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Blue-green algae (*Arthrospira platensis*) as an ingredient in pasta: free radical scavenging activity, sensory and cooking characteristics evaluation

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Abstract
The effects of semolina enrichment with blue-green algae (*Arthrospira platensis*) at three different levels (1, 2 and 3 g/100 g of semolina) on the colour, cooking properties, firmness, free radical scavenging activity and sensory characteristics of pasta are reported. Microalgae addition resulted in higher swelling index and lower cooking loss than the control sample. A significant increase in pasta firmness was evidenced with an increase of added microalgae due to structural reinforcement. In addition to colouring, the use of *A. platensis* (2 g/100 g of semolina) can enhance the sensory quality and nutraceutical potential as evaluated by free radical scavenging activity of pasta.

Keywords: Arthrospira platensis*, pasta, colour, cooking quality, antioxidant*

Introduction

Arthrospira (*Spirulina*) *platensis* is an exceptionally important edible blue-green alga in view of its high nutritional value and medicinal properties (Gouveia et al. 2008; Gad et al. 2010). Besides, *Spirulina* flour or its protein extract has interesting functional properties with respect to water retention, fat absorption, emulsification capacity and foaming capacity (Anusuya Devi and Venkataraman 1984; Nirmala et al. 1992). 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 humans' health due to their original chemical composition. The current report discusses the impact of *A. platensis* addition on the cooking properties, firmness, sensory characteristics and free radical scavenging activity of the pasta products.

Materials and methods

Microalgae and physicochemical composition

Sun-dried microalgae (*A. platensis*) were purchased from a local microalgae industry (Algoprocess, Djerba, Tunisia). Dry matter, proteins, fat, total carbohydrates, soluble sugars and ash contents were determined as described by Dubois et al. (1956) and AOAC (1997).

Pasta processing and evaluation of its quality and antioxidant property

Pasta was prepared using a laboratory pasta machine (Simac PastaMatic™ 1400, Vittorio Veneto, Italy) to obtain a *tagliatelle*-shaped pasta (Figure 1). *A. platensis* (1, 2 or 3 g/100 g of semolina) was initially dry-mixed

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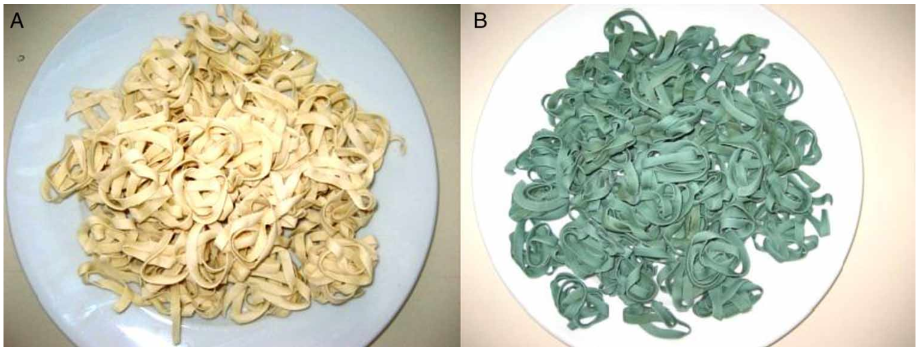

Figure 1. (A) Control (0 g microalgae/100 g of semolina) and (B) microalgae-enriched (2 g microalgae/100 g of semolina) pasta products.

with semolina to prepare pasta containing microalgae. Colour measurements of pasta samples were carried out before and after cooking using a Hunter Lab system with a colorimeter (Minolta CR-300, Minolta, Japan). Cooking loss (%, the amount of solid substance lost to cooking water) and swelling index (%, grams of water absorbed per gram of dry pasta) of different pasta samples were determined as described by Ajila et al. (2010). The firmness (*N*), which represents the force required for extrusion of pasta through a grid, of pasta was measured using a texturometer (Texture analyzer, Lloyd Instruments Ltd, West Sussex, UK). The organoleptic characteristics were evaluated by 35 panelists, who were asked to evaluate the products for firmness, taste and overall acceptability using a five-point hedonic scale ranging from 5 (like extremely) to 1 (dislike extremely) for each sensory characteristic. The DPPH radical scavenging activity in the ethanol extracts of cooked pasta was measured as described by Ajila et al. (2010). The percentage of DPPH radical scavenging activity was plotted against the amount of the sample (mg) before cooking. All analytical determinations were performed at least in duplicate. Values were expressed as the mean ± SD ($n = 3$). Multiple comparisons of the means were conducted using Tukey's test, and analysis of variance of the effect of microalgae level and cooking process on the pasta colour was analysed by a two-way ANOVA test.

Results and discussion

Table I presents mean values of a gross chemical composition of *A. platensis* used in the pasta formulations. These blue-green algae are exceptionally characterized by its high protein content (73.24 g/100 g of dry weight), which is one of the main reasons

Table I. Approximate composition of *A. platensis* (means ± SD).

Moisture	10.9 ± 0.10
Total carbohydrates*	4.68 ± 0.15
Soluble sugars*	0.91 ± 0.04
Proteins*	73.24 ± 0.62
Fat*	6.73 ± 0.60
Ash*	7.88 ± 0.05

*These have been taken in g/100 g of dry weight.

to consider them as an unconventional source of proteins (Soletto et al. 2005). Addition of *A. platensis* significantly increased the protein content of pasta products (Table II). In fact, protein content and gluten strength of semolina are important factors influencing pasta quality (Feillet and Dexter 1996).

Pasta formulated with *A. platensis* presented an accentuated green tonality (lower a^*; Table III). Microalgae are recognized as an excellent source of pigments such as chlorophylls, carotenoids and phycobiliproteins. This fact explained the reduction in colour parameter values. After cooking, all the pasta samples enriched with microalgae were slightly brighter (higher L^*) and more yellow (higher b^*), but the a^* index remained stable (Table III). Cooking process did not affect the a^* measurements ($p = 0.32$), suggesting that leaching and/or degradation of colour pigments were limited. *A. platensis* is, therefore, efficient in colouring pastas.

Our results indicated that the loss due to cooking of pasta decreased with the increase in *A. platensis* level (Table II). The lowest cooking loss observed can be explained by the reinforced dough matrix of microalgae proteins and gluten, which is able to entrap starch in the resulted network. We also noticed that the swelling index of pasta increased with increase in blue-green algae level (Table II). Higher swelling index values of the samples enriched with microalgae indicated that they absorbed higher amounts of water during cooking. This might be due to the addition of microalgae proteins. In fact, *A. platensis* biomass possesses an important water holding capacity (373.7 ± 21 g/100 g of microalgae; unpublished data). Firmness of pastas containing *A. platensis* appeared to be higher than that of the control pasta, which can be related to the embedding of gelatinizing starch granules in a mixed 3D network of gluten and microalgal proteins. Sensory evaluation relative to the pasta firmness was in concordance with the instrumental firmness analysis (Table II). Higher taste and overall acceptability scores were also observed in the pasta fortified with microalgae as than the control. It can be said that *A. platensis* could be incorporated up to 2 g/100 g of semolina in the formulation of pasta with improving its sensory quality (Table II). Interestingly, the retained

Table II. Protein content, cooking characteristics, firmness and sensory evaluation scores of microalgae-enriched pasta preparations.

Level of microalgae addition (g/100 g of semolina)	Protein content (g/100 g of dry weight)	Cooking loss (%)	Swelling index (%)	Firmness (*N*)	Sensory analysis: Firmness	Sensory analysis: Taste	Sensory analysis: Overall acceptability
0 (control)	13.1 ± 0.09[a]	9.76 ± 0.05[a]	110.45 ± 0.12[a]	555.02 ± 8.1[a]	2.9 ± 0.35[a]	2.6 ± 0.25[a]	2.4 ± 0.35[a]
1	14 ± 0.1[b]	9.7 ± 0.065[a]	122.38 ± 0.98[b]	576.9 ± 7.9[a]	3.3 ± 0.35[ab]	2.9 ± 0.35[a]	3.1 ± 0.25[bc]
2	14.7 ± 0.13[c]	9.35 ± 0.043[b]	130.82 ± 3.9[bc]	610 ± 8.5[b]	3.5 ± 0.40[ab]	3.6 ± 0.40[b]	3.6 ± 0.40[c]
3	15.3 ± 0.14[d]	9.0 ± 0.042[c]	138.09 ± 6.79[c]	733.5 ± 19.8[c]	3.8 ± 0.50[b]	3.0 ± 0.40[a]	3.1 ± 0.35[bc]

Notes: Control was made without microalgae addition. Dry pasta (100 g) was cooked in 1 l of boiling water (100°C) for a period of 4 min. Different letters in the same column indicate statistical differences ($p < 0.05$).

Table III. Effects of microalgae level and cooking process on the colour characteristic of pasta preparations.

Level of microalgae addition (g/100 g of semolina)	L^* Dried	L^* Cooked	a^* Dried	a^* Cooked	b^* Dried	b^* Cooked
0 (control)	78.08 ± 1.44	84.58 ± 0.36	−1.17 ± 0.05	−2.13 ± 0.2	13.68 ± 0.52	17.85 ± 0.81
1	63.08 ± 1.0	65.6 ± 0.25	−9.28 ± 0.05	−9.04 ± 0.05	3.78 ± 0.05	10.36 ± 0.25
2	56.40 ± 0.9	58.97 ± 0.16	−10.32 ± 0.2	−10.07 ± 0.05	2.27 ± 0.05	8.28 ± 0.50
3	52.97 ± 0.36	56.6 ± 0.36	−11.12 ± 0.3	−10.9 ± 0.06	2.02 ± 0.05	9.12 ± 0.36

Notes: L^*, a^* and b^* represent bright, red and yellow indexes, respectively. Control was made without microalgae addition.

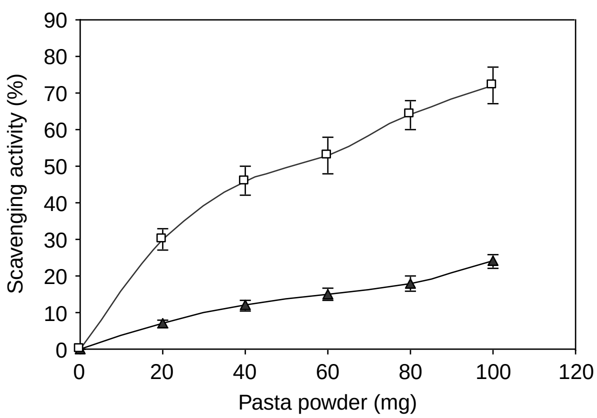

Figure 2. DPPH radical scavenging activity of control (▲) and microalgae-enriched (2 g microalgae/100 g of semolina) cooked pasta (□).

product (2 g microalgae/100 g of semolina) showed an increase in the free radical scavenging activity as compared with the control (Figure 2). This is may be attributed to the *A. platensis* presenting interesting free radical scavenging activity due to its higher content of vitamin E, carotenoids, chlorophyll and phycobiliproteins, which are able to decrease DPPH radicals by their hydrogen-donating ability (Gad et al. 2010). Although pasta processing and cooking, *A. platensis* enriched semolina enhance the nutraceutical property by increasing the antioxidant activity of pasta product.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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