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IMPACT OF SEASONAL CHANGES ON THE DIETARY FIBRE CHARACTERISTICS OF EDIBLE SEAWEEDS FROM RAMESWARAM

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Abstract:
The present study was undertaken to evaluate the dietary fibre content of six selected edible seaweeds, namely *Acanthophora spicifera* , *Gracilaria corticata*, *Gracilaria edulis*, *Ulva lactuca*, *Ulva reticulata*, and *Stoechospermum marginatum* collected across different seasons. The results revealed that all the selected seaweeds contained high levels of dietary fibre, which varied significantly ($p < 0.01$) among species as well as across seasons. Among them, the red seaweed *Gracilaria edulis* exhibited the highest total dietary fibre (TDF) content, with values of 42.4 ± 1.69 g during the pre-monsoon season, 41.3 ± 0.61 g in the post-monsoon season, and 41.23 ± 1.12 g in the monsoon season. Notably, the highest soluble dietary fibre (SDF) content was also recorded in *Gracilaria edulis* during the monsoon season. Overall, the findings underscore that red seaweeds, particularly *Gracilaria edulis*, are rich sources of dietary fibre and hold promising potential for use in the development of diabetic-friendly food formulations and nutraceuticals.

Keywords: Edible seaweeds, Dietary fibre, Antidiabetic activity, in vitro glycemic index, Seasonal variation

INTRODUCTION

Seaweeds are traditionally consumed as human food in several Asian countries, where they are cultivated on a large scale. A wide range of seaweeds belonging to different genera has been known as a food source since prehistoric times (Mouritsen et al., 2013). Marine seaweeds are a good source of dietary fibres, polysaccharides, polyphenol, polyunsaturated fatty acids, minerals and vitamins, which possess various biological activities like anti diabetic, anti-inflammatory and antioxidant activity (Kim & Shin, 2009). Lahaye and Kafeer (1997) stated that the carbohydrate content of algae is relatively high (33-75%) but algae are not energy rich food because the digestibility of these carbohydrates is low. Edible seaweed contains 35-50% total fibres on a dry weight basis, which is higher than the levels found in higher plants and these fibres are rich in soluble fractions (Lahaye, 1991). The dietary fibre included in marine algae are classified into two types, insoluble such as cellulose, mannans and xylan and water soluble dietary fibre such as agar, alginic acid, fucoidans, laminarin and porphyran (Krann, 2012).Marine algae contain large amounts of non- starch polysaccharides that cannot be digested completely by the human digestive system and which therefore have potential as new sources of dietary fibre, prebiotics or other functional ingredients (Rioux et al., 2007).Inadequate level of DF in the diet has been implicated in coronary heart disease (CHD), high blood pressure, obesity, hypercholesterolemia, hyperlipidemia, gallstones, varicose veins, diabetes, constipation and diverticulitis (Macpherson, 1993).Thahira Banu and Umamageshwari (2011) stated that seaweeds offer a wide range of therapeutic possibilities both internally and externally. Eating unprocessed dried seaweeds can yield many healing benefits. Many physical ailments in human can be regularly resolved with the simple addition of seaweeds to their respective diets. A number of research studies reported that the nutrient composition of the seaweed varies depending on the environmental conditions. Hence this study aims to determine the total dietary fibre content of the selected edible seaweeds in various seasons.

MATERIALS AND METHODS

Sample collection

Six seaweeds namely *Acanthophora spicifera* , *Gracilaria corticata*, *Gracilaria edulis*, *Ulva lactuca*, *Ulva reticulata* and *Stoechospermum marginatum* were collected in the Gulf of Mannar, the south coast area of Rameswaram, Tamil Nadu, India. Seasonal variation of the seaweeds was studied in three seasons, namely monsoon (June - September), post monsoon (October - December) and pre monsoon (March - May). The brown seaweed *Stoechospermum marginatum* was not available in the post monsoon season. Hence the study was carried out using only the five seaweeds in post monsoon seasons. Balakrishan et al. (2013) studied the algal sources from Mandapam coast Tamil Nadu during summer and reported that the brown algae *Stoechospermum marginatum* was not available in the month of April and May. The collected edible seaweeds were identified by Scientist from Central Salt and Marine Chemicals Research Institute, Mandapam camp, Ramanathapuram, Tamil Nadu, India. The collected seaweeds were individually washed and dried. The dried samples were powdered and stored in High Density Poly Ethylene bags (HDPE) at room temperature 250c ±20c.

Determination of the dietary fibre content

The powder sample was analyzed for fibre content using enzymatic methods to determine insoluble dietary fibre, soluble dietary fibre, and total dietary fibre following the AOAC (1990) method.

Statistical analysis

The total dietary fibre, Insoluble Dietary Fibre and Soluble Dietary Fibre content were performed in triplicate. All the data were expressed in terms of mean ± SD (Standard Deviation). Two-way ANOVA was employed to test the significance of variability of the concentration of TDF, IDF and SDF with respect to different seaweeds and seasons using SPSS version 23.

RESULTS

Composition of dietary fibre content of selected edible seaweeds

The American Association of Cereal Chemists (AACC, 2001) defines dietary fibre as the edible part of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fibre includes polysaccharides, oligosaccharides, lignin, and associated plant substances which promote beneficial physiological effects including laxation and/or blood cholesterol and blood glucose attenuation.

Table 1 indicates that the dietary fibre content of the selected edible seaweeds collected in the various seasons. Insoluble Dietary Fibre (IDF), Soluble Dietary Fibre (SDF) and Total Dietary Fibre content were determined using enzymatic method.

Table 1. Total Dietary Fibre, Insoluble Fibre and Soluble Dietary Fibre content of the selected seaweeds in various seasons

Seaweeds	Season	TDF	IDF	SDF
Acanthophora spicifera	Monsoon	22.05±1.00	19.55±0.39	2.5±0.7
	Post monsoon	20.66±0.54	17.1±0.17	3.5±0.2
	Pre monsoon	27.25±1.39	23.4±2.03	3.8±0.76
Gracilaria corticata	Monsoon	30.83±0.85	18.46±0.80	12.3±0.40
	Post monsoon	34.83±0.76	20.5±0.86	14.23±0.25
	Pre monsoon	38.6±0.58	25.6±0.83	13±0.5
Gracilaria edulis	Monsoon	41.23±1.12	20.55±1.07	20.7±0.27
	Post monsoon	41.3±0.61	21.58±0.52	19.8±0.31
	Pre monsoon	42.4±1.69	24.5±1.80	17.9±0.11
Ulva lactuca	Monsoon	25.6±0.82	15.91±0.56	9.7±1.13
	Post monsoon	28.06±0.30	18.3±0.45	9.73±0.37
	Pre monsoon	27.53±1.36	15.73±0.64	11.8±0.72
Ulva reticulata	Monsoon	31.2±1.25	16.8±1.59	14.4±0.65

	Post monsoon	33.3±0.51	17.3±1.01	16.5±1.41
	Pre monsoon	36.3±1.18	19.7±0.60	16.8±0.57
Stoechospermum marginatum	Monsoon	25.2±0.80	18.7±0.49	6.43±0.49
	Pre monsoon	21.7±0.37	16.65±0.30	5.1±0.26
ANOVA seaweed	F value	471.057	47.119	781.671
	P value	.000***	.000***	.000***
ANOVA Season	F value	43.805	37	4.285
	P value	.000***	.000***	.02**
ANOVA Seaweed*Season	F value	17.884	15.006	10.503
	P value	.000***	.000***	.000***

*** and ** are significant at ($P<0.001$) and ($P<0.05$) respectively.

TDF- Total Dietary Fibre Content, IDF- Insoluble Fibre, SDF- Soluble Dietary Fibre

DISCUSSION

Total dietary fibre content

The TDF content of the selected edible seaweeds ranged from 22.05±1.00 to 42.4±1.69g. Seaweeds typically contain high levels of dietary fiber, which varies widely among species, ranging from 5.7% to 64.7% in red seaweeds (Afonso et al., 2021). The high amount of dietary fibre was determined in the red seaweed *Gracilaria edulis* collected in the post monsoon season. The minimum range of dietary fibre was detected in the red seaweed *Acanthophora spicifera* in monsoon season. *Gracilaria corticata* showed 34.83±0.76, 30.83±0.85 and 38.6±0.59g of TDF content in post monsoon, monsoon and pre monsoon season respectively. Total dietary fibre content in 26 species of Hawaiian marine macroalgae was determined and reported by Dermid et al. (2005), the TDF values ranged from 23.5 to 59.8%, with 13 species containing more TDF than wheat bran (42.7% TDF). In the selected Rhodophyta species had TDF concentrations over 40%. Similar results were observed in the present study also with red seaweed having more dietary fibre than other seaweeds. The green seaweeds *Ulva lactuca* and *Ulva reticulata* collected during post monsoon season had 28.0±0.30 and 33.8±0.51g of TDF content respectively. While in the seaweeds collected during monsoon and the pre monsoon season a slight decrease in TDF was observed. It was found that in the pre monsoon the dietary fibre of *Ulva lactuca* and *Ulva reticulata* was 25.6±0.82, 31.1±1.25g and a slight increase was noticed in the pre monsoon season with 27.53±1.36, 36.3±1.18g of TDF content respectively. Carvalho et al. (2009) reported that 399.2g kg-1 (dry basis) of total dietary fibre content in Ulva fasciata. The brown seaweed *Stoechospermum marginatum* collected in monsoon season had 25.2±0.8g of TDF. While in the pre monsoon season the TDF was 21.7±0.37g in *Stoechospermum marginatum*. The statistical value reported that the TDF content significantly ($p<0.01$) varied within the seaweeds and between the seasons. The brown seaweed *S. dulicatum* had 33.48 percent of TDF content (Zailanie&Kartikaningsih, 2016), this is higher than the fibre content of the selected brown seaweed *Stoechospermum marginatum*.

Higher levels of non-digestible polysaccharide in their cell wall make seaweeds a rich source of dietary fibre (330-500 g. kg–1, dry weight basis) (Rupérez& Calixto, 2001). The seaweed polysaccharides possess a higher Water Holding Capacity (WHC) than cellulosic fibres. There is an interest in seaweed hydrocolloids for human nutrition as they can act as dietary fibre since their physiological properties are closely related to their physicochemical properties such as solubility, viscosity, hydration and ion exchange capacities in the digestive tract (Lahaye&Kaeffer, 1997). A study on functional properties of the seaweeds was done and water holding capacity was found to be high in seaweed in general. With reference to red and brown seaweeds it had the high-water holding capacity (Reka et al., 2016 and 2017). A number of research studies reported that the major polysaccharides found in algae are alginates, carrageenans, agars, fucans, laminarins, ulvans, and floridean starch.

Insoluble and Soluble Dietary Fibre content

The insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) contents of the selected seaweeds ranged from 15.73 ± 0.64 to 25.6 ± 0.83 g and 2.5 ± 0.7 to 20.7 ± 0.26 g, respectively. The highest IDF content was observed in the red seaweed *Gracilaria corticata* collected during the pre-monsoon season (25.6 ± 0.83 g), followed by 20.5 ± 0.86 g in the post monsoon and 18.46 ± 0.80 g in the monsoon season. In contrast, the lowest IDF content was recorded in *Ulva lactuca* during the pre-monsoon season (15.73 ± 0.64 g), while the same species exhibited values of 18.3 ± 0.45 g and 15.9 ± 0.56 g in the post-monsoon and monsoon seasons, respectively. Among the red seaweeds, *Acanthophora spicifera* and *Gracilaria edulis* showed IDF contents of 19.55 ± 0.39 g and 20.55 ± 1.07 g during the monsoon, 17.1 ± 0.17 g and 21.58 ± 0.52 g in the post-monsoon, and 23.4 ± 2.03 g and 24.5 ± 1.80 g in the pre-monsoon seasons, respectively.

The green seaweed *Ulva reticulata* exhibited IDF contents of 17.3 ± 1.01 g, 16.8 ± 1.59 g, and 19.7 ± 0.60 g during the post-monsoon, monsoon, and pre-monsoon seasons, respectively. *Stoechospermum marginatum* contained 18.7 ± 0.49 g of IDF in the monsoon season and 16.65 ± 0.30 g in the pre-monsoon season.

Red seaweeds *Acanthophora spicifera* , *Gracilaria corticata* and *Gracilaria edulis* collected in the monsoon season had 2.5±0.7, 12.3±0.40 and 20.7±0.27g of SDF content respectively. SDF found in 3.5±0.2, 14.23±0.25 and 19.8±0.31g in the post monsoon season and 3.8±0.76, 13±0.5 and 17.93±0.115g in the pre monsoon. *Ulva lactuca* had 9.73±0.37, 9.7±1.126 and 11.8±0.72g in post monsoon, monsoon and the pre monsoon season respectively. Whereas in the *Ulva reticulata* the dietary fibre content in post monsoon, monsoon and pre monsoon season was found to be 16.5±1.41, 14.4±0.65 and 16.8±0.57g respectively.

The brown seaweed *Stoechospermum marginatum* collected across all three seasons exhibited soluble dietary fibre (SDF) contents of 6.43 ± 0.49 g in the monsoon and 5.1 ± 0.26 g in the pre-monsoon season. Statistical analysis revealed that the IDF and SDF contents varied significantly ($p < 0.01$) both among seaweed species and between seasons. Overall, the TDF, IDF, and SDF contents of the selected seaweeds were higher during the pre-monsoon season compared to the monsoon and post-monsoon seasons. This observation aligns with the findings of Munda and Kremer (1997) and Perfeto (1998), who reported that favourable environmental factors such as water availability, temperature, salinity, and pH positively influence carbohydrate synthesis, thereby contributing to the higher fibre content in the pre-monsoon season. Similarly, Banerjee et al. (2009) observed maximum carbohydrate content in seaweeds collected during the pre-monsoon season, with values correlating positively with salinity and surface water temperature.

Supporting evidence from Benjama and Masniyom (2011) further highlights seasonal variation in fibre composition, reporting that *Ulva pertusa* contained 30.4 ± 3.7% and 21.8 ± 0.4% SDF, and 25.3 ± 0.6% and 33.5 ± 0.3% IDF during rainy and summer seasons, respectively. Similarly, *Ulva intestinalis* exhibited 39.6 ± 0.9% and 22.6 ± 2.6% SDF, along with 25.3 ± 0.3% and 26.0 ± 0.3% IDF in rainy and summer seasons, respectively.

Beyond seasonal trends, dietary fibre is recognized for its functional roles in food systems, enhancing water- and oil-holding capacities, emulsification, and gel formation. Studies have demonstrated that incorporation of dietary fibre into food products such as bakery items, dairy, jams, meats, and soups can improve textural properties, prevent syneresis, stabilize high-fat emulsions, and extend shelf life (Elleuch et al., 2011). Physiologically, dietary fibre influences digestion and metabolism by delaying gastric emptying, accelerating gut transit, binding minerals, modifying enterohepatic circulation, regulating mucosal cell proliferation, and altering gut hormone release, particularly enteroglucagon, gastric inhibitory polypeptide, and somatostatin (Roehrig, 1998). Soluble dietary fibre, in particular, retards digestion and nutrient absorption, lowers blood glucose and cholesterol levels, and plays an important role in preventing constipation, colon cancer, cardiovascular disease, and obesity (Ortiz, 2006). In contrast, insoluble dietary fibre has been associated with increased fecal bulk and reduced intestinal transit time (Potty, 1996).

CONCLUSION

The study confirmed that all the selected edible seaweeds are rich sources of dietary fibre. The TDF, IDF, and SDF contents varied significantly ($p < 0.01$ and $p < 0.05$) across species and seasons. Among the studied seaweeds, *Gracilaria edulis* collected during the pre-monsoon season exhibited the highest levels of TDF, IDF, and SDF. Incorporating such seaweeds into the human diet could contribute substantially to meeting the daily recommended intake of dietary fibre. Furthermore, the high proportion of soluble dietary fibre in these seaweeds highlights their potential role in managing obesity, hypercholesterolemia, and hyperglycemia, underscoring their value in the development of functional and health-promoting foods.

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