Dietary seaweed and human health

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Introduction

For centuries seaweed has been consumed in Asia[1]; however, it is not a usual part of the Western diet. A recent move to introduce seaweed into European cuisine has met with limited success though it has gained acceptance in some Westernised cultures such as California and Hawaii, where there are large Japanese communities who have had a tangible influence on local dietary practices. Low consumer awareness regarding the potential health benefits of seaweed challenges its use in the daily diet[2].

Not surprisingly therefore consumption of seaweed in the UK is minimal at present[3] though there appears to be no reliable intake data from routine dietary surveys[4]. In the USA and Canada, seaweed is cultivated in onshore tanks and the market is growing. In Ireland there is renewed interest in seaweed that once formed part of the traditional diet. Recipe books promoting the use of 'sea vegetables' or 'marine vegetables'[5] in home-cooking are becoming more popular. Consumer health and nutrition are becoming increasingly influential in the food industry, thus seaweed is gaining in popularity[5], and associated product development appears to be slowly evolving. Seaweeds are macroalgae; subclassified as brown (phaeophyta), red (rhodophyta) or green (chlorophyta), some of which are edible, and blue-green algae (cyanophyta), which are toxic[6]. To date, seaweed as a 'whole-food' has been added to pasta[7], bread[8,9], and processed (Fairclough, personal communication) and low fat meats[10].

Nutritional profile and acceptability of seaweed

Habitual consumption of seaweed may offer a nutritionally rich addition to the diet; however, micronutrient intakes in excess of the RNI may be of concern to nutritionists, particularly where bioavailability is high. Previous authors have eloquently reported the nutritional value of 9 common edible seaweeds [6]. The rich mineral and trace element content of seaweed compared to terrestrial foods can however, impact negatively on its organoleptic characteristics[6]. However, it has been shown to be acceptable to consumers when baked into breads (*Ascophyllum nodosum* up to 5% w/w; Hall et al., 2010[9]; Mahadevan and Fairclough, personal communication) and added to pasta (*Undaria pinnatifida* up to 10% w/w[7]). Seaweed is high in fibre and contains many other potentially "bioactive" compounds[6]. Collectively, these results suggest that seaweed may be successfully combined into acceptable food products to potentially enhance their nutritional quality.

Seaweed as a whole-food

Observational evidence linking seaweed intake to reduced disease risk is currently only relevant in South East Asian populations where seaweed is habitually consumed. Recent data are summarised in Table 1. In humans, an inverse correlation between seaweed consumption (*Alaria esculenta* (L.)) and serum oestradiol was demonstrated in a recent randomised controlled trial[14] which may in part explain epidemiology linking seaweed intake with reduced risk of hormone related diseases such as breast and endometrial cancers. *Rodophycaeae* seaweed significantly reduced the glycaemic response to a carbohydrate load in a small sample of healthy females[15] with possible implications for the management of type II diabetes and/or obesity.

Table 1. Summary of recent observational studies relating to dietary seaweed intake and health

Disease/health concern	Study design	Odds ratio (95% CI) of highest seaweed to lowest	Reference
Type II diabetes and pre-diabetes	3,405 Korean individuals, aged 20 - 65 y. retrospective study. Adjusted for diet and lifestyle	0.66 (0.43-0.99) for men and 0.80 (0.51-1.24) for women	30
Osteoporosis	214 Japanese elderly participants. Prospective study assessing calcaneus stiffness changes over 5 years. No adjustment of data.	0.22 (0.07-67) in all individuals	31
Obesity	3760 Japanese women aged 18-20 y. Cross-sectional study assessing 3 different eating patterns	0.57 (0.37-0.87) for BMI >25.0[a]	32
CV mortality	40547 Japanese men and women aged 40-79 y. prospective study over seven years of follow-up. Not adjusted	0.73 (0.59 -0.90)[a]	33
Allergic rhinosinusitis	1002 pregnant Japanese women. Cross-sectional study. Data adjusted for lifestyle and risk factors	0.51 (0.30–0.87)	34
Breast cancer occurrence	South Korean case-control study. 362 cases (30-65y) with controls matched for age and menopausal status. Data adjusted for multivitamin supplement use, number of children, breastfeeding, dietary factors, education, exercise, oral contraceptive use.	0.48 (0.27-0.86)	35

[a] Seaweed was included as part of a healthy/traditional Japanese eating pattern (i.e. high intakes of vegetables, mushrooms, seaweeds, potatoes, fish and shellfish, soy products, processed fish, fruit and salted vegetables) and was not assessed independently. CV = cardiovascular

The antimicrobial properties of seaweed isolates have been well documented[16-18]; however, there is a paucity of data on the antimicrobial properties and preservative effects of seaweed as a 'whole-food' ingredient. In processed meat products (3% w/w incorporation) we have shown *Ascophyllum nodosum* to elicit an antimicrobial effect. These were most noticeable against specific types of Gram negative micro-organisms (Fairclough, personal communication). Interestingly seaweed isolates have been shown to act more favourably against Gram positive organisms[17,19]. We added *Ascophyllum* *nodosum* to preservative-free wholemeal bread (1.25% w/w) as a replacement for salt (as sodium chloride) with an associated suppression of mould growth up to 9 days compared to 3 days for the control bread (containing 5 g sodium chloride without seaweed) (Fairclough, personal communication). Such applications may be of considerable interest to food industries aiming to meet public health recommendations to voluntarily reduce the salt content of processed foods.

Seaweed isolates

Isolated viscous seaweed polysaccharides are frequently used by the food industry in a wide variety of applications to benefit texture and stability[20]. In molecular gastronomy, such novel polysaccharides also present structural advantages in the production of foams and mousses, and allow both direct and reverse spherification. The above applications of seaweed polysaccharides benefit the organoleptic quality of foods. Experimental data exists suggesting that such factors, when used at higher concentrations, could benefit human health. For instance, alginate incorporation into foods and/or beverages has been shown to benefit acute physiological effects of meal consumption including reducing hunger and food intake and enhancing satiety[21-24], improving glycaemic control[21,22] and reducing fat absorption[24,25]. Similar results have been reported in animal-feeding studies (reviewed elsewhere[1, 26]).

Potential negative effects of consuming seaweed or seaweed isolates

Components of seaweed bind to and adsorb heavy metals[27], meaning that seaweed is particularly prone to contamination from polluted water and its consumption is a potential route of heavy metals entering the body. Additionally, toxic blue-green algae species may grow on edible seaweed and have been noted in the literature to be a causative factor in food poisoning occurrences[28]. Alginates and other seaweed isolates bind to divalent cations, which could affect the bioavailability of dietary calcium, iron and some trace elements (reviewed elsewhere[26]).

High consumption of seaweed in Japan and Korea by lactating mothers has been linked to neonatal iodine toxicity and consequent hypothroidism[29]. High iodine intake is also not advisable in thyroid patients. Given the low levels of consumption of seaweed in the West, such concerns are of little public health relevance at present, although accurate dietary intake data for monitoring purposes would be useful in the light of increasing popularity with consumers.

Summary

Seaweed may be an important ingredient across many public health disciplines including environmental sustainability, food safety, nutrition and health. This information may be beneficial for policy makers, practitioners, researchers and academics who contribute to the promotion of public health. Existing evidence presents a compelling argument for moderate inclusion of seaweed in the Western diet. However, long-term intervention studies (particularly well-powered, appropriately designed randomised-controlled trials) are necessary to assess whether dietary seaweed/seaweed fibre impacts positively on human health.

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