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Chemical and nutritional characteristics of brown seaweed lipids: A review

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ABSTRACT

Several brown seaweeds show high total lipids (TL) contents, ranging from 10 to 20 wt.% per dry weight. The main lipid class is glycoglycerolipids (GL), which are rich in 18:4n−3, 20:5n−3 and 20:4n−6. Brown seaweed TL also contains fucoxanthin as a key functional compound. Despite the high levels of 18:4n−3, 20:5n−3 and 20:4n−6, brown seaweed lipids are stable to oxidation. Their high oxidative stability is partly related to the presence of these polyunsaturated fatty acids in their GL forms. Brown seaweed lipids show anti-obesity and anti-diabetic effects, which are mainly due to the up-regulatory effect of fucoxanthin on energy expenditure in abdominal white adipose tissue and glucose utilization in muscle.

Contents

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1. Introduction

Algae can be divided into two groups, macro-algae (seaweeds) and micro-algae. Seaweeds are photosynthetic-like plants that form basic biomass in intertidal zones. There are approximately 9000 seaweed species, which are broadly classified into three main groups based on their pigmentation: brown (*Phaeophyta*), red (*Rhodophyta*) and green (*Chlorophyta*) seaweeds. As seaweeds lack many of the distinct organs found in terrestrial plants, whole parts are available as a biomass source. Recently, much attention has been paid to seaweeds as effective biomass sources because of their high carbon dioxide absorption rate relative to those of terrestrial plants. Therefore, seaweeds have been explored as sources of food, medicine, cosmetics, fertilizer, feed and bio-energy (Jang, Shirai, Uchida, & Wakisaka, 2012; Khan et al. 2009; Pangestuti and Kim, 2011).

The most abundant food component of seaweeds is non-starch polysaccharides, such as carrageenan and alginate (Holdt & Kraan, 2011). These substances are not degraded by mammalian enzymes; thus, seaweeds can be regarded as fiber-rich materials (Wong & Cheung, 2003). Seaweeds also biosynthesize fucose-containing sulfated polysaccharides, such as fucoidan, which has been reported to possess a variety of biological activities (Damonte, Matulewicz, & Cerezo, 2004; Jiao, Yu, Zhang, & Ewart, 2011). The quality of seaweed protein is acceptable compared to other diet vegetables, mainly due to its high content of essential amino acids (Fleurence, 1999). Much concern about seaweeds antioxidants has been given to polyphenols, especially, phlorotannins, which are the largest group of polyphenols in brown seaweeds (Kang, Heo, Kim, Lee, & Jeon, 2012b; Kang et al., 2004, 2012a; Nakai, Kageyama, Nakahara, & Miki, 2006; Pangestuti & Kim, 2011; Shibata, Ishimaru, Kawaguchi, Yoshikawa, & Hama, 2008). Recently, seaweed lipids have drawn increased interest due to their several health benefits (Miyashita et al., 2011).

Although seaweeds have significantly lower lipid contents than marine fish, they are still a potential source of functional lipids due to their large stock in coastal waters. While the lipid content in oily fish has been reported to be approximately 20 wt.% per dry weight (DW), occasionally reaching 50 wt.% per DW, seaweeds may contain up to 1–5 wt.% total lipids (TL) per DW (Arao & Yamada, 1989; Bhaskar, Hosokawa, & Miyashita, 2004a; Bhaskar & Miyashita, 2005; Li, Fan, Han, & Lou, 2002; Terasaki et al., 2009; Vaskovsky, Khotimchenko, Xia, & Hefang, 1996). On the other hand, a recent study reported that contents of TL and omega-3 polyunsaturated fatty acids (PUFAs) of seaweeds vary seasonally, indicating that the TL of some Sargassaceae brown seaweeds could reach 15 wt.% TL per DW and could contain over 40 wt.% omega-3 PUFAs per total fatty acids (Nomura et al., 2013).

Brown seaweed lipids contain many types of bioactive compounds, such as omega-3 PUFAs, omega-6 arachidonic acid, fucoxanthin, fucosterol and some polyphenols. Among these compounds, fucoxanthin, a major carotenoid in brown seaweeds, is regarded as a nutraceutical compound specific to brown seaweed lipids, as it shows several physiological effects based on unique molecular mechanisms (Miyashita et al., 2011). Therefore, brown seaweed lipids represent a potent functional lipid source. On the other hand, because of the high level of omega-3 PUFAs, such as eicosapentaenoic acid (20:5$n-3$) and stearidonic acid (18:4$n-3$), brown seaweed lipids may be susceptible to oxidation. In the present review, we describe the chemical and nutritional characteristics of brown seaweed lipids.

2. Seaweed lipids

The seaweed lipid content varies by species, geographical location, season, temperature, salinity and light intensity as well as interactions among these factors. (Sánchez-Machado, López-Cervantes, López-Hernandez, and Paseiro-Losada, 2004a,b) reported that tropical species have significantly lower lipid contents than cold-water species (Table 1). A quantitative lipid analysis revealed that the TL content of a major brown seaweed family, Sargassaceae, was higher in subarctic zones (approximately 5 wt.% per DW) than tropical zones (0.9–1.8 wt.% per DW) (Bhaskar & Miyashita, 2005; Bhaskar, Hosokawa, & Miyashita, 2004a; Bhaskar et al., 2004b; Terasaki et al., 2009). A recent study reported approximately 15 wt.% TL per DW of Sargassaceae collected in the subarctic zone of the North Pacific Ocean in the spring (Nomura et al., 2013). In contrast, Ghosh et al. (2012) found TL levels of more than 10 wt.% per DW of three tropical brown seaweeds, *Dictyota bartayresii* (11.91 ± 2.00 mg/g DW), *Dictyota dichotoma* (10.80 ± 0.99 wt.% per DW) and *Spatoglossum macrodontum* (11.73 ± 0.49 wt.% per DW), and two tropical green seaweeds, *Caulerpa sertularioides* (13.04 ± 1.46 wt.% per DW) and *Derbesia tenuissima* (12.14 ± 5.9 wt.% per DW) (Table 1). High TL contents have also been reported from brown seaweeds collected in tropical areas of the Indian Ocean (7–8 wt.% per DW) (Thinakaran, Balamurugan, & Sivakumar, 2012) and the Hawaiian coast (16–20 wt.% per DW) (McDermid & Stuercke, 2003) (Table 1).

Although the class composition of seaweed lipids also varies by species, geographical location and environmental factors, the glycoglycerolipid (GL) class is most common, consisting of monogalactosyl-diacylglycerols (MGDG), digalactosyl-diacylglycerol (DGDG) and sulfoquinovosyl-diacylglycerol (SQDG). (Bhaskar, Hosokawa, & Miyashita, 2004c; Bhaskar & Miyashita, 2005; Bhaskar, Hosokawa, & Miyashita, 2004a; Bhaskaret al., 2004b; Dembitsky, Rozentsvet, & Pechenkina, 1990; Holdt & Kraan, 2011; Jones & Harwood, 1992; Kamenarska et al., 2002; Shevchenko et al., 2007;Vaskovsky, Khotimchenko, Xia, & Hefang, 1996). GL usually represented more than half of the TL content. The other lipid classes present include phospholipids (PL), triacylglycerols (TAG), sterols and pigments. The total fatty acid content in seaweeds has been reported as 20–50 wt.% per TL (Gosch, Magnusson, Paul, & De Nys, 2012), and these fatty acids generally contain high levels of omega-3 (20:5$n-3$, 18:4$n-3$ and 18:3$n-3$) and omega-6 (20:4$n-6$ and 18:2$n-6$) PUFAs (Holdt & Kraan, 2011).