Research Article

Microalgae *Dunaliella salina* for use as Food Supplement to Improve Pasta Quality

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ABSTRACT

The effect of mixing *Dunaliella salina* algae powder with semolina on pasta quality was studied. *D. salina* showed high contents of protein, fat and ash (22.42, 3.0 an 52.8%, respectively).Therefore, increasing mixing algae (1-3%) with semolina increased the nutritional value of pasta. *D. salina* is rich in minerals, where pasta of 3% algae contained calcium, iron, magnesium and potassium up to 66.60, 7.72, 23.80 and 100.34 mg/100g, respectively. *D. salina* revealed high amount of phytochemicals, where chlorophyll A, chlorophyll B and carotene contents reached to 7.676, 9.632 and 0.629 mg/g, respectively. Mixing 1% of algae with semolina increased chlorophyll A, chlorophyll B and carotene contents in pasta up to 1.183, 0.866 and 0.143 mg/g, respectively. In addition, the oil of *D. salina* contained appreciable amount of unsaturated fatty acids (17.51%). Rheological properties of mixed algae with semolina were studied. Farino graph parameters showed that, water absorption increased as the percentage of algae increased in semolina. Cooking quality of pasta showed that, the weight and volume of formulated pasta with *D. salina* (1-3%) increased as compared to control sample (pasta 100%semolina). Cooking loss of pasta also increased by increasing *D. salina* level. Hunter color parameters (L*, a* and b*) of pasta samples were evaluated. Results showed that, the color of pasta was darker by increasing the mixing level of algae. Moreover, sensory evaluation indicated that, mouth feel and overall acceptability of pasta fortified with 1 and 2% algae didn't significantly affected as compared to control sample, while flavor didn't significantly affected in pasta with 1% algae.

Keywords: *Dunaliella salina*, pasta quality, phytochemicals, rheological properties, sensory evaluation.

INTRODUCTION

Algae are the primary source of different nutrients. The high protein content in various species of algae is one of the main reasons to consider them as an unconventional source of proteins and oils. Because algae also represent an important source of vitamins, minerals, antioxidants and natural colorants, the incorporation of the whole biomass in food and feed could be used to provide the color, increment the nutritional value and improve the texture or resistance to oxidation. The incorporation of algae into the traditional food is a way to design healthy new products [1], as plant materials are a rich source of many compounds used in human medicine.[2, 3]

The possibility of using algal products rich in minerals and amino acids for increasing the nutritive value of bread was firstly examined by Medvedeva et al.[4] The goal of previous study was to assess the protein quality of baladi bread prepared from formulas containing added fish flour and green algae (*Scenedesmus obliquus*).[5]Dunaliellaalga was used as a protein supplement in white wheat pan bread.[6]Applications of dried blue green algal powders in bread-making were studied using species; *Oscillatoria amphibia* and *Spirulina platensis*. Studies with Spirulina added in different concentrations (2, 2.5, and 3% related to flour) were also made by other authors.[7]Increase in the proteins and minerals content was observed in the final bread product compared to the control bread, without Spirulina. In a recent study, Achouret al.[8] prepared enriched breads with 1 and 3% of dry biomass of local microalgae Spirulina. The enrichment with Spirulina has improved the nutritional quality (protein and ash) of bread. All enriched breads presented a good global acceptability.

Recent scientific studies have increasingly focused on gluten-free bread (GFB).[9-12]To increase the protein content of GFB, dried *S. platensis* micro alga was added to the products in the range of 2-5% (flour basis).[13] The addition of Spirulina to GFB resulted in products with improved nutritional quality, a significant increase in the protein content as well as in some essential amino acids (threonine, methionine, isoleucine and leucine) when compared to bread without the addition of the algae. Authors have also observed significant changes in the volume, texture and crumb color.

S.platensis is an exceptionally important edible blue-green alga in view of its high nutritional value and medicinal properties.[14, 15] Besides, Spirulina flour or its protein extract has interesting functional properties with respect to water retention, fat absorption, emulsification capacity and foaming capacity.[16]Nowadays, there is increasing consumer demand for more natural food products having healthy benefits. Microalgae are able to enhance the nutritional content of conventional food and hence, to positively affect on humans' health due to their original chemical composition. Therefore, the current work discusses the impact of *D. salina* algae addition on the cooking properties and sensory characteristics of the pasta products.

MATERIALS AND METHODS

Materials

Semolina was purchased from the North Cairo Flour Mills Company, Egypt. The green algae *D. salina* was obtained from Algal Biotechnology Unit, National Research Centre (NRC), Dokki, and Giza, Egypt.

Analytical methods

Moisture, ash, fat and protein contents of raw materials (Semolina and *D. salina*) and pasta samples were determined according to AACC.[17]Total carbohydrates were calculated by difference. Individual elements (Ca, P, K, Fe and Mn) in *D. salina* and pasta were determined according to the method described by Chapman and Pratt.[18]

Determination of fatty acids composition

Fatty acids composition was carried out according to the method of Senter et al.[19] Chromatography analysis was carried out using GLC apparatus (DANI 86.10) equipped with flame ionization detector. Fatty acids were separated on a capillary column coated with FFAP-TPA stationary phase (30 cm length; 0.32 mm internal diameter; 0.25 mm film thickness). Temperature programming of column started at 160 °C and reached to 220 °C with 2 °C/min increase. Temperature of the detector was set at 260°C. Methyl esters were identified by their retention time (RT) and expressed as percentage of total detected methyl esters.

Preparation of semolina and algal mixture

Semolina was well blended with algae powder to produce individual mixtures containing 0, 1, 2 and 3% algae. All samples were stored in airtight containers and kept at 5-7°C till use.

Rheological properties

Rheological properties of dough were evaluated using Farino graph (Brabender Farino graph model No. 178507) according to AACC.[17]

Color measurement

Hunter color parameter (L*, a* and b*) were measured using Hunter Lab. Scan XE-Reston VA, USA. The instrument was standardization against a White Tile of Hunter Lab Color Standard (LX No.16379): X= 77.26, Y= 81.94 and Z= 88.1 before each measurement. The color assessment system is based on the Hunter L*, a* and b* coordinates. L* was representing lightness and darkness, +a* redness, -a* greenness, + b* yellowness and - b* blueness.

Cooking quality of pasta

Cooking quality of pasta were carried out by measuring the increases in weight, volume and cooking loss after cooking according to the methods of AACC.[17]

Chlorophyll content

Chlorophyll a, chlorophyll b and carotenoids content were measured using spectrophotometer according to Yang et al.[20] Algae and lasagna pasta (0.25 g) were homogenized with 5 ml of 85 % aqueous acetone for 5 min, then centrifuged and the supernatant was made up to known volume with 85 % acetone. The absorbance was measured at 452.5, 644 and 663 nm.

Sensory evaluation

Sensory evaluation of cooked pasta was evaluated as described by Hussein et al.[21]

Texture profile analysis of pasta

Hardness, deformation at hardness, peak stress and fracture ability with 1% of load sensitivity analysis of cooked pasta samples was conducted using CT3 Texture Analyzer (Brookfield) according to Manual No. M08-372-C0113. Data were collected using Texture Pro CT Software.

RESULTS AND DISCUSSION

The gross chemicals of semolina, *D. salina* and pasta mixed with *D. salina*

The gross chemical composition of semolina, *D. salina* algae powder and the pasta of different mixing level with algae (1, 2 and 3%) were presented in Table (1). *D. salina* algae powder characterized with its high content of protein (22.42%), fat (3.00%) and ash (52.80%) compared to semolina which declined to 13.0, 1.05 and 0.95%, respectively. Therefore, increasing mixing level of algae (1-3%) with semolina led to increase the nutritional value of pasta where, protein, fat, ash and carbohydrate ranged between (13.35-13.60%), (1.11-1.18%), (1.15-2.10%) and (84.39-83.12%), respectively. It was also possible to observe that, the pasta of mixed *D. salina* with semolina showed some similarity with those found by several authors.[22-24]

The high difference between ash content in *D. salina* and semolina led to predict high difference between minerals content. Sodium, calcium, iron, zinc, magnesium and potassium were presented in Table (2). The obtained data showed that, all of these minerals increased in pasta according to increasing their level content from algae. Therefore, pasta of 3% algae could be used as a functional food product, where calcium, iron, magnesium and potassium reached to 66.60, 7.72, 23.80 and 100.34 mg/100g, respectively. These results agree with those reported by Osman et al.[25], Khalid et al. [26], Michalak and Chojnacka[27] and Oluwamukomi and Adeyemi.[28]

Table 1: Effect of mixing *D. salina* powder with semolina on chemical composition of pasta (dry weight basis)

Samples	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrates (%)
D. salina	5.16±0.22	22.42±0.76	3.00±0.11	52.81±1.65	21.77±0.35
Semolina	12.06±0.56	13.00±0.65	1.05±0.09	0.95±0.06	85.00±0.69
Pasta (100% semolina)	5.41±0.28	13.16±0.48	1.08±0.07	0.90±0.03	84.86±0.75
Pasta with1% *D. salina*	4.86±0.18	13.35±0.39	1.11±0.08	1.15±0.09	84.39±0.86
Pasta with 2% *D. salina*	4.65±0.16	13.45±0.52	1.15±0.03	1.65±0.11	83.75±0.82
Pasta with 3% *D. salina*	4.60±0.19	13.60±0.46	1.18±0.05	2.10±0.13	83.12±0.75

Results are expressed as mean± standard deviations (S.D.) on the dry weight basis

Table 2: Effect of mixing *D. salina* powder with semolina on minerals content of pasta (mg/100 gm)

Samples	Calcium	Iron	Zinc	Magnesium	Potassium	Sodium
D. salina	350±2.00	86.42±0.25	16.0±0.03	8.65±0.11	187±0.70	190±1.15
Semolina	55.06±0.65	5.51±0.05	0.72±0.02	22.0±0.13	93.44±0.75	85.12±0.65
Pasta (100% semolina)	58.18±0.77	5.7±0.02	0.82±0.05	23.50±0.19	95.27±0.82	88.0±0.62
Pasta with1% *D. salina*	62.5±0.82	6.52±0.03	0.91±0.01	23.65±0.10	97.59±0.76	90.12±0.77
Pasta with 2% *D. salina*	64.65±0.55	7.05±0.01	1.05±0.03	23.72±0.09	99.15±0.66	91.66±0.83
Pasta with 3% *D. salina*	66.60±0.60	7.72±0.03	1.13±0.01	23.80±0.15	100.34±0.58	93.0±0.79

Fatty acids composition

Fatty acids content of *D. salina* was evaluated and presented in Table (3). The obtained results showed that, algae contained 83.01% saturated fatty acids (SFA), 17.51% unsaturated fatty acids (USFA) consisting of 14.78% monounsaturated fatty acids and 2.73% of polyunsaturated fatty acids. The obtained proportion of SFA and USFA are similar to those reported by Hofmann and Eichenberger[29] and Osman et al.[25]Also, the results showed that, *D. salina* algae oil contained an appreciable amount of unsaturated fatty acids including, palmitoleic acid, linoleic acid, oleic acid, linolenic acid, erucic acid, arachidonic acid. It is worthy to mention that, monounsaturated fat consumption has been associated with decreased low-density lipoprotein (LDL) cholesterol and possibly increased high-density lipoprotein cholesterol (HDL-C).[30]

Table 3: Fatty acids content of *D. salina* oil

Fatty acids		Relative %
Tridecylic acid	C13:0	39.63
Myristic acid	C14:0	0.90
Pentadecylic acid	C15:0	2.30
Palmitic acid	C16:0	6.04
Margaric acid	C17:0	0.09
Stearic acid	C18:0	31.54
Behenic acid	C22:0	2.43
Arachidic acid	C20:0	0.08
Total saturated fatty acids %		83.01
Palmitoleic acid	C16:1	0.83
Oleic acid	C18:1	5.93
Arachidonic acid	C20:1	0.11
Erucic acid	C22:1	7.91

Total monounsaturated fatty acids %		14.78
Linoleic acid	C18:2	1.85
Linolenic acid	C18:3	0.88
Total polyunsaturated fatty acids %		2.73
Total unsaturated fatty acids %		17.51

Rheological properties

A rheological property of mixed dough with D. salina was evaluated at three mixing levels as shown in Table (4). Farino graph parameters showed that, water absorption was 57.5% in semolina, while it increased in semolina and algae mixture with increasing the percentage of algae. Algae powder could contribute to the high water-absorbing capacity as it competed for water with other constituents. This also could be due to, the hydroxyl groups in the hydrocolloid structure of algae which allow more water interactions through hydrogen bonding.[31, 32] The addition of *D. salina* powder decreased dough development time and dough stability time. Dough stability is a measure of the time needed for the curve to stay at or above 500 BU. The stability value is an indication of flour strength, with lower values suggesting weaker dough. Most commercial bread flours have a stability value up to 10 min.[33]The mixing tolerance index parameter represents the resistivity of wheat flour to the mixing, where higher mixing tolerance index values indicate stronger flour. According to the current findings, the addition of *D. salina* powder decreased dough strength.

Table 4: Effect of mixing *D. salina* powder with semolina on rheological properties of Farinograph

Samples	Water absorption (%)	Arrival time (min)	Dough development time(min)	Dough stability (min)	Mixing tolerance index (BU)	Dough weakening (BU)
100% semolina	57.5	6.5	10.5	11	25	55
1% *D. salina*	57.8	6.5	12.0	11.0	10	55
2% *D. salina*	58.5	6.0	10.0	10.0	40	60
3% *D. salina*	60.7	6.5	9.0	8.0	60	100

Color

Color is one of the most important sensory attribute that affect directly on the consumer preference of any product. Therefore, the color parameters (L*, a* and b*) of pasta samples were evaluated and presented in Table (5). Scale range of whiteness (L*) is from 0 black to 100 white; a* scale extends from a negative value (green hue) to a positive value (red hue) and b* scale from negative blue to positive yellow. Formulated pasta with algae (1-3%) was darker than pasta of control sample (100%) semolina, where lightness (L*) significantly decreased but yellowness (b*) significantly increased as level of algae increased. This result due to the fact that, algae contains pigments i.e. chlorophylls, carotenoids and phycobiliproteins. This fact explained the reduction in color parameter values.

Table 5: Effect of mixing *D. salina* algae powder with semolina on color parameter of pasta

Samples	L*	a*	b*
Pasta (100% semolina)	77.61a ±0.28	1.89±0.035	20.05d ±0.05
Pasta with1% *D. salina*	57.57 b ±1.02	-6.89±0.02	29.58c ±0.45
Pasta with 2% *D. salina*	51.17 c ±1.11	-7.19±0.09	31.18b ±0.82
Pasta with 3% *D. salina*	46.85 d ±0.92	-8.96±0.21	33.12a ±0.95
LSD at 0.05	1.501	NS	1.551

Cooking quality

Effect of mixing semolina with *D. salina* on cooking quality of pasta was evaluated at three mixing levels as shown in Table (6). The obtained data revealed that, the weight and volume (swelling %) of formulated pasta (1, 2 and 3%) increased as compared to control pasta (semolina 100%). This result could be due to, increase in protein level of algae led to increase weight of cooked pasta. Cooking loss of pasta (represent loss of solids in cooking water) increased as algae level increased. This result could due to, reinforced dough matrix of microalgae proteins and gluten which is able to entrap starch in the resulted network. It was also noticed that, the volume of pasta increased with the increase of *D. salina* level. Higher volume values of the samples in pasta with algae indicated that, they absorbed higher amounts of water during cooking. This might be due to, the addition of microalgae that increased proteins content.

Table 6: Effect of mixing *D. salina* powder with semolina on cooking quality of pasta

Samples	Weight increase (%)	Volume increase (%)	Cooking loss (%)
Pasta (100% semolina)	220±2.82d	165±4.42d	3.5±0.141d
Pasta with1% *D. salina*	230±3.00c	177±3.20c	4.00±0.112c
Pasta with 2% *D. salina*	245±4.32b	190±5.60b	4.6±0.182b
Pasta with 3% *D. salina*	265±5.33a	205±3.55a	4.9±0.124a
LSD at 0.05	10.771	11.223	0.353

Chlorophyll A, chlorophyll B and carotene

Table (7) showed that, *D. salina* algae contain high amounts of Chlorophyll A, chlorophyll B and carotene reached to 7.676, 9.632 and 0.629 mg/g, respectively. Therefore, mixing 1% algae with semolina increased chlorophyll A, chlorophyll B and carotene contents in pasta to 1.183, 0.866 and 0.143 mg/g, respectively, while they only decreased after cooking to 0.641, 0.342 and 0.0219 mg/g, respectively.

Table 7: Chlorophyll A, chlorophyll B and carotene contents of *D. salina*, uncooked and cooked pasta of 1% *D. salina* (mg/g)

Samples	Chlorophyll A	Chlorophyll B	Carotene
D. salina	7.676	9.632	0.629
Uncooked pasta of 1% *D. salina*	1.183	0.866	0.143
Cooked pasta of 1% *D. salina*	0.641	0.342	0.0219

Pasta of control sample (100% semolina) and pasta of formulated *D. salina* at three levels are clearly shown in Photos (1) and (2).

Control

1 %

2 %

3 %

Photo 1: Pasta before cooking for control sample (100% semolina) and pasta with 1, 2 and 3% *D. salina*

Control

1%

2 %

3 %

Photo 2: Pasta after cooking for control sample (100% semolina) and pasta with 1, 2 and 3% *D. salina*

Sensory properties

Effect of mixing *D. salina* at the same three levels with semolina was evaluated sensorial on pasta. Table (8) revealed that, pasta color significantly decreased in pasta of different algae mixing levels, this result is confirmed with the previous color parameter (L, a and b) where darkness was increased with increasing replacement of algae. But elasticity of control pasta did not significantly affected with increasing replacing levels of algae up to 3%. Mouth feel is one of the most important characteristics in pasta quality. The obtained sensorial results indicated that, mouth feel and overall acceptability of pasta fortified with 1 and 2% algae did not significantly affected compared to control sample, while flavor didn't significantly affected in pasta with 1% algae.

Table 8: Effect of mixing *D. salina* with semolina on sensory properties of pasta

Samples	Color (10)	Flavor (10)	Mouth feel (10)	Elasticity (10)	Overall acceptability (10)	Total (50)
Control	9.73a ±0.42	9.53a ±0.33	9.50a ±0.43	9.82a ± 0.62	9.62a ± 0.66	47.96a ± 1.32
Pasta (1% *D. salina*)	8.8b ± 0.37	9.03a ± 0.45	9.01a ± 0.52	9.50a ± 0.53	9.15a ± 0.52	46.19a ± 1.44
Pasta (2% *D. salina*)	7.59c ±0.35	8.51b ±0.37	8.80a ±0.55	9.33a ± 0.45	8.83a ± 0.61	43.93b± 1.49
Pasta (3% *D. salina*)	7.11c ±1.41	8.06b ±0.56	7.90b ±0.61	9.17a ± 0.68	8.14b ± 0.36	41.96b ±1.64
LSD at 0.05	0.8324	0.8632	0.9421	NS	0.8264	2.121

CONCLUSION

From the above results it can be concluded that, the addition of *D. salina* algae to pasta improved the cooking properties, sensory characteristics of the pasta products. Also, mixing *D. salina* with pasta improved the nutritional quality of pasta product. In addition, increasing level of algae with semolina to 3% pasta could be used as a functional food.

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