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ScienceDirect
Food Chemistry 101 (2007) 1707–1713
Food Chemistry
www.elsevier.com/locate/foodchem

Studies on use of *Enteromorpha* in snack food

B.S. Mamatha [a], K.K. Namitha [b], Amudha Senthil [a,*], J. Smitha [c], G.A. Ravishankar [b]

[a] *Department of Sensory Science, Central Food Technological Research Institute, Mysore 570 020, Karnataka, India*
[b] *Department of Plant Cell Biotechnology, Central Food Technological Research Institute, Mysore 570 020, Karnataka, India*
[c] *Department of Biochemistry and Nutrition, Central Food Technological Research Institute, Mysore 570 020, Karnataka, India*

Received 16 February 2006; received in revised form 22 March 2006; accepted 24 April 2006

Abstract

Seaweeds, also known as sea vegetables, are of nutritional interest, as they are rich in vitamins, minerals and dietary fiber. *Enteromorpha compressa* (Linnaeus), green seaweed (*chlorophyta*), which is a rich source of iron and dietary fibre was used as an ingredient in the preparation of *Pakoda*, a common traditional snack food in India. *Pakoda* samples showed increases in ash, protein and total dietary fibre contents with increase in *Enteromorpha* level, accompanied by a nearly fivefold increase in iron content (26.4–126 mg/100 g) and fourfold increase in calcium content (30.1–124 mg/100 g). Bioavailability of iron in *Enteromorpha*, and *Pakoda* containing 7.5% of *Enteromorpha*, did not show any difference (55–56%) at pH 7.5 (intestinal condition). But, at pH 1.35 (gastric condition) the bioavailability of iron in *Pakoda* containing *Enteromorpha* was found to be slightly higher (27.1%) than that in *Enteromorpha*. Reducing power (155–222 μg/g) increased as the *Enteromorpha* level increased from 0% to 15%. But the addition of *Enteromorpha* was found to decrease free radical-scavenging activity and the total phenol content. *Pakoda* containing up to 7.5% of *Enteromorpha* was found to have a sensory quality comparable with that of *Pakoda* without *Enteromorpha*.

Keywords: *Enteromorpha*; Nutrient content; Bioavailability; *Pakoda*; Sensory profile

1. Introduction

Algae are classified as unicellular microalgae and macroalgae, which are macroscopic plants of marine benthoses (Darcy-Vrillon, 1993). Macroalgae, also known as seaweed, are distinguished according to the nature of their pigments: brown seaweed (*phaeophyta*), red seaweed (*rhodophyta*) and green seaweed (*chlorophyta*). In Asian countries, several species of seaweed are used as human food, to provide nutrition and a characteristic taste. Fresh dried seaweed is extensively consumed, especially by people living in coastal areas. They are of nutritional interest as they are low calorie foods but rich in vitamins, minerals and dietary fibre (Jensen, 1993; Noda, 1993; Oohusa, 1993).

The chemical composition of seaweeds varies with species, habitats, maturity and environmental conditions (Ito & Hori, 1989). Seaweed polysaccharides, considered as a good source of dietary fibre cannot be entirely digested by human intestinal enzymes (Urbano & Goni, 2002). The physical properties of polysaccharides in green seaweed are closer to those of land plant leaves than to other classes of seaweeds (Ito & Hori, 1989). *Enteromorpha* is a green seaweed (*chlorophyta*) containing chlorophyll *b* and minerals, such as calcium, magnesium and iron. It has been shown that edible *chlorophyta* species have 16–22.1% of protein, 12.4–18.7% of ash and 43.4–60.2% of carbohydrate as percentage of dry matter. It is reported that seaweed composition could interfere with bioavailability of dietary components (Urbano & Goni, 2002). Edible seaweeds are rich in a wide variety of minerals but they are also rich in other components, such as dietary fibre and resistant protein, which may pass through the intestine without being absorbed and can retain dietary mineral components.

* Corresponding author. Tel.: +91 821 2515842; fax: +91 821 2517233.
E-mail address: amudhasen12@yahoo.com (A. Senthil).

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doi:10.1016/j.foodchem.2006.04.032

Apart from their nutritional quality, the seaweeds are reported to have free radical-scavenging activity. Methanol extract was reported to have high antioxidative activity. Nishibori and Namiki (1988) had identified pheophytin as a major antioxidant in *Enteromorpha*.

In the Far-Eastern countries, various kinds of seaweeds are used in the preparations of foods, such as Nori, prepared by making thin sheets of crushed *Porphyra* species and *Kombu* made from dried *Laminaria*. Seaweed *Undaria* is processed into either a dried or a boiled and salted product, known as *Wakame* (Watanabe & Nishizawa, 1984). *Enteromorpha* species are commonly processed to obtain dried green lavers. These lavers are lightly roasted, crushed and used as topping or coating on other foods or in soups. They are also available in powder form for similar uses. However, in India use of *Enteromorpha* as a food is very limited and also there is no report on the use of *Enteromorpha* as a food ingredient. In the present study, *Enteromorpha* was used as an ingredient in the preparation of a high fibre snack, namely *Pakoda*, a common Indian product made from chickpea flour.

2. Materials and methods

2.1. Materials

Enteromorpha compressa L. was received from the Central Salt and Marine Chemical Research Institute (CSMCRI), Bhavnagar (India). The sample was washed with water and dried at 60–65 °C in a cross-flow drier and ground to a coarse powder in a multimill. Other ingredients, namely chickpea flour, rice flour, onion, refined vegetable oil, mint, spice mix, green chilly and table salt, were purchased from the local market.

2.2. Functional properties of Enteromorpha powder

Water-holding capacity (WHC), oil holding capacity (OHC), swelling capacity (SWC) and soluble solids (SS) of the *Enteromorpha* powder were assessed in duplicate, according to the standard methods (Ruperez, Fulgencio, & Saura-Calixto, 2001).

2.3. Product (Pakoda) preparation

Pakoda preparation comprises the following steps: chickpea flour (55 parts) is mixed with chopped onion (40 parts) and 5 parts of rice flour. Small quantities of green chillies, mint leaves, spice mixture and common salt were added to provide a desirable flavour. Hot oil (10 parts) was added to this mixture, followed by addition of the required quantity of water.

All the ingredients are manually mixed in a bowl to obtain a thick batter. The batter was formed manually into a ball (around 1.5 cm dia) shape and deep fat-fried at 175 ± 2 °C. Frying was continued to the development of golden brown colour.

2.4. Incorporation of Enteromorpha

Chickpea flour in the *Pakoda* formulation was replaced with *Enteromorpha* powder at levels of 5%, 7.5%, 10%, 12.5% and 15%. *Pakoda* was made with a proportion of other ingredients, using the method described above.

2.5. Chemical composition

Enteromorpha and *Pakoda* samples were analysed for moisture, fat and ash contents according to AOAC (1984) methods. Protein was estimated by the micro-Kjeldahl method (AACC, 2000) and percentage of protein was calculated by using a 6.25 conversion factor. Crude fibre was estimated by the BIS (1978) method. The carbohydrate content was calculated by difference. Dietary fibre was estimated according to the AOAC method (1984). All the analyses were done in duplicate and the mean values reported on a dry weight basis.

Iron and calcium contents of samples were estimated according to the AOAC method (1984). Determinations of mineral elements (iron and calcium) in samples were carried out by dry ashing in a muffle furnace maintained at 525 °C after dissolving in 1 N HCl. The final diluted solution for calcium contained 1% (w/v) lanthanum to overcome interferences. The concentrations of the elements were determined by an atomic absorption spectrophotometer and the values were obtained from a calibration curve of the standard elements.

2.6. Bioavailability of iron

In vitro bioavailability of iron in *Enteromorpha* and *Pakodas* containing *Enteromorpha* was determined according to the procedure of Narasinga Rao and Prabhavathi (1978) at pH 1.35 and 7.5, incubating the samples for 60 min. The reading was taken in a Shimadzu UV–Vis spectrophotometer at 510 nm.

2.7. Vitamin analysis

Vitamins A and E were estimated according to AOAC methods (2000 and 1993).

2.8. Reducing power

The reducing power of the extracts was determined according to the method of Oyaizu (1986). About 1 g of powder sample was extracted in 10 ml of boiling water (w/v) or methanol and centrifuged at 3000*g* for 15 min at room temperature and the supernatants were designated as water and methanol extracts, respectively. Extracts (0–10 mg) in phosphate buffer (2.5 ml, 0.2 M, pH 6.6) were added to potassium ferricyanide (2.5 ml, 10 mg/ml), and the mixture was incubated at 50 °C for 20 min. TCA (2.5 ml, 100 mg/ml) was added to the mixture and centrifuged at 650 g for 10 min. The supernatant (2.5 ml) was

mixed with distilled water (2.5 ml) and ferric chloride (0.5 ml, 1.0 mg/ml), and then the absorbance was read spectrophotometrically at 700 nm. Higher absorbance of the reaction mixture indicated greater reducing powers.

2.9. Determination of effect on DPPH (α,α-diphenyl-β-picryl hydrazyl) radical

The effect of extract (water and methanol extract) on DPPH radical was estimated according to the method of Hatano, Kagawa, Yasuhara, and Okuda (1988). The extract was added to a methanolic solution (0.5 ml) of DPPH radical (final concentration of DPPH was 0.2 mM). The mixture was shaken vigorously and left standing at room temperature for 30 min; the absorbance of the resulting solution was then measured spectrophotometrically at 517 nm. The tests were run in duplicate and analyses of all samples were run in triplicate and averaged.

2.10. Determination of total phenols

The phenol content was determined according to the method of AOAC (1984) and results were expressed as gallic acid equivalents. Samples (0.1 ml) were mixed with 1 ml of twofold-diluted Folin–Ciocalteu's reagent and 2 ml of 10% sodium carbonate solution. The absorbance was measured at 765 nm with a spectrophotometer after incubating for 30 min at room temperature.

2.11. Sensory evaluation

Samples of *Pakoda*, with and without *Enteromorpha*, were subjected to preliminary sensory evaluation to generate descriptors of sensory attributes. A trained panel was familiarized with the quality attributes and descriptors in the training sessions. Based on the preliminary trials, a scorecard suitable for quantitative descriptive analysis (QDA) was developed. The scorecard consisted of selected sensory attributes of *Pakoda* and, against each attribute, a 15-cm scale was given that was anchored at 1.25 and 13.75 cm for low and high intensities of sensory notes, respectively. The panellists were served with three digit-coded samples and were asked to mark the intensities of perceived samples. The panellists were also asked to indicate the overall quality of the product, on an intensity scale which was anchored at very poor, fair and very good to assess the liking (preference) of *Pakoda*.

2.12. Data analysis

The mean scores of individual attributes were calculated and a profilogram was drawn. Significant differences between sensory attributes were determined by Duncan's multiple range test (DMRT) at $p \leqslant 0.05$ (Duncan, 1955).

3. Results and discussion

3.1. Functional properties

Results of the functional properties of *Enteromorpha* powder and chickpea flour are given in Table 1. Higher water-holding capacity (WHC) (10.44 ± 0.17 g/g) and swelling capacity (SWC) (4.0 ± 0.4 ml/g) in *Enteromorpha* are due to water bound to the hydrophilic polysaccharide, and water held within the fibre matrix or trapped within the cell wall lumen. Water binding sites on the protein molecules are also known to influence WHC and SWC (Wong & Cheung, 2000) Because of its capacity to bind water, *Enteromorpha* can be used as a functional ingredient to reduce calories and to modify the texture of the formulated product (Wong & Cheung, 2000). OHC is another important functional property that influences the sensory quality of formulated foods. High OHC of *Enteromorpha* powder (4.29 ± 0.05 g/g) is reported to be related to the particle size, overall charge density and hydrophilic nature of the individual particles (Fleury & Lahaye, 1991). While preparing *Pakoda*, with and without *Enteromorpha*, the quantities of water and oil added to the batter were kept constant. In the absence of added *Enteromorpha*, the batter had homogeneity and could be easily shaped by hand. With the addition of *Enteromorpha*, the consistency of batter changed significantly, resulting in a non-homogeneous batter; this was more pronounced with the increase in *Enteromorpha* content. Differences between *Enteromorpha* and chickpea flour, with regard to WHC and OHC, were shown to influence the batter characteristics. It is seen that WHC and OHC of chickpea flour (1.25 ± 0.24 and 1.96 ± 0.01 g/g) were lower than those of *Enteromorpha*. The non-homogenity of batter containing *Enteromorpha* could be due to its higher absorption of water and oil.

3.2. Chemical composition of Enteromorpha and Pakoda samples

The proximate composition of *Enteromorpha* powder are as follows (dry weight basis): total protein, 21.0%; ash, 18.6%; crude fibre, 1.3%; fat, 0.3%; moisture, 10%; carbohydrate by difference, 48.2%. These values are similar to those reported by Lahaye (1991). Total dietary fibre content was found to be 45.3% which is considerably higher than the value (33.4%) given by Lahaye (1991).

Table 1
Functional properties of *Enteromorpha* and chickpea flour

	WHC[a] (g/g)	OHC[b] (g/g)	SS[c] (%)	SWC[d] (ml/g)
Enteromorpha	10.44 ± 0.17	4.29 ± 0.05	3.80 ± 0.18	4.00 ± 0.14
Chickpea flour	1.25 ± 0.24	1.96 ± 0.01	0.11 ± 0.00	0.20 ± 0.00

Mean values of duplicate determinations ± standard deviation.
[a] Water-holding capacity.
[b] Oil holding capacity.
[c] Soluble solids.
[d] Swelling capacity.

Variations in batter consistency were observed to have some effect on moisture and fat content of fried *Pakoda* (Table 2). The less homogeneous batter containing *Enteromorpha* tended to lose more moisture on frying, as shown by the significantly lower moisture content, even in *Pakoda* containing 5% *Enteromorpha*. But the fat content did not show any such trend and was seen to be in the range of 16.7–19.9%. Dietary fibre content in the *Pakoda* samples was markedly increased by the addition of *Enteromorpha*, and ranged from 30% to 37%. Protein content was also shown to increase with the addition of *Enteromorpha*, ranging from 15.6% to 20%. Considering its proximate composition, *Pakoda* made with *Enteromorpha* can be regarded as a high fibre fried snack, having moderate fat content and fairly high protein content.

Iron and calcium contents of *Enteromorpha* were 277 mg/100 g and 312 mg/100 g, respectively. *Pakoda* had low contents of iron and calcium, which increased to significantly higher levels upon the addition of *Enteromorpha* (Table 2). A 10% addition was found to increase the iron content of *Pakoda* from 26.4 to 117 mg/100 g and the calcium content from 30.1 to 91.3 mg/100 g.

3.3. Bioavailability of iron

Bioavailability of Iron in *Enteromorpha*, under gastric conditions, was found to be low but it was 55.8% under Intestinal conditions (Table 3). Similarly, the soluble iron content was higher under intestinal conditions. With the addition of 7.5% of *Enteromorpha Pakoda*, the iron bioavailability under gastric conditions was found to increase from 22.6% to 27.1% and soluble iron content increased from 2.16% to 11.3%. Bioavailability, under intestinal conditions, was not significantly altered by the addition of *Enteromorpha*.

3.4. Vitamin content

The fat-soluble vitamin contents of *Enteromorpha* and *Pakoda* containing different levels of *Enteromorpha* are given in Table 4. *Enteromorpha* showed a vitamin A content of 0.870 mg/100 g, which is much lower than the values reported for other seaweeds, such as *Undaria pinnatifida* (140–810 mg/100 g), and *Ulva* Spp. (600–1500 mg/100 g) (Darcy-Vrillon, 1993) Vitamin E content of *Enteromorpha* was found to be 23.9 mg/100 g. Seaweed was reported to have a higher variable vitamin E content and it has been reported that green, red and sublittoral brown seaweed are rather poor in vitamin E (Ito & Hori, 1989).

Table 3
Bioavailability of iron in *Enteromorpha* and *Pakoda*

Percentage of *Enteromorpha* in *Pakoda*	pH 1.35		pH 7.5	
	Ionizable (%)	Soluble (%)	Ionizable (%)	Soluble (%)
0	22.6	2.16	56.9	5.68
7.5	27.1	11.3	55.1	6.13
Enteromorpha powder	14.9	9.23	55.8	20.3

Table 4
Vitamin content of *Enteromorpha* and *Pakoda* containing different levels of *Enteromorpha*

Vitamin (mg%)	*Enteromorpha* powder	*Pakoda* containing *Enteromorpha*					
		0%	5%	7.5%	10%	12.5%	15%
A	0.870	0.02	0.02	0.05	0.11	0.12	0.18
E	23.9	0.13	0.11	0.22	0.21	0.27	0.73

Vitamin A and E contents of *Pakoda* were 0.02 and 0.13 mg/100 g, respectively. As these vitamins are present at higher levels in*Enteromorpha*, *Pakoda* prepared with added *Enteromorpha* had increased levels of vitamins A and E. Use of *Enteromorpha* at the 15% level increased vitamin A and E contents of *Pakoda* to 0.18 and 0.73 mg/100 g, respectively.

3.5. Antioxidant activity of Enteromorpha and product containing Enteromorpha

Reducing power of *Enteromorpha* and *Pakoda*, containing 0–15% *Enteromorpha*, was determined and is depicted in Table 5. Results showed dose-dependent increase in the activity. Despite decrease in the concentration of

Table 2
Chemical composition of *Pakoda*

Percentage of *Enteromorpha* in *Pakoda*	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Crude fibre (%)	Carbohydrate by difference (%)	Iron content (mg/100 g)	Calcium content (mg/100 g)
0	12.8 ± 0.10	19.9 ± 0.13	6.5 ± 0.02	14.2 ± 0.10	2.5 ± 0.06	44.1	26.4 ± 0.12	30.1 ± 0.34
5	7.5 ± 0.14	18.5 ± 0.00	6.9 ± 0.04	15.6 ± 0.18	2.9 ± 0.02	48.6	38.6 ± 0.22	61.6 ± 0.89
7.5	6.5 ± 0.16	16.7 ± 0.08	7.7 ± 0.03	17.5 ± 0.08	3.0 ± 0.05	48.6	99.6 ± 0.09	71.0 ± 0.48
10	5.5 ± 0.14	17.2 ± 0.06	8.6 ± 0.07	18.5 ± 0.16	3.2 ± 0.02	47.0	116.7 ± 0.86	91.3 ± 0.71
12.5	5.7 ± 0.17	16.7 ± 0.07	8.7 ± 0.05	18.8 ± 0.07	3.5 ± 0.06	46.6	114 ± 0.43	95.2 ± 0.76
15	4.2 ± 0.02	17.1 ± 0.01	8.8 ± 0.03	20.0 ± 0.00	4.1 ± 0.04	45.8	126 ± 0.71	124 ± 0.94

Values are on dry basis for fat, ash, protein and crude fibre.
Results are means ± standard deviation for two determinations.
Carbohydrate content is calculated by difference.

Table 5
Reducing power of *Enteromorpha* and *Pakoda* containing *Enteromorpha*

Percentage of *Enteromorpha* in *Pakoda*	Reducing power (μg/g)
0	155
5	152
7.5	200
10	207
12.5	211
15	222
Enteromorpha powder	5.54

Pakoda base from 100% to 85%, a 1.6-fold increase in the observed activity may be attributed to increase in the concentration of *Enteromorpha* from 5% to 15%. Although *Enteromorpha* had very low reducing power, its addition was seen to result in a dose-dependent increase in the reducing power of *Pakoda*. Probably, this is due to interaction between *Enteromorpha* and *Pakoda* base. On the other hand, with the increase in the concentration of *Enteromorpha*, free radical- scavenging activity showed variations that are not consistent with the percentage of added *Enteromorpha* (Table 6). Water extracts and methanol extracts did not show any pattern in their free radical-scavenging activities. In general, the free radical-scavenging activity was higher in the methanol extract. In their work on the antioxidant activity of seaweed Nakayama, Tamura, Kikuzaki, and Nakatani (1999) reported a higher antioxidant activity of methanol extract than of the water extract. Table 7 gives the phenolic acid content of the *Pakoda* samples. Gallic acid and protocatechic acid contents decreased with the addition of *Enteromorpha*. *p*-Coumaric acid and ferulic acid were not present in the water extract or the methanol extract of *Enteromorpha*. Ferulic acid content of *Pakoda* was found to vary with the addition of *Enteromorpha*; the methanol extract did not contain ferulic acid.

It has been reported that the reducing power of seaweed methanol extracts might be related to their phenolic hydroxyl groups (Ragan & Glombitza, 1986). However, in the present study, we could not establish any relationship between antioxidant activity and phenolic content of *Enteromorpha*. The observed enhanced reducing power, is possibly due to non-phenolic compounds.

Table 6
Free radical scavenging activity of *Pakoda* samples

Percentage of *Enteromorpha* in *Pakoda*	H_2O extract IC_{50} in μg (phenol content)	Methanol extract IC_{50} in μg (phenol content)
0	4.9	12.2
5	5.43	13.6
7.5	3.88	13.0
10	4.5	16.1
12.5	3.3	16.5
15	3.5	15.3

Table 7
Determination of phenolic content (mg) in *Enteromorpha* and *Pakoda* containing *Enteromorpha*

Samples	Gallic acid	Protocatechic acid	*p*-Coumaric acid	Ferulic acid
H_2O extract (%)				
Enteromorpha	0.032	NF	NF	NF
0	0.615	0.016	0.0049	0.005
5	0.580	0.0055	0.005	0.019
15	0.430	0.0045	0.0035	0.0035
Methanol extract (%)				
Enteromorpha	0.023	0.0025	NF	NF
0	0.515	NF	0.002	NF
5	0.175	0.0145	NF	NF
15	0.092	0.013	NF	NF

NF, not found.

3.6. Sensory analysis of Pakoda

Preliminary sensory evaluation revealed that the addition of *Enteromorpha*, at levels of 12.5% or more,

Table 8
Sensory quality of *Pakoda*

Attributes	Percentage of *Enteromorpha* in *Pakoda* 0%	5%	7.5%	10%
Colour				
Brownish	6.07 ± 1.37^{a}	9.70 ± 1.68^{b}	10.4 ± 1.14^{b}	10.9 ± 0.94^{b}
Texture				
Crisp	7.55 ± 2.00^{a}	9.99 ± 0.61^{b}	$9.47 \pm 1.36b^{c}$	11.3 ± 4.34^{c}
Gritty	5.83 ± 1.39^{a}	7.00 ± 1.53^{ab}	7.88 ± 1.23^{bc}	8.97 ± 3.37^{c}
Flavour				
Grassy	3.96 ± 1.13^{a}	6.97 ± 1.54^{b}	7.61 ± 1.96^{b}	7.58 ± 2.20^{b}
Pulse like	7.71 ± 1.39^{b}	5.00 ± 1.77^{a}	6.03 ± 1.74^{ab}	5.32 ± 1.88^{a}
Spicy	7.48 ± 1.35^{a}	7.81 ± 1.32^{a}	7.81 ± 1.32^{a}	7.41 ± 1.97^{a}
Bitter	3.50 ± 0.50^{a}	3.73 ± 0.52^{a}	3.80 ± 1.07^{a}	3.80 ± 0.20^{a}
After taste	0.47 ± 0.05^{a}	0.75 ± 0.04^{b}	0.96 ± 0.05^{b}	1.76 ± 0.21^{b}
Overall Quality	9.87 ± 1.18^{b}	9.61 ± 0.38^{b}	9.50 ± 1.07^{b}	8.10 ± 1.39^{a}

Mean values with different superscripts differ significantly at $p \leqslant 0.05$ by DMRT.

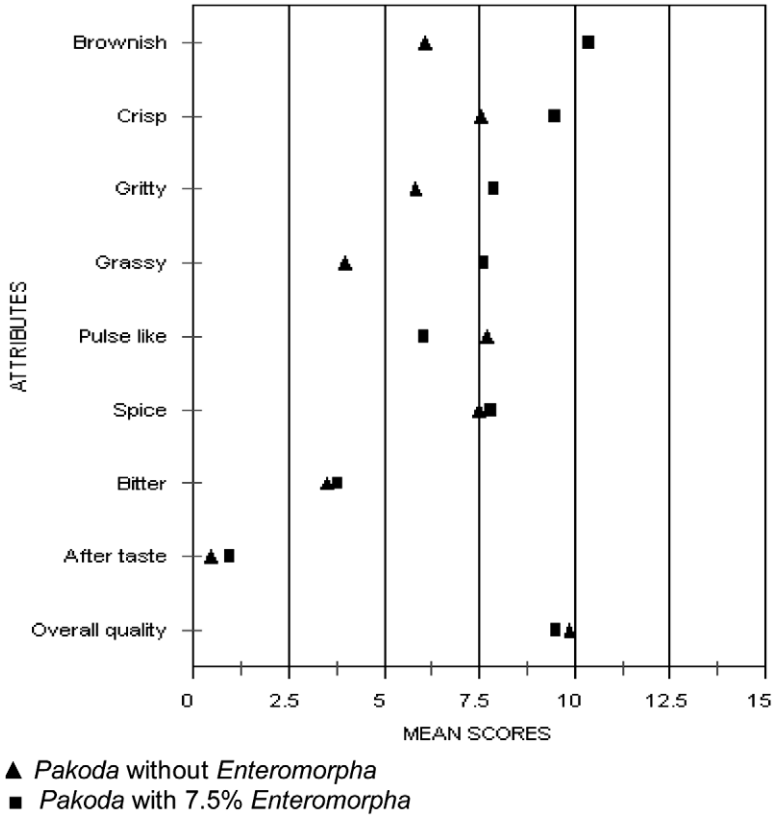

Fig. 1. Profilogram of *Pakoda* containing 7.5% of *Enteromorpha* powder.

imparted a distinct and undesirable grassy aroma to *Pakoda*. Therefore, further trials were confined to preparation of *Pakoda* containing up to 10% of *Enteromorpha*, and the results of sensory analysis are given in Table 8. Colour and appearance were significantly affected by the addition of *Enteromorpha*; the product became more brownish and had higher scores for grittiness and crisp texture. Since the addition of water during dough making was kept constant, the dough containing *Enteromorpha* was less homogeneous and could not be shaped with ease. Changes in dough consistency resulted in crisper and grittier *Pakoda*. Panellists perceived a grassy flavour, which was attributed to the characteristic flavour of *Enteromorpha*. Even at the lowest level of addition (5%), the sensory score for grassy note was as high as 6.97. The dominance of grassy flavour was found to suppress the pulse-like aroma that is characteristic of *Pakoda*. However, the grassy aroma did not significantly influence the overall quality or the acceptability of the product. This could be partly due to the dominance of spicy aroma, the intensity of which was unaffected by the presence of *Enteromorpha* in the product. Aftertaste was perceived to some extent but sensory scores were too low to have any impact on the product quality. Samples containing 5% and 7.5% *Enteromorpha* had the overall quality scores of 9.61 ± 0.38 and 9.50 ± 1.07, respectively, which are comparable with that of the control sample (9.87 ± 1.18). At 10% addition, the overall quality was significantly ($p \leqslant 0.05$) lowered (8.10 ± 1.39) (Fig. 1).

4. Conclusion

Enteromorpha can be used to enhance the nutritional quality of common Indian snack foods, such as *Pakoda*. Addition of *Enteromorpha* results in higher iron and calcium contents and significant increases in dietary fibre, protein and vitamin contents. Reducing power was found to increase with the addition of *Enteromorpha*. *Pakoda* containing *Enteromorpha* up to 7.5% was sensorily acceptable.

Acknowledgements

Authors thank Dr. P.V. Subbarao for supplying the seaweed and express heartfelt gratitude to Dr. V. Prakash, Director, Central Food Technological Research Institute (CFTRI), Mysore, for providing necessary facilities to carry out the above work. Also, sincere thanks go to Dr. Shylaja Dharmesh, Scientist, Biochemistry and Nutrition Department and Mr. K.K. Bhat, Head, Sensory Science Department, for their valuable suggestions and constant encouragement. We also thank Mr. R. Ravi for his assistance in statistical analysis. The authors gratefully acknowledge the Department of Biotechnology, Govt of India for providing funds for the project.

References

Association of Official Analytical Chemists. (1984). *Official method of Analysis* (14th ed.). Washington, DC, USA.

American Association of Cereal Chemists. (2000). *Approve methods of AACC*, method 46-13, (10th ed.). St. Paul, Minnesota, USA.

Association of Official Analytical Chemists. (2000). AOAC, 2000, 992.04, *Official method of analysis* (14th ed.). Washington, DC, USA.

Association of Official Analytical Chemists. (1993). Official method of Analysis, vol. 76 (14th ed.). Washington, DC, USA, p. 399.

Bureau of Indian standards (BIS). (1978). IS: 2639-1984, Appendix-H, pg-11.

Darcy-Vrillon, B. (1993). Nutritional aspect of the developing use of marine macroalgae for the human foods industry. *International Journal of Food Science and Nutrition, 44*, S23–S35.

Duncan, D. B. (1955). Multiple range and multiple *F*-test. *Biometrics, 11*, 1–42.

Fleury, N., & Lahaye, M. (1991). Chemical and physico-chemical characterization of fibers from *Laminaria digitata*. *Journal of Science Food Agriculture, 55*, 389–400.

Hatano, T., Kagawa, H., Yasuhara, T., & Okuda, T. (1988). Two new flavnoids and other constituents in licorice root: their relative astringency and radical scavenging effect. *Chemical and Pharmacological Bulletin, 36*, 2090–2097.

Ito, K., & Hori, K. (1989). Seaweed; chemical composition and potential food uses. *Food Review International, 5*(1), 101–144.

Jensen, A. (1993). Present and future needs for alga and algal products. *Hydrobiology, 260/261*, 15–21.

Lahaye, M. (1991). Marine algal as a source of dietary fiber: determination of soluble and insoluble and insoluble dietary fiber contents in some ''sea vegetable''. *Journal of Science of Food Agriculture, 54*, 587–594.

Nakayama, R., Tamura, Y., Kikuzaki, H., & Nakatani, N. (1999). Antioxidant effect of the constituents of susabinori (*Porphyra yezoensis*). *Journal of Oil Chemist Society, 76*(5), 649–653.

Narasinga Rao, B. S., & Prabhavathi, T. (1978). An in vitro method for predicting the bioavailability of iron from foods. *American Journal of Clinical sNutrition, 31*, 169–175.

Nishibori, S., & Namiki, K. (1988). Antoxidative substance in green fractions of the lipids of *Aonori* (*Enteromorpha* Spp.). *Journal of Home Economics, Japan, 39*, 1173–1178.

Noda, H. (1993). Health benefits and nutritional properties of Nori. *Journal of Applied Phycology, 5*, 255–258.

Oohusa, T. (1993). Recent trend in Nori products and market in Asia. *Journal of Applied Phycology, 5*, 155–159.

Oyaizu, M. (1986). Studies on products of product of browning reaction: antioxidative activity of product of browning reaction prepared from glucosamine. *Japnese Journal of Nutrition, 44*, 307–315.

Ragan, M. A., & Glombitza, K. W. (1986). *Phlorotannins brown algal polyphenols in progress in phycological research* (pp. 130–132). London: Round-chapman, Biopress.

Ruperez, P., Fulgencio, A., & Saura-Calixto, F. (2001). Dietary fiber and physicochemical properties of edible Spanish seaweeds. *European Food Research Technology, 212*, 349–354.

Urbano, M. G., & Goni, I. (2002). Bioavailability of nutrient in rats fed on edible seaweed, Nori (*Porphyra tenera*) Wakame (*Undaria pinnatifida*), as a source of dietary fiber. *Food Chemistry, 76*, 281–286.

Watanabe, T., & Nishizawa, K. (1984). The utilization of wakame (*Undaria pinnatifida*) in Japan and manufacture of ''*haiboshi wakame*'' and some of its biochemical and physical proerties. *Hydrobiologia, 116/117*, 106.

Wong, K. H., & Cheung, P. C. K. (2000). Nutritional evaluation of some subtropical red and green seaweed. Part 1 – Proximate composition; amino acid profile and some physico chemical properties. *Food Chemistry, 71*, 475–482.