



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

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

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

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

73 Household food security in Egypt is very fragile and fluctuating food prices can cause severe  
74 shocks resulting in malnutrition among the low-income families. Hunger and malnutrition can drive  
75 children away from schools. Malnutrition among Egyptian children results in: (a) 11% of children deaths,  
76 (b) 33% stunted children (age 6-18 years.) and their ability to comprehend and concentrate during class  
77 are impacted, (c) 2% of these children are likely to fail in education and (d) 6 % repetition rate in primary  
78 governmental schools [19]. Therefore, the current Government of Egypt invests USD 110 million per year  
79 on the National School Feeding Programme which reaches 12.5 million pupils. The goals of this program

80 are: (a) enhancing students' health by providing nutritious meals on a daily basis to increase  
81 their concentration in class, (b) educating the students and parents about the importance of the healthy  
82 nutritious meals and (c) motivating students to attend their classes and decrease school dropout rates  
83 and absences. However, the nutritional composition of these meals must be enhanced [20].

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

104 In recent years, novel attractive healthy foods have been prepared from *spirulina* [30,33-35].  
105 Traditional foods such as salad dressings, dips, puddings, gelled desserts, biscuits, cookies, bread,  
106 noodles, pasta, smoothies, ice cream and health drinks such as micro-algal sour milk and micro-algal  
107 green tea were supplemented with *Spirulina* to add coloring and functional attributes, making the  
108 products more sensorial attractive with health benefits due to the high content of carotenoids,  
109 polyunsaturated fatty acids, antioxidant and anti-inflammatory compounds [22,30, 34-37].

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

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

115

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

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118 Table 2. Amino acids in fresh dried *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

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127 Table 3. Fatty acids in fresh dried *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

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132 Table 4. Minerals in fresh dried *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

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141 Table 5. Vitamins in fresh dried *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

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145 Table 6. Biomass and protein yields and environmental growth conditions of *Spirulina* [31-36].

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

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## 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* was added to the first portion (control), 14 g *spirulina* were added to the second portion (5%), 28 g *spirulina* 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, Rayovac, Argentina) and the cookies were baked for 14 min. Each backed cookie weighed approximately 30 g.

### Sensory Evaluation

Sensory evaluations were carried out on the baked cookies to determine some of the physical properties (texture and shredding/breaking) and to evaluate the acceptability of color, smell and taste of the cookies. The procedure described by Ghaly et al. [38] was followed. A panel of 10 evaluators was formed from among technicians, undergraduate and graduate students and professors in the Agricultural Engineering Department, Faculty of Agriculture, Cairo University. The panel included males and females

195 who varied in age from 18 to 55 years. The sensory evaluation sheets used in this study (Figures S-1-5) in  
196 appendix were those developed by Ghaly et al. [38].

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## 198 **Nutritional Value**

199 The nutritional contents of the cookies were analyzed. The analyses include the determination of  
200 energy, protein, amino acids, carbohydrate, fat, vitamins and mineral contents. These analyses were  
201 performed according to the procedures described in Official Methods of Analyses of the Association of  
202 the Official Chemists [39].

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## 204 **RESULTS AND DISCUSSION**

### 205 **Texture**

206 The results of the texture appearance and mouth feel of the cookies are presented in Table  
207 7. The addition of *spirulina* to the cookies affected both the texture and mouth feel compared to  
208 the control (0% *spirulina*). The cookies that received no *spirulina* (control samples) had  
209 smoother texture and moist-smooth mouth feel whereas those received *spirulina* had sandy-  
210 courses texture and heavy-chewy mouth feel. Increasing the percentage of *spirulina* made the  
211 surface of the cookies more sandy-courses and made the mouth feel more firmer and chewier.

212 Salehifar et al. [40] reported that the addition of 0.5-1.5% *spirulina* into traditional Iranian cookies  
213 did not alter the texture of the cookies. Lyer et al. [41] found that increasing *spirulina* content from 2  
214 to 10% did not significantly alter the texture of biscuits. Sharma and Dunkwal [42] reported that the  
215 incorporation of 10% *spirulina* into biscuits did not have any significant effect on the biscuits texture.  
216 Lemes et al. [43] noted no statistical differences in the textures of pasta samples containing *spirulina* at  
217 concentrations of 0, 5 and 10%. However, Morsy et al. [44] reported that the addition of 2.5-7.5%  
218 *spirulina* to several extruded products did not significantly alter the texture of products but concentrations  
219 above 7.5 % had a significant effect on the texture of these products. Vijayarani et al. [44] noticed slight  
220 differences in the texture of extruded products when the *spirulina* content was increased from 5% to 15%.  
221 trey. Ghaly et al. [38] reported that the addition of *spirulina* to chocolate chip oatmeal cookies affected  
222 their texture and mouth feel as compared to the original cookies (no *spirulina* added) but increasing the  
223 percentage of *spirulina* from 3 to 9% did not show any significant differences.

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228 Table 7. Effect of *spirulina* on the texture and mouth feel of cookies.  
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<i>Spirulina</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	Heavy and Chewy	4
	Course	4		
10	Smooth	3	Heavy and Chewy	7
	Sandy	3	Firm & Chewy	3
	Course	4		
15	Smooth	2	Firm & Chewy	8
	Sandy	3	Rough and Chewy	2
	Course	5		

230 Texture is appearance, finish or consistency of the surface of a cookie

231 Mouth fell is the feeling of moistness and dryness or chewiness and smoothness of a substance in the mouth.

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238 **Shred/Fragmentation/Beak Line**

239 The toughness (the degree of easiness with which breaking cookies is made), fragmentation  
 240 (appearance of the broken parts) and the appearance of the break line were evaluated for the cookies  
 241 receiving different amounts of *spirulina*. The results are presented in Table 8. The addition of *spirulina*  
 242 affected the easiness with which breaking a cookie was made, the fragmentation and the appearance of  
 243 the break line. Increasing the *spirulina* content made the cookies more firm and harder to beak. However,  
 244 the addition of 5% *spirulina* did not affect the toughness of the cookies. The panel reported a toughness  
 245 rating of soft-easy to beak for both 0 and 5% *spirulina* and firm-easy to beak to firm-hard to break for the  
 246 cookies that received 10 and 15% *spirulina*, respectively

247 Also, higher content of *spirulina* affected the fragmentation and the appearance of the break line.  
 248 However, irregular large parts and continuous beak lines were observed with the cookies that received no  
 249 *spirulina* while more granules and smaller parts with irregular line were observed with all the cookies that  
 250 received *spirulina*. Increasing the percentage of *spirulina* made the parts firmer and stickier. The results

251 showed that adding *spirulina* to cookies may help maintain their integrity and reduce breakage during  
 252 packaging and distributions.

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

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## 260 Color

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

267 The intensity or saturation of the color was rated in scale of 1:10 with 1 considered dull color and 10  
 268 considered vivid color. The intensity rating of the color by the sensory panel varied from  $6.88 \pm 0.89$  for  
 269 the yellow-orange color to  $10.00 \pm 0.00$  for the green-yellow-green color. The results obtained from the  
 270 sensory panel showed that increasing the amount of *spirulina* in the cookies increased the vividness of  
 271 their color.

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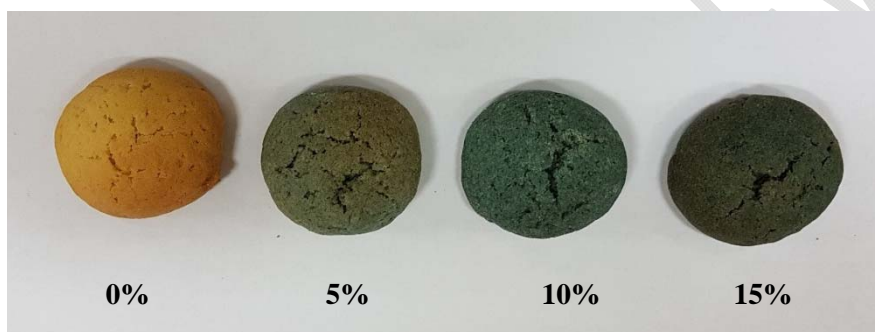
274 Table 8. Effect of *spirulina* on the toughness, fragmentations and breaking line of cookies.

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<i>Spirulina</i> 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
			Large parts	4	Irregular	7

	Firm and hard to break	2	Sticky parts	2		
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

276 Toughness is the easiness with which breaking of a cookie is made  
 277 Fragmentation is the appearance of the broken parts of a cookie  
 278 Break line is the appearance of the breaking line of a cookie  
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 293 Figure 1. Samples of baked cookies with varying amounts of *spirulina*.

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 297 Table 9. Effect of *spirulina* on the color of cookies.

<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

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

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305 Salehifar et al. [40] reported that the addition of 0.5-1.5% *spirulina* into traditional Iranian  
306 cookies did not alter their color compared to that of the original cookies. Morsy et al. [44] reported that  
307 the addition of 2.5% *spirulina* to several extruded products did not change their color, but the addition of  
308 5- 12.5% *spirulina* to these products significantly altered their color. Lemes et al. [43] noted that the  
309 addition of 5% *spirulina* to pasta did not change its color from that of the original pasta, but the addition  
310 of 10% altered the color of the pasta. Vijayarani et al. [45] noticed slight change of the color of extruded  
311 products when the *spirulina* content was increased from 5 to 15%. Sharma and Dunkwal [42] found  
312 change in the color of biscuits due to the addition of 10% *spirulina*. Lyer et al. [41] found that increasing  
313 the content of *spirulina* from 2 to 10% in Indian biscuits decreased the color appearance acceptance and  
314 concluded that addition of up to 5% of *spirulina* may be acceptable. Ghaly et al. [38] reported a change  
315 of the color of chocolate chip oatmeal cookies when spirulina was added to the cookies and increasing the  
316 spirulina content from 3 to 9% increased the vividness of the color. They stated that the color of the  
317 cookies was acceptable as reported by the members of the sensory panel.

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### 319 **Odor**

320 All the baked samples had a noticeable smell. The odor intensity was measured on a scale of 0:  
321 10 (0= no odor and 10= very strong odor) and the results are shown in Table 10. The results indicated  
322 that the odor intensity ranged from faint (4.06-4.89) to strong (8.19-8.69) for the all cookies. However,  
323 the number of panelists who reported strong odor increased with increasing the spirulina content. The  
324 weighted average for the odor intensity was 6.11, 5.53, 6.02 and 6.63 for the cookies receiving 0, 5, 10  
325 and 15% spirulina, all of which are rated weak odors. Increasing the amount of *spirulina* from 5 to 15%  
326 (3 fold) only increased the odor intensity by 19.6 % (from 5.33 to 6.63).

327 The nature of the smell (Hedonic Tone) was also rated on a scale of 1:10 with a score of 1-2  
 328 considered as extremely pleasant odor and a score of 10 considered as intolerable odor. The sensory panel  
 329 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 %  
 330 *spirulina*, respectively. The nature of the smell of the cookies that received 0 and 5% *spirulina* was  
 331 pleasant (cookies smell and sweat-yeast smell, respectively) while that of the cookies that received 10 and  
 332 15% *spirulina* was must-seawater and fishy-seawater, respectively. The weighted average for the Hedonic  
 333 Tone was 2.97, 3.88, 4.69 and 4.74 for the cookies receiving 0, 5, 10 and 15% *spirulina*, all of which are  
 334 within the pleasant odor range. Increasing the amount of *spirulina* from 5 to 15% (3 fold) increased the  
 335 Hedonic Tone by 18.14 % (from 3.88 to 4.74). The results showed that adding 5% *spirulina* did not affect  
 336 the odor and the addition of a strong aromatic compound to mask the smell of *spirulina* may be required  
 337 with higher concentrations (10-15%) of *spirulina*.

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339 Table 10. Effect of *spirulina* on the odor of cookies.

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

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

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

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350 Sharma and Dunkwal [42] found that the addition of 10% *spirulina* into biscuits did not  
351 significantly alter the smell of the biscuit as compared with the biscuits without *spirulina*. Lemes et al.  
352 [43] noted no difference in the odor of pasta containing 5- 10 % *spirulina*. Vijayarani et al. [44] found no  
353 significant differences in the odor of extruded products containing 5- 15% *spirulina*. Ghaly et al. [38]  
354 reported no change of the smell of chocolate chip oatmeal cookies when spirulina was added to the  
355 cookies at 3% and increasing the spirulina content from 3 to 9% increased the smell of spirulina and  
356 stated that a strong aromatic compound may be require to musk the smell of spirulina.

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### 358 **Taste**

359 The sensation of flavor perceived in the mouth and throat on contact with pieces of cookies was  
360 evaluated by the sensory panel. The degree of acceptance of the taste was also rated on a scale of 1  
361 (nasty): 10 (delicious). The results are presented in Table 11. The addition and/or increasing the amount  
362 of *spirulina* affected both the taste and the degree of acceptance. The taste of the cookies that received no  
363 *spirulina* was rated sweet/delicious with a degree of acceptance between 8.33 and 10.00 (sweet and  
364 delicious). The taste of the cookies that received *spirulina* varied from sweet to sour or sour-fishy or  
365 bitter-fishy and the degree of acceptance also varied from 8.06 (Sweet) to 4.16 (unpleasant) for the  
366 cookies receiving 5% spirulina to from 8.09 (Sweet) to 2.38 (bad) for the cookies receiving 15%  
367 spirulina. The results showed that adding 5% *spirulina* did not affect the taste but addition of a flavoring  
368 agent to the cookies to musk the taste of *spirulina* may be required with higher concentrations of *spirulina*  
369 (10-15%).

370 Lyer et al. [41] reported that increasing *spirulina* content in Parathas bread and biscuits from 2 to  
371 10%) changed the taste but remained acceptable. Sharma and Dunkwal [42] found that the addition of  
372 10% *spirulina* into biscuits did not result in any significant change in the taste. Lemes et al. [43] noted  
373 differences in the taste of pasta containing 5% *spirulina* compared to the pasta containing no *spirulina*.  
374 Morsy et al. [44] reported that the addition of 2.5% *spirulina* did not significantly alter the taste of the  
375 extruded products, but higher concentrations of 5-12.5% resulted in an undesirable taste. Ghaly et al. [38]  
376 reported the addition of 3% spirulina to chocolate chip oatmeal cookies did not change their taste but  
377 increasing the spirulina content in the cookies from 6 to 9% may require a strong aromatic compound to  
378 musk the smell of spirulina.

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### 380 **Nutritional Content**

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

385

386 Table 11. Effect of *Spirulina* on the taste of the cookies.

<i>Spirulina</i> (%)	Taste	Degree of Acceptance	Panellists
	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

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

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

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391 Table 12. Nutritional facts for cookies with different spirulina contents.

Amount per serving	<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
Praline (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	0.0108
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

392 Cookie Weight = 30 g

393 Cookie Size = 5 cm diameter x 0,5 cm height

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

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

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414

## CONCULOSION

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416 The incorporation of *spirulina* into cookies will enrich their nutritional values by increasing the  
417 protein content and adding vitamins, minerals, omega 3 and omega 6 oils and amino acids. *Spirulina* is a  
418 good source of protein, beta carotene and iron. The protein content in *spirulina* (65%) is much higher than  
419 that in milk (4.3%), eggs (13.3%), pulses (24%) and soybean (43.2%). The beta carotene in *spiruina*  
420 (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).  
421 The iron content in *spirulina* (0.522 mg/g) is also higher than spinach (0.109 mg/g) and soy bean (0.115  
422 mg/g). However, adding spirulina to cookies affected their smell, color, appearance, texture and taste.

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424 The addition of *spirulina* to the cookies affected both the texture and mouth feel  
425 compared to the control (0% spirulina). The cookies that received no *spirulina* had smoother  
426 texture and moist-smooth mouth feel whereas those received *spirulina* had sandy-courses texture  
427 and heavy-chewy mouth feel. Increasing the percentage of spirulina made the surface of the  
428 cookies more sandy-courses and made the mouth feel firmer and chewier.

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432 Table 13. Health benefits of amino acids in *spirulina* [46-49].

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Amino Acid	Health Benefits
Alanine	Is a critical player in the body's <i>protein biosynthesis</i> 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 causes 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 flashes 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 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

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growth of skin, prevents plaque buildup in arteries and treats shingles.

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

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

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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.

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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.

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

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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

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

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 (H)	Helps maintain proper metabolic function, controls the level of sugar in the 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.

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

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,

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Table 18. Health benefits of *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 ai effective antimicrobial.
	Salicylic acid	Protects and treats colorectal cancer and blood thinning, reduces pain, hep with skin cleansing, removal of warts and corns, curs acne, calluses and dandruff.
Hydroxy-cinnamic acids	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.
	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.

508

509

UNDER PEER REVIEW

510 The addition of *spirulina* affected the easiness with which breaking a cookie was made, the  
511 fragmentation and the appearance of the break line. Increasing the *spirulina* content made the cookies  
512 more firm and harder to beak. However, the addition of 5% spirulina did not affect the toughness of the  
513 cookies. The panel reported a toughness rating of soft-easy to beak for the cookies that received 0 and 5%  
514 spirulina and firm-easy to beak to firm-hard to break for the cookies that received 10 and 15% *spirulina*,  
515 respectively. Also, higher content of spirulina affected the fragmentation and the appearance of the break  
516 line. Irregular large parts and continuous lines were observed with the cookies that received no *spirulina*  
517 while more granules and smaller parts with irregular line were observed with all the cookies that received  
518 *spirulina*. Increasing the percentage of *spirulina* made the parts firmer and stickier. The results showed  
519 that adding *spirulina* to cookies may help maintain their integrity and reduce breakage during packaging  
520 and distributions.

521 The sensory panel members described the color of the control sample (0% spirulina) as yellow  
522 and yellow-orange and the samples that received the 5 and 10% spirulina green as yellow-green and  
523 green-yellow-green while the sample that received 15% spirulina as green, yellow-green, green-yellow-  
524 green and Green-blue-green. The color shifted from dark green to bluish green with the increase of  
525 spirulina content. The intensity rating of the color by the sensory panel varied from  $6.88 \pm 0.89$  for the  
526 yellow-orange color to  $10.00 \pm 0.00$  for the green-yellow-green color. Increasing the amount of *spirulina*  
527 increased the vividness of the color

528 All the baked samples had a noticeable smell. The odor intensity ranged from faint (4.06-4.89) to  
529 strong (8.19-8.69). The weighted average for the odor intensity was 6.11, 5.53, 6.02 and 6.63 for the  
530 cookies receiving 0, 5, 10 and 15% spirulina, all of which are within the weak odor range. Increasing the  
531 amount of *spirulina* from 5 to 15% (3 fold) only increased the odor intensity by 19.6 % (from 5.33 to  
532 6.63). The sensory panel rating for the Hedonic Tone was 4.06, 4.63, 5.78 and 6.33 for the cookies that  
533 received 0, 5, 10 and 15 % *spirulina*, respectively. The nature of the smell of the cookies that received 0  
534 and 5% *spirulina* was pleasant while that of the cookies that received 10 and 15% *spirulina* was must-  
535 seawater and fishy-seawater, respectively. The weighted average for the Hedonic Tone was 2.97, 3.88,  
536 4.69 and 4.74 for the cookies receiving 0, 5, 10 and 15% spirulina, all of which are within the pleasant  
537 odor range. Increasing the amount of *spirulina* from 5 to 15% (3 fold) increased the Hedonic Tone by  
538 18.14 % (from 3.88 to 4.74). The results showed that adding 5% *spirulina* did not affect the odor and the  
539 addition of a strong aromatic compound to the cookies to musk the smell of *spirulina* may be required  
540 with higher concentrations (10-15%) of *spirulina*.

541 The addition and/or increasing the amount of *spirulina* affected both the taste and the degree of  
542 acceptance. The taste of the cookies that received no *spirulina* was rated sweet/delicious with a degree of  
543 acceptance between 8.33 and 10 while the taste of the cookies that received *spirulina* varied from sweet-

544 sour to bitter-fishy and the degree of acceptance also varied from 8.06 (Sweet) to 4.16 (unpleasant) for  
545 the cookies receiving 5% spirulina to from 8.09 (Sweet) to 2.38 (bad) for the cookies receiving 15%  
546 spirulina. The results showed that adding 5% spirulina did not affect the taste and the addition of a  
547 flavoring agent to mask the taste of spirulina may be required with higher concentrations of spirulina  
548 (10-15%).

549

550

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712 **64. Appendix:**

713 65.

714 66. Name: \_\_\_\_\_ Date: \_\_\_\_\_

715 \_\_\_\_\_

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

719 68.

720 69. A-Please describe the surface appearance and mouth feel of the samples using the following list

721 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)

722 \_\_\_\_\_ 71.

723 \_\_\_\_\_ 72.

724

## 73. RATING

Sample	Appearance	Mouth Feel
1		
2		
3		
4		

725

74. Thank you for your time

726

75. Figure S-1. Texture evaluation sheet (adopted from [38].

727

76.

728

77.

729

78.

730

79.

731

80. Name: \_\_\_\_\_

Date:

732

\_\_\_\_\_

733

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

734

82.

735

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.

736

737

**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)

738

85.

739

86.

740

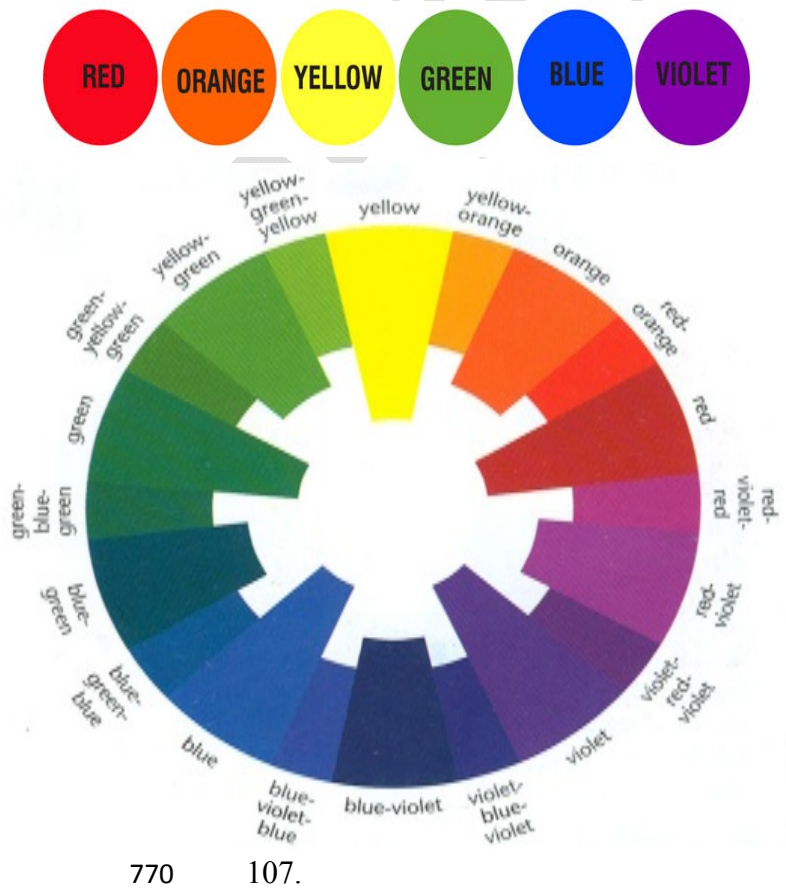
## 87. RATING

Sample	Toughness	Fragmentation	Break Line
1			
2			



741 88. Thank you for your time  
 742 89. Figure S-2. Shred/break evaluation sheet (adopted from [38].  
 743 90. .  
 744 91.  
 745 92.  
 746 93.  
 747 94.  
 748 95. Name: \_\_\_\_\_ Date: \_\_\_\_\_  
 749 \_\_\_\_\_

750 96. The color is the property of  
 751 reflecting light of a  
 752 particular wavelength. The  
 753 distinct colors of the  
 754 spectrum are red, orange,  
 755 yellow, green, blue, indigo,  
 756 and violet. Each of these  
 757 colors is shading into the  
 758 next as shown in the  
 759 diagram.



760 97.  
 761 98.  
 762 99.  
 763 100.  
 764 101.  
 765 102.  
 766 103.  
 767 104.  
 768 105.  
 769 106.

771  
 772 108.  
 773 109. Please identify the color of the samples according to the above diagram and rate  
 774 the saturation of the color using scale of 1:10 (dull=1 and vivid=10).  
 775 110.

111. RATING

Sample	Color	Saturation
--------	-------	------------

---

1

---

2

---

3

---

4

---

777 112. Thank you for your time

778 113. Figure S-3. Color evaluation sheet (adopted from [38].

779 114. .

780 115. Name \_\_\_\_\_

Date: \_\_\_\_\_

781 \_\_\_\_\_

782 116.

O

783 der/Smell is the property of substance that activates the sensory smell. The intensity is the  
784 perceived strength of odor/smell sensation. Hedonic assessment is the process of rating on a scale  
785 ranging from extremely unpleasant to extremely pleasant. The characters of the odor are the  
786 ability to distinguish the nature of odor/smell.

787 117.

788 118.

A

789 -Please rate the samples as to the presence of odor/smell (Intensity) and the odor/smell Hedonic  
790 Tone using the following scale

791 119.

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

792 120.

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

Mold  
Musty  
Fish  
Stagnant water  
Sea water  
Earthy

Yeast  
Ammonia  
Animal feed  
Sour  
Rotten cabbage  
Other (Please specify)

796 122.

797

123. RATING

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

- 798 124. Thank you for your time
- 799 125. Figure S-4. Odor evaluation sheet (adopted from [38].
- 800 126. Name: \_\_\_\_\_ Date: \_\_\_\_\_
- 801 \_\_\_\_\_
- 802 127. Taste is the sensation of a flavor perceived in the mouth and throat on contact with a
- 803 substance. The characters of the taste are the ability to distinguish flavors. The Degree of
- 804 acceptability is the process of rating the taste on a scale ranging from nasty to delicious
- 805 128.
- 806 129. 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)	

807

130.

808

131. RATING

Sample	Taste	Hedonic Tone
1		
2		
3		
4		

809 132. Thank you for your time

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

811