379
- 639 29. McCarty, F. M. 2007. Clinical potential of *spirulina*: A source of phycocyanobilin. Journal of
640 Medical Food, 10(4):566-570
- 641 30. Gouveia, L., C. Coutinho, E. Mendonça, A. P. Batista, I. Sousa, A. Bandarra, N. M. Raymundo.
642 2008. Functional biscuits with PUFA- ω 3 from *Isochrysis galbana*. Journal of the Science of Food
643 and Agriculture, 88(5): 891–896.
- 644 31. Spolaore, P., C. Joannis-cassan and E. Duran. 2006. Commercial applications of microalgae.
645 Journal of Bioscience and Bioengineering, 101(2): 87-96.
- 646 32. Priyadarshani, I. and B. Rath. 2012. Commercial and industrial applications of microalgae- A
647 review. Journal of Algal Biomass Utilization, 3(4):89-100.
- 648 33. Gouveia, L., A. E. Marques, J. M. Sousa, P. Moura and N. M. Bandarra. 2010. Microalgae source
649 of natural bioactive molecules as functional ingredients. Food Science & Technology Bulletin:
650 Functional Foods 7(1): 21–37.
- 651 34. Chen, Y.Z. and Y.M. Li. 1999. Development of nutritious *Spirulina* noodle. Zhongguo Liangyou
652 Xuebao, 14(4): 13-15.
- 653 35. Fradique, M., A. Batista, M. Nunes, L. Gouveia, N. Bandarra and A. Raymundo. 2010.
654 Incorporation of *Chlorella vulgaris* and *Spirulina maxima* biomass on pasta products. Part 1:
655 preparation and evaluation. Journal of Science, Food and Agriculture, 90(12): 1656-1664.
- 656 36. Feng, C. F. and S. P. Peng. 1991. Production method of blue-bacteria- *Spirulina* drink. Chinese
657 Patent, CN1035425A.

- 658 37. Adiba, B. D., B. Salem, S. Nabil and M. Abdelkim. 2011. Preliminary characterization of food
659 tablets from date phoenix dactylifera and *Spirulina* (*Spirulina* sp.) powders. Powder Technology,
660 208:725-730.
- 661 38. Ghaly, A., A. Hamouda and A. Alhatab. 2015. Developmebt and sensory evaluation International
662 Journal of Bioprocasse and Biotechnological Advances 1(2):63-73
- 663 39. AOAC, 2012. Official Methods of Analysis. Association of Analytical Chemists, Rockville,
664 Maryland.
- 665 40. Salehifar, M., S. Shahbazizadeh, K. Khosravi Darani, H. Behmadi and R. Ferdowsi. 2013.
666 Possibility of using microalgae *Spirulina platensis* powder in industrial production of Iranian
667 traditional cookies. Iranian Journal of Nutrition Sciences & Food Technology, 7(1): 63-72.
- 668 41. Lyer, U. M., S. A. Dhruv and I. U. Mani. 2007. Spirulina and its therapeutic implications as a
669 food product. In: Gershwin, M.E. and A. Belay. Spirulina in human nutrition and health. CRC
670 Press, Boca Raton, Florida, (pp: 51).
- 671 42. Sharma, V. and V. Dunkwal. 2012. Development of *Spirulina* based “biscuits”: a potential
672 method of value addition. Ethno Medicine, 6(1):31-34.
- 673 43. Lemes, A. C., K. P. Takeuchi, J. C. M. de Varvalho and E. D. G. Danesi. 2012. Fresh pasta
674 production enriched with *Spirulina platensis* biomass. Brazilian Archives of Biology and
675 Technology, 55(5): 741-750.
- 676 44. Morsy, O. M., A. M. Sharoba, A. I. El-Desouky, H. E. M. Bahlol and E. M. Abd El Mawla. 2014.
677 Production and evaluation of some extruded food products using spirulina algae. Annals of
678 Agricultural Science, Moshtohor Journal, 54(4): 329-342.
- 679 45. Vijayarani, V., S. Ponnalaghu and J. Rajathivya. 2012. Development of value-added product
680 using *spirulina*. International Journal of Health Science and Research, 2(4):42-47.
- 681 46. Foure, A. and D. Bendahan. 2017. Is branched-chain amino acids supplement an efficient
682 nutritional strategy to alleviate skeletal muscle damage: A system review. Nutrients 9(10):1047-
683 1059.
- 684 47. Nattia, J. S., K. Kamisoglu, M. G. Ierapetriton, I. P. Androulakis and F. Berthiaume. 2013.
685 Branched-chain amino acids supplementation: Impact on signaling and relevant to critical illness.
686 Bio-Medicine, 5(4): 449-460.
- 687 48. Bifari, F., C. Roucco, I. Decimo, G. Fumagalli, A. Valerio and E. Nisoli. 2017. Amino acids
688 supplements and metabolic health: A potential interplay between intestinal microbiota and system
689 control. Genes and Nutrition, 12(1):12-27.
- 690 49. Akram, M., H. M. Asif, M. Uzair, N. Akhtar, A. Madni and S. M. A. Saleh. Amio acids: A
691 review article. Journal of Medicinal Plants, 5(17): 33997-4000.
- 692 50. Swanson, D., R. Block and S. Mousa. 2012. Omega-3 fatty acids EPA and DHA: Health benefits
693 throughout life. Advances in Nutrition 3(1): 1-7.
- 694 51. Pipingas A., R. Cockerell, N. Grima, A. Sinclair, C. Stough, A. Scholey, S. Myers, K. Croft, A.
695 Sali and M. P. Pase. 2014. Randomized controlled trial examining the effects of fish oil and
696 multivitamin supplementation on the incorporation of omega-3 and omega-6 fatty acids into red
697 blood cells. Nutrients, 6(6):1956–1970.
- 698 52. Stonehouse, W., L. C. 2014. Does consumption of LC omega-3 PUFA enhance cognitive
699 performance in healthy school-aged children and throughout adulthood? Evidence from clinical
700 trials. Nutrients. 6(6):2730–2758.
- 701 53. Kamangar, F. and A, Emadi. 2012. Vitamins and minerals supplements: Do we really need them?
702 International Journal of Reviews in Medicine, 3(3):221-226.
- 703 54. Meyer F., P. Galan, P. Douville, I. Bairati, P. Kegle and S. Bertrais. 2005. Antioxidant vitamin
704 and mineral supplementation and prostate cancer prevention in the SU.VI.MAX trial.
705 International Journal of Cancer, 116(1):182–6.
- 706 55. Lippman, S. M., E. A.Klein,P. J. Goodman, M. S. Lucia, I. M. Thompson and L. G. Ford. 2009.
707 Effect of selenium and vitamin E on risk of prostate cancer and other cancers: The Selenium and
708 Vitamin E Cancer Prevention Trial, Journal of American Medical Association, 301(1):39–51.

- 709 56. ATBC-CPG. 1994. The effect of vitamin E and beta carotene on the incidence of lung cancer and
 710 other cancers in male smokers. The Alpha-Tocopherol, Beta Carotene Cancer Prevention Study
 711 Group. *New England Journal of Medicine*, 330(10):1029–1035
 712 57. Omenn, G. S, G. E. Goodman, M. D. Thornquist, J. Balmes, M. R. Cullen and A. Glass. 1996.
 713 Effects of a combination of beta carotene and vitamin A on lung cancer and cardiovascular
 714 disease. *New England Journal of Medicine*, 334(10):1150–1155.
 715 58. Sesso, H. D., J. E. Buring, W. G. Christen, T. Kurth, C. Belanger and J. MacFadyen. 2008.
 716 Vitamins E and C in the prevention of cardiovascular disease in men: The Physicians' Health
 717 Study II randomized controlled trial. *Journal of American Medical Association*, 300(11):2123–
 718 2133.
 719 59. Gaziano, J. M., R. J. Glynn, W. G. Christen, T. Kurth, C. Belanger and J. MacFadyen . 2009.
 720 Vitamins E and C in the prevention of prostate and total cancer in men: The Physicians' Health
 721 Study II randomized controlled trial. *Journal of American Medical Association*, 301(1):52–62.
 722 60. Clarke, R., J. Halsey, S. Lewington, E. Lonn, J. Armitage and J. E. Manson. 2010. Effects of
 723 lowering homocysteine levels with B vitamins on cardiovascular disease, cancer, and cause-
 724 specific mortality: Meta-analysis of 8 randomized trials involving 37 485 individuals. *Archives of*
 725 *International Medicine*, 170(10):1622–1631.
 726 61. Meyers, K. J., C. B. Watkins, M. P. Pritts and R. H. Liu, 2003. Antioxidant and ant proliferative
 727 activities of strawberries. *Journal of Agricultural and Food Chemistry* 51(6): 6887- 6892.
 728 62. Olsson, M. E., C. S. Andersson, S. Oredsson, R. H. Berglund and K. Gustavsson. 2006.
 729 Antioxidant levels and inhibition of cancer cell proliferation in vitro by extracts from organically
 730 and conventionally cultivated strawberries. *Journal of Agricultural and Food Chemistry* 54(4):
 731 1248 - 1255.
 732 63. Becker, E. W. 2007. Micro algae as a source of protein. *Journal of Biotechnology Advances*,
 733 25(2) 207-210.
 734 **64. Appendix:**
 735 65.
 736 66. Name: _____ Date: _____
 737 _____
 738 67. The texture is the appearance, finish or consistency of a surface of a substance. It is the
 739 characteristic of the physical structure of an object given by the size, shape, arrangement and
 740 proportions of its parts. It could also be defined as the way that a food feels in the mouth.
 741 68.
 742 69. A-Please describe the surface appearance and mouth feel of the samples using the following list
 743 70.

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)

744
745
746

71.
72.
73. RATING

Sample	Appearance	Mouth Feel
1		
2		
3		
4		

747
748
749
750
751
752
753
754
755
756
757
758
759

74. Thank you for your time
75. Figure S-1. Texture evaluation sheet (adopted from [38]).
76.
77.
78.
79.
80. Name: _____ Date: _____
81. Shredding/breaking is a method of cutting or breaking food into small pieces.
82.
83. Please describe the easiness with which breaking is made, the appearance of the broken parts and the breaking line of the samples using the following list.
84.

Toughness/Easiness	Appearance of 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)

760 85.
761 86.
762 87. RATING

Sample	Toughness	Fragmentation	Break Line
1			
2			
3			
4			

763 88. Thank you for your time
764 89. Figure S-2. Shred/break evaluation sheet (adopted from [38]).
765 90. .
766 91.
767 92.
768 93.
769 94.
770 95. Name: _____ Date: _____

771 _____
772 96. The color is the property of
773 reflecting light of a
774 particular wavelength. The
775 distinct colors of the
776 spectrum are red, orange,
777 yellow, green, blue, indigo,
778 and violet. Each of these
779 colors is shading into the
780 next as shown in the
781 diagram.
782 97.



783 98. 788 103.
 784 99. 789 104.
 785 100. 790 105.
 786 101. 791 106.
 787 102. 792 107.

793
 794
 795
 796
 797
 798

108.
 109. 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).
 110.

111. RATING

Sample	Color	Saturation
1		
2		
3		
4		

799 112. Thank you for your time
 800 113. Figure S-3. Color evaluation sheet (adopted from [38].
 801 114. .

802 115. Name _____ Date:
 803 _____

804 116. O
 805 der/Smell is the property of substance that activates the sensory smell. The intensity is the
 806 perceived strength of odor/smell sensation. Hedonic assessment is the process of rating on a scale
 807 ranging from extremely unpleasant to extremely pleasant. The characters of the odor are the
 808 ability to distinguish the nature of odor/smell.

809 117.
 810 118. A
 811 -Please rate the samples as to the presence of odor/smell (Intensity) and the odor/smell Hedonic
 812 Tone using the following scale

813 119.

Intensity	Hedonic Tone

No odor	0	No Smell	0
Very Faint	1-2	Extremely Pleasant	1-2
Faint	3-4	Pleasant	3-4
Weak	5-7	Neutral	5-7
Strong	8-9	Un Pleasant	8-9
Very Strong	10	Intolerable	10

814 120.
815 121. B- Please describe the character of the odor/smell of each sample by giving an
816 appropriate descriptive term using the list below. You may use a term of your choice which you
817 feel properly describes the odor/smell.

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

818 122.
819 123. RATING

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

820 124. Thank you for your time

821 125. Figure S-4. Odor evaluation sheet (adopted from [38].

822 126. Name: _____ Date: _____

823
824 127. Taste is the sensation of a flavor perceived in the mouth and throat on contact with a
825 substance. The characters of the taste are the ability to distinguish flavors. The Degree of
826 acceptability is the process of rating the taste on a scale ranging from nasty to delicious

827 128.

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

Characters	Degree of Acceptance

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)		

829
830

130.

131. RATING

Sample	Taste	Hedonic Tone
1		
2		
3		
4		

831 132. Thank you for your time

832 133. Figure S-5. Taste evaluation sheet (adopted from [38]).

833