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Amino acids, fatty acids, and dietary fibre in edible seaweed products

Christine Dawczynski, Rainer Schubert, Gerhard Jahreis *

Friedrich Schiller University of Jena, Institute of Nutrition, Dornburger Strasse 24, D-07743 Jena, Germany

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Abstract

The nutritional compositions of 34 edible seaweed products of the *Laminaria* sp., *Undaria pinnatifida*, *Hizikia fusiforme* and *Porphyra* sp. varieties were analyzed.

This study determined amino acid and fatty acid (FA) distributions and contents of protein, fat, and total fibre of these seaweed varieties. In general, the marine macroalgae varieties tested demonstrated low lipid contents with 2.3 ± 1.6 g/100 g semi-dry sample weight (s.w.) and proved to be a rich source of dietary fibre (46.2 ± 8.0 g/100 g s.w). The pure protein content of seaweed products varied widely (26.6 ± 6.3 g/100 g s.w. in red algae varieties and 12.9 ± 6.2 g/100 g s.w. in brown algae varieties). All essential amino acids were detected in the seaweed species tested and red algae species featured uniquely high concentrations of taurine when compared to brown algae varieties. Interestingly, the FA distribution of seaweed products showed high levels of n-3 FA and demonstrated a nutritionally ideal n-6/n-3 FA ratio. The predominante FA in various seaweed products was eicosapentaenoic acid (C20:5, n-3) which was at concentrations as high as 50% of total FA content.

Keywords: Edible seaweed; Fat; Protein; Fatty acids; Amino acids; Dietary fibre

1. Introduction

Commercially available varieties of marine macroalgae are commonly referred to as ‘‘seaweeds’’. Macroalgae can be classified as red algae (Rhodophyta), brown algae (Phaeophyta) or green algae (Chlorophyta), depending on their nutrient and chemical composition. Red and brown algae are mainly used as human food sources.

The protein content of seaweed varieties varies greatly and demonstrates a dependence on such factors as season and environmental growth conditions. For example, the protein content of brown algae species, e.g., *Laminaria japonica*, *Hizikia fusiforme* or *Undaria pinnatifida*, is relatively low with 7–16 g/100 g dry weight (d.w.) (Jurković, Kolb, & Colić, 1995; Kolb, Vallorani, & Stocchi, 1999; Rupérez & Saura-Calixto, 2001). In contrast, red algae, e.g., *Palmaria palmata* (Dulse) and *Porphyra tenera* contain 21–47 g protein/100 g d.w. (Fleurence, 1999; Rupérez & Saura-Calixto, 2001).

Abbreviations: AA, amino acids; AAS, amino acid score; Ala, alanine; ALA, α-linolenic acid; Arame, Eisenia bicyclis; Arg, arginine; Asp, aspartic acid; Cys, cysteine; d.w., dry weight; Dulse, *Palmaria palmata*; EAA, essential amino acids; EAAI, essential amino acid index; essential AA/non-essential AA, EAA/NEAA; EPA, eicosapentaenoic acid; FA, fatty acids; FAO, Food and Agriculture Organization of the United Nations; FAME, fatty acid methyl esters; Glu, glutamic acid; Gly, glycine; Hijiki, *Hizikia fusiforme*; Ile, isoleucine; *Konbu*, *Laminaria* sp.; LA, linoleic acid; LCFA, long-chain fatty acids; LC-PUFA, long-chain polyunsaturated fatty acids; Leu, leucine; Lys, lysine; MCFA, middle-chain fatty acids; Met, methionine; MUFA, monounsaturated fatty acids; N, nitrogen; Nori, *Porphyra* sp.; NPN, non-protein nitrogen; Phe, phenylalanine; P- Ser, phosphoserine; PUFA, polyunsaturated fatty acids; SCFA, short-chain fatty acids; SD, standard deviation; SDA, stearidonic acid; SFA, saturated fatty acids; semi-dry sample weight, s.w.; Tau, taurine; Thr, threonine; Trp, tryptophan; Val, valine; Wakame, *Undaria pinnatifida*; WHO, World Health Organization.

* Corresponding author. Tel.: +49 3641 949 610; fax: +49 3641 949 612. *E-mail address:* Gerhard.Jahreis@uni-jena.de (G. Jahreis).

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The protein in algae contains all essential amino acids (EAA) and all EAA are available throughout the year although seasonal variations in their concentrations are known to occur (Galland-Irmouli et al., 1999). For example, the proportion of EAA is 45–49% in *Hizikia* sp. and *Eisenia bicyclis* (Arame). In both these brown algae varieties, Trp is the first limiting EAA, followed by Lys (Kolb et al., 1999). The EAA contents of some species (e.g., *Porphyra* sp.) can be compared with those of soy and egg protein (Fleurence, 1999; Galland-Irmouli et al., 1999). In addition, high concentrations of Arg, Asp and Glu are found in many seaweed species (Fleurence, 1999).

The fat content of marine macroalgae accounts for 1–6 g/100 g d.w. (Fleurence, Gutbier, Mabeau, & Leray, 1994; Jurković et al., 1995; Herbreteau, Coiffard, Derrien, & De Roeck-Holtzhauer, 1997). In some brown algae varieties, such as *Hizikia* sp. and Arame, only 0.7–0.9 g/100 g d.w. of fat content were found (Kolb et al., 1999).

Red algae (e.g., *Porphyra* sp.) have high concentrations of eicosapentaenoic acid (C20:5, n-3, EPA), with 48.0–51.0% of total FAME, and marginal concentrations of arachidonic acid (C20:4, n-6), with 2.1–10.9% of total FAME and, linoleic acid (C18:2, n-6, LA), with 1.3–2.5% of total FAME (Fleurence et al., 1994; Takagi, Asahi, & Itabashi, 1985). In contrast, brown algae (e.g., *Laminaria* sp., *Undaria* sp., *Hizikia* sp.) have high concentrations of oleic acid (C18:1, n-9) with 4.1–20.9% of total FAME, LA with 4.0–7.3% of total FAME as well as α-linolenic acid (C18:3, n-3, ALA) with 3.6–13.8% of total FAME but low concentrations of EPA with 5.9–13.6% of total FAME (Fleurence et al., 1994; Takagi et al., 1985). Interestingly, in *Porphyra* sp., *Laminaria* sp., and *Undaria* sp., the concentrations of docosahexaenoic acid (C22:6, n-3, DHA) and docosapentaenoic acid (C22:5, n-3) were below the detection limit (less than 0.1% of total FAME) (Fleurence et al., 1994; Takagi et al., 1985).

The types and abundance of carbohydrates vary strongly between algae species. Typical carbohydrates in red algae varieties consist of floridean starch (α-1.4-binding glucan), cellulose, xylan, and mannan. The water-soluble fibre fraction is formed by sulfur-containing galactans, e.g., agar and carrageen (Jiménez-Escrig & Sánchez-Muniz, 2000; Van den Hoek, Jahns, & Mann, 1993). The typical carbohydrates in brown algae varieties consist of fucoidan, laminaran (β-1.3-glucan), cellulose, alginates, and mannitol. Brown algae fibres are mainly cellulose and insoluble alginates. Alginates are Ca, Mg, or Na salts of alginic acid (1.4-linked polymer of β-D-mannuronic acid and α-L-guluronic acid). The amorphous, slimy fraction of brown algae fibres consists mainly of water-soluble alginates and/or fucoidan. Main reserve polysaccharides of Phaeophyta are laminaran (β-1.3-glucan) and mannitol (Kolb et al., 1999; Van den Hoek et al., 1993). The typical algae carbohydrates are not digestible by the human gastrointestinal tract and, therefore, they are dietary fibres. The content of total dietary fibre ranges from 33–50 g/100 g d.w. (Jiménez-Escrig & Cambrodon, 1999; Lahaye, 1991; Rupérez & Saura-Calixto, 2001). Accordingly, the fibre content of seaweed varieties is higher than those found in most fruits and vegetables. The human consumption of algal fibre has been proven to be health-promoting and it benefits are well documented in the scientific literature. The consumption of this dietary fibre has been related to the following health promoting effects: (1) its consumption promotes the growth and protection of the beneficial intestinal flora (Fujii, Kuda, Saheki, & Okuzumi, 1992; Goni, Guidel-Urbano, Bravo, & Saura-Calixto, 2001; Kuda, Yokoyama, & Fujii, 1997; Kuda, Goto, Yokoyama, & Fujii, 1998a, Kuda, Goto, Yokoyama, & Fujii, 1998b), (2) its consumption, in combination with high glycemic load foods, reduces the overall glycemic response, seaweed fibre acts as a hypoglycaemic (Goni, Valdivieso, & Garcia-Alonso, 2000), (3) its consumption greatly increases stool volume (Jiménez-Escrig & Sánchez-Muniz, 2000) and (4) its consumption reduces the risk of colon cancer (Guidel-Urbano & Goni, 2002).

In addition, seaweed varieties are rich sources of vitamin C, vitamin B-complex, e.g., folic acid and B12, and vitamin A precursors, such as β-carotene (McDermid & Stuercke, 2003; Takenaka et al., 2001; Watanabe et al., 1999, Watanabe, Takenaka, Kittaka-Katsura, Ebara, & Miyamoto, 2002; Yamada, Yamada, Fukuda, & Yamada, 1999; Yon & Hyun, 2003).

Because seaweed species are rich in beneficial nutrients, in countries such as China, Japan, and Korea, they have been commonly utilised in human alimentation (since ancient times) (Lahaye, 1991). For example, Japanese people consume more than 1.6 kg algae (d.w.) per year *per capita* (Fleurence, 1999). In addition to their importance as traditional Asian foods, seaweed species are utilised industrially as a source of hydrocolloids, such as agar, carrageen, and alginate (Jiménez-Escrig & Sánchez-Muniz, 2000).

Over the past few decades, the consumption of seaweed products has increased in European countries. Currently, approximately 15–20 edible algae strains are being commonly marketed for consumption in Europe. These seaweed varieties differ greatly in their quality, colour, consistency, and nutrient content. Therefore, this investigation evaluates and compares the nutrient and chemical contents of 34 commercially available seaweed products which were locally purchased in German food stores and speciality shops.

2. Materials and methods

2.1. Samples

Thirty four dried macroalgae were analysed, which are classified as 17 brown algae (Phaeophyta) and 17 red algae (Rhodophyta). The brown algae samples were dried and consisted of eight *Laminaria* sp. (Konbu), seven *Undaria pinnatifida* (Wakame), and two *Hizikia fusiforme* (Hijiki) products. The brown algae varieties originate from China,