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Chemical composition, antioxidant activity and sensory evaluation of five different species of brown edible seaweeds

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ABSTRACT

The chemical and volatile composition as well as sensory profile of five brown edible seaweeds collected in the United Kingdom, was evaluated. The ash content was 190–280 mg/g, NaCl 35.1–115.1 mg/g, protein 2.9–6.0 g/g, and fat 0.6–5.8 g/g (dry basis). *Fucus vesiculosus*, *Fucus spiralis* and *Ascophyllum nodosum* showed higher antioxidant activities (DPPH and FRAP). Nucleotide concentrations were of the same order of magnitude as reported in other foods such as tomatoes or potatoes, except for *F. vesiculosus* where levels of nucleotides were 10 times higher. The fatty acids profile was dominated by oleic acid (21.9–41.45%), followed by myristic (6.63–26.75%) and palmitic (9.23–16.91%). Glutamic and aspartic acids (0.15–1.8 mg/g and 0.05–3.1 mg/g) were the most abundant amino acids. Finally, sensory and volatile analyses illustrated that *Laminaria sp.* had the strongest seaweed and seafood-like aroma and taste.

1. Introduction

Due to their low content of lipid, high concentration of polysaccharides, natural richness in minerals, polyunsaturated fatty acids and vitamins as well as their high content of bioactive molecules, marine algae have, in recent years, received great attention (Gupta & Abu-Ghannam, 2011a,b). Algae are grouped into two main categories; the microalgae, found in both benthic and littoral habitats and also throughout the ocean waters as phytoplankton, and the macroalgae or seaweeds, which occupy the littoral zone, and can be classified as red (*Rhodophyta*), brown (*Phaeophyta*) or green (*Chlorophyta*), depending on their nutrient and chemical composition (Dawczynski, Schubert, & Jahreis, 2007; Gupta & Abu-Ghannam, 2011a).

Red and brown algae are mainly used, within the traditional Japanese diet as sushi wrappings, seasonings, condiments and vegetables and can thus constitute between 10% and 25% of food intake of most Japanese people. Although the principal uses of seaweeds in Europe are as a source of phycocolloids (thickening and gelling agents) for various industrial applications, including uses in foods or as feed and fertiliser (Ortiz, Bozzo, Navarrete, Osorio, & Rios, 2006; Yaich et al., 2011), consumption of seaweed products has recently increased with currently, approximately 15–20 edible algae species being commonly marketed for consumption. These seaweed varieties differ greatly in their quality, colour, consistency, and nutrient content (Dawczynski et al., 2007; Mišurcová, 2011; Mišurcová, Ambrožová, et al., 2011; Mišurcová, Machů, et al., 2011). Different authors have pointed out that the chemical composition of seaweeds varies with species, habitats, maturity and environmental conditions (Ortiz et al., 2006; Sanchez-Machado, Lopez-Cervantes, & Lopez-Hernandez, 2004).

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The European seaweed industry is dominated by Norwegian, French and Irish production, while Spain, Portugal and the UK are small producers and suppliers. Particularly, in the UK, the market for seaweed (therapeutic, biotechnology, bio-fuel seaweeds based, or foods) is mostly imported, whereas there is abundance of growing seaweeds around the islands, with some local producers already harvesting them for commercial purposes. Particularly, in the coast of Scotland there are dozens of different kinds of edible seaweed, being the red seaweed dulse (*Palmaria palmata*), as well as the brown seaweeds: kelp (*Laminaria sp.*) and different wracks (*Fucus sp*., *Ascophyllum nodosum*, *Pelvetia canaliculata*) the most generally harvested (due to their abundance and accessibility).

The use of brown seaweeds, as ingredient or as a whole food, has already been reported by numerous authors to be beneficial in different aspects. For instance, as an alternative source of protein, with some brown species having higher protein content than soybeans. Their fat content accounts for 1 to 6 g/100 g dry weight with some varieties, as *Laminaria sp.* generally between 1.5 and 3.3% of dry weight (Fleurence, Gutbier, Mabeau, & Leray, 1994), and some of these species are also characterised by a high level of eicosapentaenoic acid (up to 24% of the total fatty acid fraction) (Fleurence, 2004). Antioxidants are also other important metabolites in brown seaweeds including fucoxanthin, polyphloroglucinol, phenolic compounds or bromophenols, that have been isolated from species such as *Fucus* and *Laminaria* (Fleurence et al., 2012; Gupta & Abu-Ghannam, 2011b; Xu, Fan, et al., 2004; Xu, Song, et al., 2004).

In addition, there are recent projections in the functional effects of seaweeds as means to improve the fibre content and reduce the salt content of food products. This is mainly due to their high content in umami compounds such as nucleotides or some amino acids. The aim of this study was to characterise five different brown edible seaweeds locally produced on the west coast of Scotland (Isle of Bute), UK, in terms of chemical composition as well as sensory and volatile analyses; this information might be useful to evaluate their use as food ingredients and their potential contribution to the diet.

2. Material and methods

2.1. Raw material

Five different species of brown seaweed (*Laminaria digitata*, *Ascophyllum nodosum*, *P. canaliculata*, *Fucus vesiculosus*, *and Fucus spiralis*), were obtained from the same supplier and harvested between May and August 2012 in the west coast of Scotland, United Kingdom. The samples were then freeze-dried and separated into two different batches depending on the harvesting time; seaweeds collected in May and June (batch 1), and those collected in July and August (batch 2). Samples were milled in a mechanical grinder for 10 min, to obtain a fine and homogeneous powder before performing the analyses.

2.2. Chemical analyses

All the chemical analyses were carried out in triplicate on the homogeneous powder.

2.2.1. Dry matter, ash and NaCl content

The dry matter, ash and sodium chloride content were ascertained according to the Association of Official Analytical Chemists (AOAC, 2000).

2.2.2. Protein

Total protein was determined by the Kjeldahl method. The protein was calculated using a nitrogen conversion factor of 6.25 (Ortiz et al., 2006; Yaich et al., 2011). Data were expressed as percentage of dry weight.

2.2.3. Extractable fat

The extractable fat was determined using the Soxhlet extraction method with petroleum ether 40:60 as solvent. (AOAC, 2000).

2.2.4. Fatty acids

The fatty acid composition was analysed by GC-FID after transesterification to methyl esters (FAMEs) with a mixture BF_3 methanol at 20 °C according to the IUPAC standard method (IUPAC, 1992; Yaich et al., 2011).

Fat (10 mg), hexane (0.2 mL) and BF_3 (0.5 mL) were heated at 70 °C for 1.5 h. After transesterification, saturated salt solution (0.5 mL, 25% NaCl), H_2SO_4 (0.2 mL, 10%) and hexane (7 mL) were added to the reaction medium. Analysis of FAMEs was carried out with a Hewlett Packard 6890 GC equipped with an auto sampler, an Agilent 6890 Network FID and an Agilent DB-23 (60 m × 0.25 mm, 0.25 μm) capillary column. The oven temperature was programmed from 90 °C to 240 °C at 4 °C/min and the injector and detector temperatures were set at 250 °C. The carrier gas was helium at 1.0 mL/min constant flow (split ratio 10:1). The software used for data acquisition and processing is 6890N. Data analysis identification and quantification of FAMEs was accomplished by comparing the retention times of the peaks with those of pure standards (Supelco® 37 Component FAME Mix, Sigma) and analysed under the same conditions. The results were expressed as percentage of individual fatty acids in the lipid fraction.

2.2.5. Antioxidants

Seaweed powder (0.1 g) was mixed with 2.5 mL ethanol (95%), vortexed for 30 s and stored at −20 °C overnight. The sample was centrifuged for 10 min at 2000 ×*g* at room temperature under dark conditions and the supernatant was used for analysis.

The radical scavenging activity (DPPH), was determined following the modified protocol of Brand-Williams, Cuvelier, and Berset (1995). Sample (10 μL) and deionized H_2O (90 μL) were added in a 96-well microtiter plate and the reaction started by adding 200 μL of freshly prepared DPPH solution (0.024 g/L DPPH). The absorbance was measured at 515 nm every 4 min for 32 min in total, when the absorbance value remained constant.

The reducing power of the samples (FRAP), was determined by the modified protocol described by Benzie & Szeto (1999) and Bub et al. (2000), in a 96-well microtiter plate, following a similar procedure as for DPPH. In this case the reaction was started by adding pre-warmed FRAP reagent (200 μL, 37 °C), the absorbance was determined at a wavelength of 593 nm and the reaction time was 8 min at 37 °C.

Finally, the total phenolic content (TPC) was determined following the modified protocol of the microplate Folin–Ciocalteu assay (Magalhães, Santos, Segundo, Reis, & Lima, 2010). Samples (50 μL, [1:10 v/v]) were added to Na_2CO_3 solution (100 μL, 6% [w/v]). The reaction was started by adding the Folin–Ciocalteu solution (50 μL, [1:25 v/v]), and the absorbance determined at 725 nm every 5 min for a total of 30 min, when the absorbance value remained constant.

For the DPPH and FRAP assay calibration curves of Trolox (0–1000 mM) were prepared and results were expressed as the number of equivalents of Trolox (mmol eq of Trolox/g dry weight). Gallic acid (0–1000 mM) was used for TPC and results expressed as the number of equivalents of gallic acid (mmol eq of gallic acid/g dry weight of seaweed powder).

2.2.6. Nucleotides

Nucleotides were extracted using water and hydrochloric acid following centrifugation based on a modified version of the protocol by Oruña-Concha, Methven, Blumenthal, Young, and Mottram (2007). Freeze-dried samples (0.3 g) were weighed into 15 mL screw-top vials; distilled water (5 mL) and hydrochloric acid (5 mL, 0.01 N, HCl) were added followed by stirring at 90 °C for 90 min. The mixture was allowed to stand for another 20 min and aliquots of the supernatant (1.5 mL) were centrifuged at 8500 ×*g* for 15 min.