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Evaluation of The Phytochemicals and Nutritional Characteristics of Some Microalgae Grown in Egypt as Healthy Food Supplements

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THERE is a great interest toward natural functional nutraceuticals that possess therapeutic properties in preparing healthy food products. *Spirulina platensis*, *Turbinaria decurrens* and *Cystoseira Fucales* were evaluated for their chemical composition, minerals content as well as their nutritional properties such as polyphenols, vitamins and pigments and their potential utilization in preparing some functional food products. The results showed that the *Spirulina platensis* was a rich source of protein (46.48%) and essential amino acids (424.02mg/g protein) whereas *Turbinaria decurrens* and *Cystoseira Fucales* had the highest carbohydrate content, and ash. The investigated algae could be considered as a good source for K, Ca, Na, Fe and Zn. The phenolic compounds of the algae methanolic extracts varied from 2 to 14 mg g^{-1} dry weight as gallic acid equivalent and the highest DPPH radical scavenging was found for *Spirulina platensis* extract (15.66%). *Spirulina platensis* had the highest vitamin C (13.30 mg/100g), vitamin E (145.10 mg/100g), total chlorophyll (1648.89 µg/g), total carotenoid (1854.49 µg/g) and anthocyanin (0.540 µg/g) values. *Cystoseira Fucales* had higher vitamin A and vitamin D content than *Turbinaria decurrens*. Panelists accepted the sensory properties of the noodle and seasonings powder prepared from the different algae and the overall acceptability was described as "like very much" for both dried noodles and seasonings powder and "like moderately" for cooked noodles. Such results indicated that microalgae can be used as a promising source of multifunctional compounds in preparing functional food products.

Keywords: Nutraceuticals, Functional food products, Multifunctional compounds.

Introduction

Recently, much attention has been focused on nutraceuticals-rich foods that possess a positive influence on health enhancement, and may be a tool to support the human immune system against several viruses including COVID19 (Gombart et al., 2020 and Galanakis, 2020). Microalgae have gained increasing attention in recent years from Nutrition Scientists due to their various chemical, biological and nutritional properties with potential pharmaceutical benefits as well as affordable products. Different types of microalgae are considered a good source of natural alternative nutrients due to the capability of producing beneficial nutritive compounds which are useful for many purposes, such as ingredients for nutraceuticals or food additives, natural colorants, pharmaceuticals, and animal feed (Koyandea et al., 2019). Many microalgae species are rich in nutritionally useful constituents such as carbohydrates, proteins, basic amino acids, polyunsaturated fatty acids which are considered an adequate source of vitamins such as vitamins A and E as well as minerals such as potassium, iron, magnesium and calcium (Rashad and El-Chaghaby, 2020). Due to the high content of major bioactive compounds in the algae, they

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could possess therapeutic benefits as antiviral (Santoyo et al., 2012), anti-diabetic (Ali et al., 2017), antioxidant (Maeda et al., 2018), anti-inflammatory (Lee et al., 2017), antibacterial (Capillo et al., 2018) and antitumoral (Lind et al., 2013 and Lauritano et al., 2016). In addition, growing consumer understanding of the possible adverse effects of synthetic preservatives on human health and the benefits of natural additives has become a common research concern. For example some synthetically colorants that gives an appealing look to foods or monosodium glutamate (MSG) which is used in Indomie noodles seasoning and other foods could have genotoxic effects on consumers. Indomie noodles are consumed especially by children of different developmental stages in large quantities worldwide which can be made by adding hot water and consumed as a snack (El-Hadidy & Salam, 2017). Sustainable use of algae is crucial for humankind where it is a rich source of natural chlorophylls, carotenoids and multifunctional compounds such as essential amino acids, polyunsaturated fatty acids, polysaccharides (Karpinski and Adamczak, 2019). The most commonly macroalgae are Spirulina (blue-green algae) and brown macroalgae such as *Turbinaria decurrens* and *Cystoseira fucale* contain numerous nutraceuticals compounds protein, fatty acids, polysaccharides, terpenoids, triacylglycerols, steroids (Karpinski and Adamczak, 2019), with high antioxidant activity and was suggested their used in food formulations (Athukorala et al., 2006). Because of safety concerns, Spirulina (known as "superfood") has been recognized as safe (GRAS) the USA. The U.S. Food and Drug Administration (FDA) allow using it as a color additive or as an ingredient at levels ranging from 0.5 to 3.0 grams per serving in foods (gum, candy and other packaged foods). The total number of algae species worldwide accounts for about 72500 algal species and the Spirulina production volumes is about 5000 tons of dry matter/year worldwide with large market potential (Fernando et al., 2016). The Egyptian Red Sea contains an estimated 1500 km of coral reef, more than doubled worldwide. In Egypt, Spirulina is cultivated in limited area, while *Turbincaria* and *Cystosiry* are grown in Hurghada of red sea region but little information is available concerning their characteristics and utilization as nutraceuticals or food ingredients. Therefore, the present study was to determine the phytochemicals and nutritional properties of the three microalgae species which collected from different regions in Egypt and their potential utilization for preparing some functional products like dried sheet, noodle and as ingredient in the seasonings powder for indomie as a instead for monosodium glutamate (MSG).

Materials and Methods

Microalga

Spirulina platensis (*S.platensis*) was obtained from National Institute of Oceanography and Fishers. *Turbinaria decurrens* (*T.decurrens*) and *Cystoseira fucales* (*C.fucales*) were collected from the Hurghada, Red Sea coast of Egypt. Chemicals: All chemicals were purchased from El-Nasr Pharmaceutical Chemical Company, Egypt. Other reagents and solvents were purchased from Sigma-Aldrich Company (St. Louis, Missouri, USA).

Preparation of algae samples

The fresh tested samples of algae were washed with distilled water, cleaned and dried in hot air oven at 45°C and grounded, then stored in glass bottles under dark environment at 4°C until chemically analyzed.

Chemical composition

Moisture, crude protein, crude fat, ash and crude fiber were determined according to the procedures of the AOAC (2012). Nitrogen free extract of tested algae was calculated by difference. Minerals (Ca, K, Na Fe and Zn) were determined in ash solution using Atomic Absorption Spectrometer (300VA-50-60 Hz-100-240V) UK and amino acid were analyzed using the high performance Amino Acid Analyzer (Biochrom 30) according to the AOAC (2012).

Bioactive constituents

Total phenolic content

The powder of dried tested algae samples was macerated in methanol containing 0.1% HCl at a ratio 1: 20 (w/v) at room temperature twice then filtered and evaporated under vacuum in rotary evaporator at 45°C and weighed. Total phenolic content in the extracts were measurement at 750 nm using a spectrophotometer (Optizin UV–Vis spectrophotometer model, Thermo Electron Corporation, Korea) according to the AOAC (2012) using the Folin-Ciocalteu reagent and gallic acid as standard.

Antioxidant capacity (AC)

The antioxidant capacity of the extracts was determined using 2, 2-diphenyl-1-picrihydrazyl

(DPPH) assay according to the method of Hwang and Do-Thi (2014).

Vitamin contents

Vitamin C, (ascorbic acid, V.C) was determined titremetrically by the method of Barakat et al. (1973). Vitamin A (V.A), vitamin E (V.E), and vitamin D (V.D) were determined by HPLC System Controller (SCL-6A) using a Shimadzu CTO 6-A column oven with a SPD-6AV detector (Japan), under high-pressure solvent delivery unit (LC-20AD) according to the AOAC (2012). A sample volume of 20 µl was run at a flow rate of 2 ml/min for 15 min at 20ºC. Vitamin A, vitamin E, and vitamin D were identified and quantified by comparing their retention times to known previously injected standards.

Determination of phytopigments

Chlorophylls, total carotenoids, and anthocyanins pigments were colorimetrically measured using a spectrophotometer as follows :

a- Chlorophylls and total carotenoids

The pigments were extracted with 100% acetone (50 : 1) using homogenizer at 1000 rpm for one min, filtered through 0.2 um filter paper, and then centrifuged at 2500 rpm for ten min. The filtrate was made up to 100ml with 80% solvent performed in dim light. The absorbance of the supernatant was measured at 400-700 nm against 80% acetone (as a blank). These pigments were calculated as µg/g dried weight of the algae according to the equations described by Ritchie (2008) and Connan (2015).

b- Anthocyanins

Total anthocyanins was extracted and then calculated (µg/g) according to the method described by Fuleki & Francis (1968).

Technological methods

Some suggested products were prepared as approach for utilization of algae in the functional food industry.

Dried sheets algae as snack

The samples were washed in fresh water and blanched for 13 min. The blanched tubers were cooked for 10 min, and then blended with tertiary butyl hydroquinone (TBHQ) as an antioxidant. The paste was spread on stainless steel trays coated with butter paper, for drying under vacuum pressure for ~4 h. The dried sheets were cooled, and then stored in airtight bags until further use.

Preparation of dried noodles product

The formulation used to make the noodle samples were described by Jing et al. (2018) with replacing 10% of wheat flour by dried tested algal. The noodle formula included 100 g wheat flour (72% extraction), 1g salt, 20g whole egg and 30 ml distilled water. Salt was dissolved in water prior to addition with wheat flour. The ingredients were mixed in a mixer (Philips Mixer, H.R. 1480/81 M, Egypt) for 8 min. The dough was rounded and allowed to rest at ambient temperature for 20 min. The dough was passed through the reduction rolls of an Imperia Titania Pasta Machine (Italy). Thickness of dough sheet was reduced to 2 mm. The dough sheets were rested at ambient temperature for 15 min. Dough sheets were cut into noodle strips and the strips were dried at 50˚C for 15 hr in an air oven. The dried noodle samples were packed in polyethylene bags and stored at ambient temperature prior to sensory characteristics of the noodle samples.

Preparation of cooked noodles

The dried noodles were cooked in boiling water for 10 min.

Preparation of seasonings algae powder

The dried algal of formula preparation was used toreplace monosodium glutamate in commercial seasonings. The seasonings algae powder was blended in presence of salt, black pepper, onion powder, garlic powder, red chili, curry, turmeric, paprika, cumin where the amounts of tested algae powder were added to the total weight of the solid seasoning composition by 1:9 w/w ratio .The indomie products were cooked in boiling water for 15 min. Prepared seasoningalgae powder were added to the indomie soup at levels of 1% based on the weight of indomie.

Sensory evaluation

Organoleptic properties of products were evaluated by 15 panelists trained of Food Sci. & Tech. Dept. Fac. of Agric. Univ. of Alex., according to Watts et al. (1989).

Statistical analysis

The obtained data were analyzed for statistical significance at $P \leq 0.05$ using statistical package for social sciences software (SPSS) version 22 (2018).

Results and Discussion

Chemical composition

Data in Table 1 reveal that, the dried tested algal contain 3.90–8.45 g/100g moisture. Protein is the main components of *S. platensis*

(46.48±0.78%), while nitrogen free extract was the highest percentage compound in *C.fucales* and *T.decurrens* (47.45±0.8% and 47.5±1.01% respectively*). S.platensis* had high percentage of crude ether extract (4.03%), and low concentration of total ash and crude fiber (15.98% and 3.22% respectively) compared to other algal samples. The results were found to be in the range of the values recorded by Liu & Liang, (1999) and Habib et al. (2008) who found that green-Spirulina consists of protein (55-70%), fat (2-6%), dietary fiber (2-4%), ash (3-11%), moisture (4-9%) and carbohydrates (15-25%) while, Belay (2002) reported Spirulina species rich in protein up 70%. Also, Mayhoob et al. (2015) reported that some Cystoseira species contained 13-56.78% soluble sugar, 1.25to 5.55% lipid, 9.51to 21.76% crude protein and 23.84 to31.18% ash. On the other hand, Deyab et al. (2016), reported that ecological parameters affected biochemical composition of brown seaweed. Higher protein content (37.70 mg/g DW) in *Turbinaria ornata* was found during November and higher soluble carbohydrates content (2.80 mg/g) in September month. Salem et al. (2018) reported that the carbohydrate content was higher in green (Chlorophyta) algae than brown (Ochrophyta) algae while the protein concentration was higher in red algae than green algae.

Minerals and trace elements such as zinc and iron play major role in supporting the immune system to protect against certain infections, inflammation, and possibly some cancers (Calder et al., 2020). Zinc acts as a co-factor in numerous enzymatic reactions involving dehydrogenases and polymerases in addition to its effectiveness in cell replication and micro nutrient metabolism (Arinola, 2008). Ash content and mineral profile are presented in Table 1.

Results indicate that K was the predominant element of all tested algal followed by Na and Ca. The micro-elements (Fe and Zn) ranged from 4.60 to 297.03 mg/g for Fe and 1.19 to 2.96 mg/100g for Zn, respectively. These results are in agreement with those reported by Liu & Liang(1999) and Habib et al. (2008), who reported calcium (0.5-1 g), iron (30-100 mg), zinc 2-4 mg for green-Spirulina. Also, Morsy et al. (2014) reported Spirulina rich in calcium (1.044%) and iron (0.339%). Brown algae (*Sargassum muticum*) which were collected from the Egyptian Mediterranean Sea coast, contained high levels of sodium, calcium, and potassium, as well as moderate concentrations of iron ,and zinc (Salem et al., 2018 and Rashad & El-Chaghaby, 2020). On the other hand, it was lower than that reported by Sanchez et al. (2003) who found that calcium and sodium values in spirulina were 120 and 2200 mg/100g respectively. *Cystoseira myrica* at Red Sea coast at Marsa Alam had high Fe (575.88 µg/g dry wt). According to Deyab et al. (2016), the chemical composition of marine algae is greatly influenced by the environmental and habitat conditions at a specific location during a specific season. *Turbinaria ornata* collected from Hurghada shores, Red Sea coast of Egypt during November were higher in Na, K and Ca contents than October. As a conclusion, the variations of the chemical composition of studied species may be due to the difference in cultivation conditions, harvesting time, genotype, mature stage and ecological parameters. So, it was evident that microalgae contained essential components which can be useful as a good nutrition source for the nutraceutical industry

Amino acids

Table 2 presents the amino acid composition for the algae samples. Results indicated that algae samples contained 16.3 to 196.62 mg amino acid/g sample (dry mater).The total essential amino acids in algae samples were 424.02, 199.61 and 188.08 mg/g protein in the *S. platensis*, *C.fucales* and *T. decurrens*, respectively. The amino acid pattern of defatted samples in Table 2 was nearly similar in *C. fucales* and *T. decurrens*. Similar profile of the amino acids was reported by Morsy et al. (2014) who found that the Sprilunia protein contain the same amino acids, but not as the same concentration. Tyrosine (89.67 mg/g protein) and methionine (89.67 mg/g protein) were the most presented among the essential amino acids of *S.platensis* while leucine was the most predominant essential amino acids of *C.fucales* (37.82 mg/g protein) and *T. decurrens* (39.17 mg/g protein). The *C.fucales* and *T.decurrens* contained higher proportion of non-essential amino acids to essential amino acids, where, glutamic acid and aspartic acid were the predominatednon-essential amino acids in the samples. Glutamic acid content ranged from 77.11 to 67.85% aspartic acid content ranged from 50.18 to53.39% in *C. fucales* and *T. decurrens*. The most predominant non-essential amino acids in *S. platensis* protein were aspartic acid and proline (29.88 and 29.78 mg/g, respectively). Essential amino acids in *S. platensis* protein (42.4%) were above the reference values recommended by FAO(1985) for adults (26.2%) while the essential amino acids value of the studied *C. fucales* and *T. decurrens* samples account for 75.32 and 70.97% of the total essential amino acids values recommended by FAO, for adults (Table 2). Glutamine acid recorded the highest value followed by aspartic acid of the macro-algae species (Mohamed et al., 2019).

TABLE 1. Phytochemicals constituents of dried tested algae (on dry weight basis).

Component (%)	*Spirulina platensis*	*Cystoseira fucales*	*Turbinaria decurrens*
Moisture	8.45±0.41[c]	3.9±0.25[a]	6.74±0.31[b]
Crude Protein	46.48±0.78[b]	8.17±0.39[a]	8.99±0.36[a]
Crude ether extract	2.14±0.08[a]	2.11±0.05[a]	2.34±0.18[a]
Total ash	17.64±0.28[a]	35.68±0.21[b]	35.19±0.10[b]
Crude fiber	3.22±0.62[a]	6.59±0.15[c]	5.98±0.37[b]
Nitrogen free extract	30.52±1.67[a]	47.45±0.80[b]	47.5±1.01[b]
Macroelements (mg/g)			
Calcium (Ca)	9.53±1.7	16.38±5.7	13.59±3.7
Potassium (K)	17.62±2.8	121.78±1.2	85.37±1.6
Sodium (Na)	6.72±1.9	41.40±1.7	19.84±2.5
Microelements (mg/100g)			
Iron (Fe)	297.03±2.8	9.05±1.8	4.60±0.76
Zinc(Zn)	2.96±1.3	2.20±0.05	1.19±0.21

Values are expressed as Mean±S.D, Means in columns with different letters (a-b) are significantly different ($p<0.05$), based on ANOVA.

TABLE 2. Amino acid composition of dried tested algae species and amino acid requirements of adults.

Amino Acid	*Spirulina platensis*		*Cystoseira fucales*		*Turbinaria decurrens*		Amino acid requirements of adults	
	mg/g dry matter)	mg/g protein	mg/g dry matter)	mg/g protein	mg/g dry matter)	mg/g protein	(mg/kg per day)	mg/g protein
Essential amino acids								
Therionine	17.50	37.66	2.3	28.15	2.2	24.47	15	23
Valine	26.15	56.25	2.2	26.93	2.4	26.80	26	39
Methionine	33.38	71.81	0.9	11.02	1.4	11.12	10	16
Isoleucine	27.99	60.24	2	24.48	1.9	21.13	20	30
Leucine	31.01	66.72	3.2	39.17	3.4	37.82	39	59
Hisitidine	5.74	12.34	0.6	7.34	0.7	7.79	10	15
Tyrosine	41.68	89.67	1	12.34	0.6	6.67		
Phenylalanine	6.85	14.74	2.1	25.70	2.6	28.92	+ tyrosine 25	38
Lysine	6.32	13.59	2	24.48	2..1	23.36	30	45
Total essential amino acids	196.62	424.02	16.3	199.61	17.3	188.08	175	265
Non essential amino acids								
Aspartic acid	13.89	29.88	4.1	50.18	4.8	53.39		
Glutamic acid	6.90	14.85	6.3	77.11	6.1	67.85		
Serine	5.08	10.93	1.7	20.81	1.7	18.90		
Cysteine	7.99	17.21	0.9	11.02	1.4	15.57	4	6
Glycine	4.86	10.45	2.3	28.15	2.3	25.58		
Argnine	3.49	7.51	2	24.48	2	22.25		
Alanine	8.17	17.58	2.3	28.15	2.7	30.03		
Proline	13.84	29.78	1	12.24	2.3	25.58		
Totalnon essential amino acids	64.22	138.19	20.6	252.14	23.3	259.61		

Bioactive constituents

Bioactive compounds possess antioxidant and anti-inflammatory effects, such as polyphenols, vitamins and carotenoids (Gombart et al., 2020).

Total phenolic content and antioxidant capacity

The results of the methanolic extract of *S.platensis* showed high total phenolic content of 14±0.14 mg GAE g^{-1} dry weight (Fig. 1). The extraction yield depends on the solvent polarity. This result was different than that reported by Delfan et al. (2018) who reported *Spirulina platensis* had 26.64-31.9±0.16 mg GAE/g. This different of total phenolic contents depends on many influencing factors such as algal species, geographical origin, cultivation season and environmental variations (Marinho-Soriano et al., 2006). Phenolic compounds found in brown algae include the phlorotannins which, possess different therapeutic properties such as anticancer, antioxidant, antibacterial, anti-allergic, anti-diabetes, anti-aging, anti-inflammatory and anti-HIV activities (Li et al., 2011).

The radical scavenging activity (% inhibition of DPPH radical) of the algae extracts were as follow: *S. platensis* (15.66%) >*C. fucales* (12.30%) >*T. decurrens* (10.24%) within the same concentration (Figure 1). It can be concluded that all algae extracts are moderate antioxidants. The antioxidant capacity of water soluble compounds in brown *Eisenia bicyclis* and *Hizikia fusiformis* algal was 7.53 µmol $AAg^{-1}$and 1.70 µmol AAg^{-1} respectively and 0.76 µmol $AAg–^{1}$in the green *Spirulina platensis* (Klejdus et al., 2009). The result of inhibition percentage of *S. platensis* was lower than that reported by Abu-Zaid et al. (2015) who showed that *S. platensis* water extract had highest antioxidants percentage(81.1%). Hidayati et al. (2020) stated that antioxidant activity can be affected by the phenolic compounds and pigment content.

Vitamins

Vitamins A, E and D are lipid-soluble antioxidants, and V. C is considered essential nutrients because of its ability to stimulate the immune system and maintain good human health (Achikanu et al., 2013). Vitamins content of the three different microalgae are presented in Table 3. The concentration of V. C in *S.platensis* was 13.30 mg/100 g followed by *C.fucales* (11.97 mg/100 g) and *T.decurrens* (10.64 mg/100g). In the same respect, *S. platensis* had also the highest value of V.E (145.102 mg/100 g) while, *C.fucales* and *T.decurrens* showed the highest value of V. D (5899.62 and 5369.19 µg/100 g respectively). Vitamin A (in the form of beta-carotene) in *C.fucales* (2172.34 IU/100g) was higher than *T.decurrens* (714.34 IU/100g), and *S.platensis* (669.85 IU/ 100 g). These results are less in agreement with previously reported in other studies (Fabregas et al., 1999 and Bishop & Zubeck, 2012) who found 10g dried spirulina contains 1200 IU vitamin D, 23000 IU vitamin A, 0.8 mg vitamin C and 1.0 mg vitamin E. This difference might be due to the variation of cultivation and environmental conditions. Also, there are few research data available in the literature on *C.fucales* and *T.decurrens*.

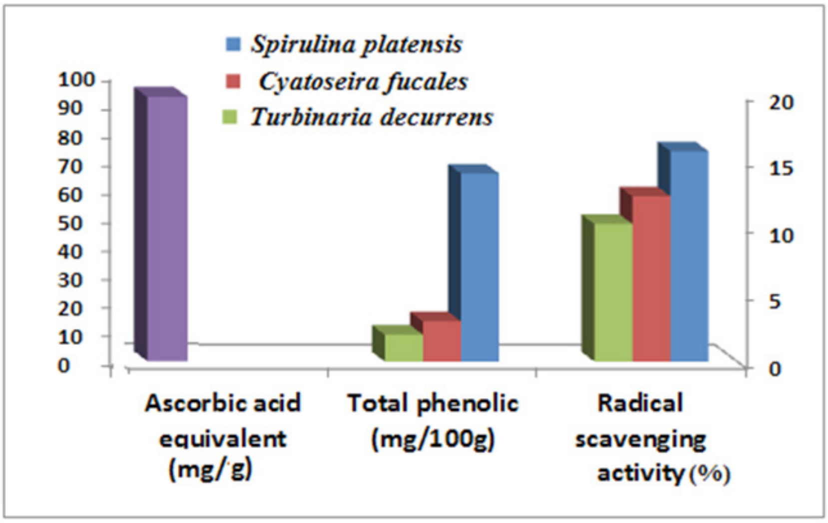

Fig. 1.Total phenolic content and antioxidant activity of algae species measured by DPPH.

TABLE 3. Vitamins content of dried tested algae species.

Vitamin	*Spirulina platensis*	*Cystoseira fucales*	*Turbinaria decurrens*
Vitamin C mg/100g	13.30±0.32	11.97±0.51	10.64±0.53
Vitamin E mg/100g	145.10	124.83	95.16
Vitamin D µg/100g	1889.40	5899.62	5369.19
Vitamin A IU/100g	669.85	2172.34	714.34

Pigments

Pigments are important bioactive components because of their anticarcenogenic, antioxidative and antihypertensive effects. Pigments namely: chlorophylls, total carotenoid and anthocyanin were measured in the dried tested algal under study (Table 4 and Fig. 2). The results showed that the chlorophyll concentration varied from 379.99 µg/g in *T.decurrens* to 1648.89 µg/g in *S.platensis*. The contents of total carotenoids significantly differed among species of the tested algal. No significant differences ($P < 0.05$) in the anthocyanin content between *C.fucales* and *T.decurrens*. Among the three tested algae *S.platensis* contained the highest concentration of total chlorophylls, total carotenoid and anthocyanin (1648.89, 1854.49 and 0.540 µg/g respectively). The lowest concentration of chlorophyll a, chlorophyll c, chlorophyll D, total chlorophylls, total carotenoids, and total anthocyanin were found in *T. decurrens* (306.14, 26.81, 7.07, 379.99, 265.66 and 380 µg/g respectively). The chlorophyll b content in *C.fucales* was higher than *T.decurrens*. Results of the pigments were lower than that reported by Liu and Liang, (1999) who found that green Spirulina had 0.6-1 g/100g chlorophyll and 0.1-0.4 g/100g carotenoids. Also, Becker (2013) reported that the total chlorophyll in Spirulina is in the range of 0.5-1.5%. These differences may be related to the variations in algal species or cultivated system and regions.

Organoleptic properties of algae products

Organoleptic properties for the dried sheets, noodles and seasoning formulas made from the tested algae are presented in Table 5 and Fig. 3. Color and texture are important properties which determine the overall quality and consumer acceptability of a food product. The data showed that *S. platensis* sheets obtained the highest scores among the three sheets with respect to appearance, color, texture, flavor and overall acceptability. The lowest score for texture was observed for *T.decurrens* followed by *C.fucales* and the overall acceptability for both was "dislike moderately". *S.platensis* sheets was the most acceptable and can be used for making rolled sushi, seaweed salads or seaweed soup and can be mixed with homemade sea food. Also, it was obvious that panelists accepted the noodles products and the overall acceptability described by the panelists as "like very much" for dried noodles and "like moderately" for cooked noodles prepared from the three different algae. No significant differences were observed for flavor scores which include both aroma and taste of all cooked noodle products. Scores obtained for the seasonings formulated using the different algae powders were "like very much" for acceptability. No significant differences were observed between commercial seasoning and those included the different algae powders. These algae seasoning could be considered a rich source of health promoting bioactive compounds. The organoleptic properties of our products are in agreement with those of Raja et al. (2014) and Morsy et al. (2014), they found that, the highest overall acceptability score was found in snack food prepared with 2.5% *S. platensis* and the replacement of flour with 10% Spirulina improved the texture parameters of snacks. Similar study by Bolanho et al. (2014) reported that the addition of 5% *Spirulina platensis* to cookies improved the nutritional value and total phenolic compounds of the final product. Burcu et al. (2016) reported that incorporation of 10% Spirulina in the bread had positive effect on the nutritional value and no mold growth was detected in bread with spirulina which was stored at room conditions. Agustini et al. (2016) reported that addition of 1% *S. platensis* to soft cheese was the best concentration, on the other hand panelist preferred ice cream without addition of *S. platensis* that gave fishy or unpleasant odor and dark green color.

Conclusion

The obtained results indicated that microalgae can be used as a promising source of nutritional and multifunctional compounds because of their high content of essential amino acids, natural colorants, vitamins and minerals that play significant roles in supporting the immune system. Therefore, there is potential for using the studied algae as natural nutraceuticals in preparing functional food products.

TABLE 4. Chlorophyll pigments content (on dry weight basis) of *Spirulinaplatensis, Cystoseira fucales* and *Turbinari adecurrens*.

Algae	Chlorophyll A (µg/g)	Chlorophyll B (µg/g)	Chlorophyll C (µg/g)	Chlorophyll D (µg/g)	Total chlorophylls (µg/g)
Spirulina platensis	1330.98±0.38[c]	217.23±0.38[c]	73.64±0.38[c]	27.04±0.38[c]	1648.89[c]
Cystoseira fucales	329.86±0.38[b]	26.59±0.38[a]	52.61±0.38[b]	15.74±0.38[b]	424.81[b]
Turbinariadecurrens	306.14±0.38[a]	39.95±0.38[b]	26.81±0.38[a]	7.07±0.38[a]	379.99[a]
LSD	2.001	1.489	2.208	1.489	8.291

TABLE 5. Organoleptic properties of some products made from dried tested algae species.

Tested algae species	Organoleptic properties				
	Color	Flavor	Texture	Appearance	Overall acceptability
	Dried sheets				
Spirulina platensis	8.75±0.64[c]	7.75±0.64[b]	7.88±0.53[b]	7.75±0.54[b]	Like Moderately
Cystoseira fucales	6.25±0.89[a]	5.50±0.75[a]	2.55±0.93[a]	3.50±0.76[a]	Dislike Moderately
Turbinari adecurrens	6.50±0.74[a]	5.63±0.46[a]	3.67±0.88[a]	4.50±0.74[a]	Dislike Moderately
	Dried noodles				
Control	8.88±0.35[b]	7.87±0.83[a]	8.63±0.35[b]	8.63±0.98[b]	like very much
Spirulina platensis	8.13±0.83[ab]	8.25±0.64[a]	8.25±0.53[ab]	7.87±0.74[ab]	like very much
Cystoseira fucales	7.63±0.52[a]	8.00±0.71[a]	7.63±0.76[a]	7.63±0.53[a]	like very much
Turbinari adecurrens	7.87±0.52[a]	7.63±0.64[a]	8.00±0.92[ab]	7.75±0.71[ab]	like very much
	Cooked noodles				
Control	8.88±0.35[b]	8.13±0.64[a]	8.71±0.76[c]	8.71±0.75[b]	like very much
Spirulina platensis	7.63±0.92[a]	8.00±0.93[a]	7.86±0.64[b]	7.50±0.76[a]	Like Moderately
Cystoseira fucales	7.43±0.97[a]	7.71±0.95[a]	7.71±0.95[b]	7.57±0.79[a]	Like moderately
Turbinari adecurrens	7.00±0.82[a]	7.57±0.53[a]	6.17±0.95[a]	7.14±0.98[a]	Like moderately
	Indomie				
Control	8.88±0.35[a]	9.00±0.35[a]	8.88±0.35[a]	8.88±0.35[a]	Like very much
Spirulina platensis	8.75±0.64[a]	8.75±0.64[a]	8.88±0.35[a]	8.75±0.64[a]	Like very much
Cystoseira fucales	8.25±0.89[a]	8.50±0.76[a]	8.63±0.74[a]	8.50±0.75[a]	Like very much
Turbinari adecurrens	8.50±0.74[a]	8.50±0.74[a]	8.75±0.35[a]	8.63±0.46[a]	Like very much

Values are expressed as mean±standard deviation. Means in the same column with different letters were significantly different at $p < 0.05$.

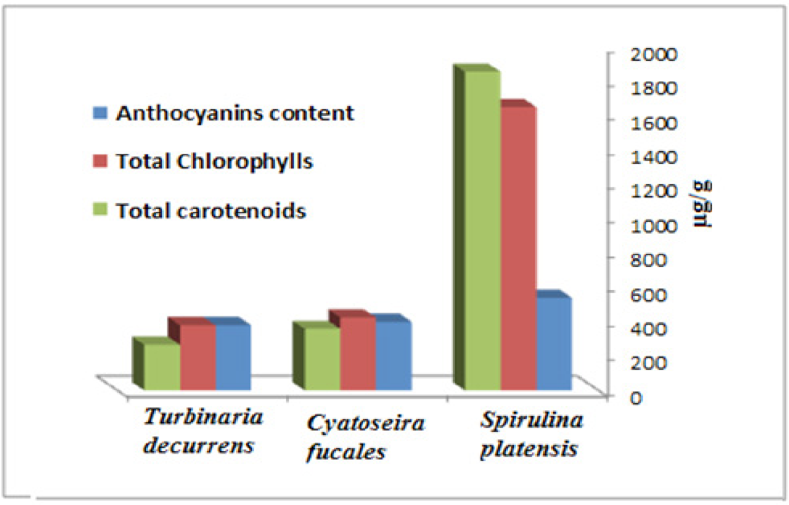

Fig. 2. Comparison between pigments content of *Spirulina platensis, Cystoseira fucales* and *Turbinari adecurrens*.

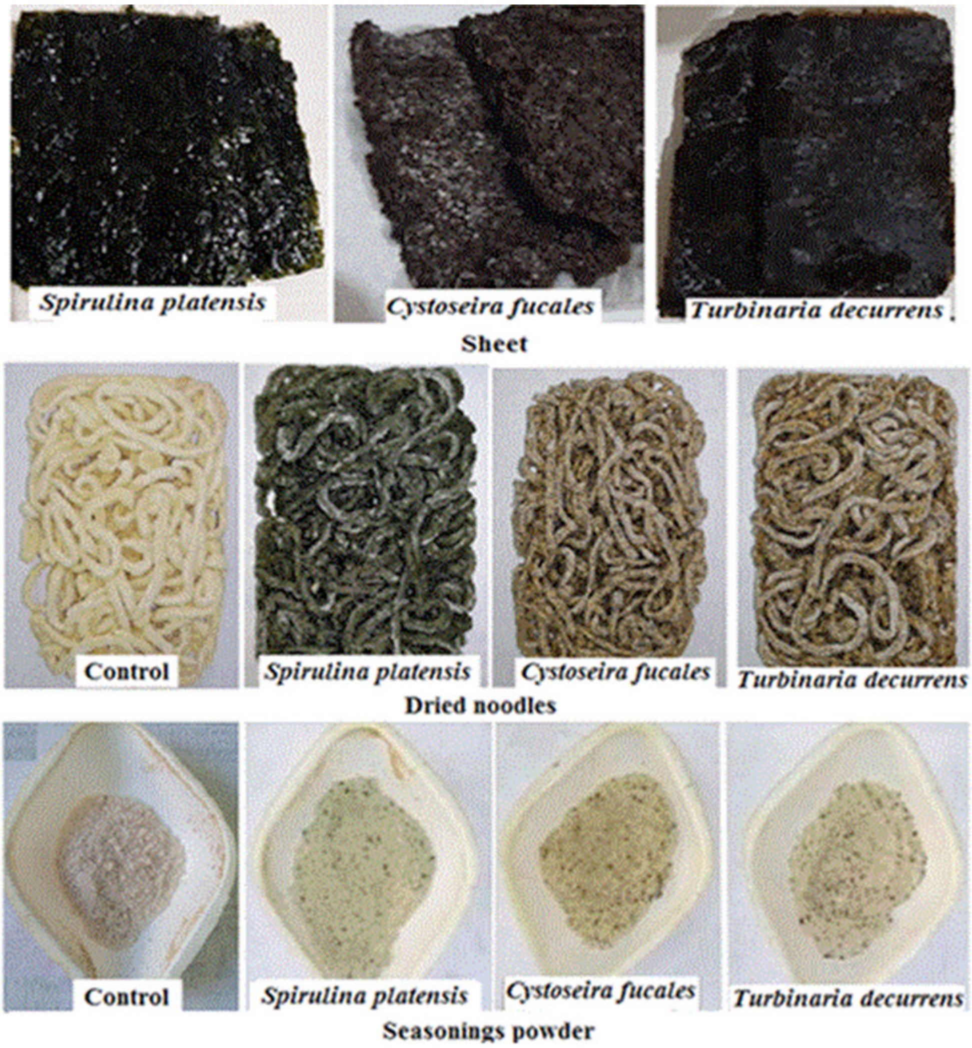

Fig. 3. General appearance of dried sheet, noodles, and seasonings powder prepared with *Spirulina platensis, Cystoseira fucales* and *Turbinari adecurrens*.

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تقييم الخواص الفيتوكيميائية والتغذوية لبعض الطحالب المزروعة في مصر كمكملات غذائية صحية

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هناك إهتمام بالمغذيات الطبيعية الوظيفية التي تتميز بخواصها العلاجية و إستخدامها فى إنتاج منتجات غذائيه صحية. تهدف هذه الدراسة إلى تقييم طحلب سبيرولينا بلاتنسيس (*S.platensis*) وتوربيناريا ديكورنس (*T.decurrens*) وسيستوزيرا فوكاليس (*C. fucales*) من خلال تقدير التركيب الكيماوى ومحتواها من المعادن و الخواص التغذوية مثل المركبات الفينولية الكلية والفيتامينات والصبغات وإمكانية الاستفادة منها في تحضير بعض المنتجات الوظيفية. أوضحت نتائج التحليل الكيماوى أن *S.platensis* مصدرًا جيد للبروتين (46.48٪) و للأحماض الأمينية الأساسية (424.02 ملجم/جم بروتين) بينما طحلب *T.decurrens* وطحلب *C. fucales* تحتوى على النسبة الأعلى فى الرماد والكربوهيدرات كما يمثل حمض الجلومتيك البروتينى أكبرنسبة فى الاحماض الامينية غير الأساسية. كذلك تعتبر الطحالب مصدراً جيداً البوتاسيوم والكالسيوم والصوديوم والحديد والزنك . كما أوضحت النتائج ان المركبات الفينولية الكليه فى مستخلصات الميثانول للطحالب تتراوح من 2 الى 14 ملجم حمض الجاليك /جم والتى أظهرت نشاط عالى للشقوق الحره (١٥,٦٦٪) فى مستخلص *S.platensis* بإستخدام DPPH). وكما تبين ان طحلب *S.platensis* يحتوى على اعلى كمية من فيتامين ج (13.30 مجم / 100 جم) وفيتامين هـ (145.10 مجم/100 جم) والكلوروفيل الكلى (1648.89 ميكروجرام/جرام) ،الكاروتينات الكلية (1854.49 ميكروجرام/جرام) والأنثوسيانين (0.540 ميكروغرام / جرام).وتميز طحلب *C. fucales* بإرتفاع محتواه من فيتامين أ و فيتامين د عن طحلب *T.decurrens* . كماأوضح التقييم الحسى للمنتجات المختلفة المصنعه من الطحالب " قبولاً من قبل المحكمين وحازت خاصية التقبل العام لكل من النودلز المجفف و مسحوق توابل الأندومى بصفة "مرغوب جدًا" بينما النودلز المطهى "قبولا معتدل". لذا يقترح إمكانية استخدام الطحالب كمصدر واعد للمركبات متعددة الوظائف في تحضير المنتجات الوظيفية.

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