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The seagrass *Syringodium filiforme* as a possible alternative for human consumption

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Abstract

Following the methods described by the Association of Official Analytical Chemists (AOAC), this study assesses the chemically-derived nutritional aspects of the seagrass *Syringodium filiforme* (Kützing), collected during a rainy season in a tropical coastal lagoon located in south-eastern Mexico. Furthermore, it compares the nutritional quality of this plant species against other foods of high human consumption and explores its possible use as an alternative food for humans. Fieldwork was conducted to collect specimens of *S. filiforme* from different parts of the lagoon. In the laboratory, a proximate analysis was applied to the samples, including determinations of crude protein, crude lipid, crude fibre, dry matter, nitrogen-free extract and ash. The results showed a high protein content (10.43%), high nitrogen-free extract (45.37%), low lipid content (2.43%), high fibre (19.43%) and high ash contents (23.43%). Given these chemical contents and the World Health Organisation reference standards, *S. filiforme* appears to be a notable potential source for human consumption. Our results are compared against the nutritional contents published in the scientific literature for other species with high nutritional values and suitable for human consumption. New possibilities for using non-conventional plant foods, such as seagrasses, particularly protein-rich species, could exist in developing functional alternatives for human consumption.

Keywords: Seagrass, *Syringodium filiforme*, proximal analysis, Términos Lagoon, Mexico

INTRODUCTION

The seagrasses represent a significant component of the coastal zones in temperate and tropical marine environments. These plants have an important ecological role because they provide a habitat and food for several organisms, modulate sedimentary processes and regulate the biogeochemical cycles [1]. Taxonomically, the seagrasses are assigned within two families (Potamogetonaceae and Hydrocharitaceae), which include 12 genera of angiosperm, with 50 species [2]. In Mexico, 6 genera are represented, including 9 species, which constitutes 50% of the genus, and 13% of the species, found around the globe [3]. In addition to their ecological contribution, due to their high primary productivity rates (production of organic matter by weight, as a result of the conversion of sunlight through the process of photosynthesis), these data suggest that this species represents a potential source of food for humans.

The nutritional content of aquatic species is relatively well documented [4]. For example, the high nutrient content in macroalgae (Rhodophyta, Phaeophyta and Chlorophyta) indicate their potential use as a source for human consumption [5]. Although knowledge about the nutritional content of seagrasses is still limited, these species have been used in ancient times as food in some coastal populations [6], as an alternative treatment against certain diseases (fever and skin irritations) [7], as fertiliser, and even as food for livestock [8].

In this context, it is imperative to define the chemical composition of seagrasses as possible sources of proteins, carbohydrates and lipids available to humans yet the available information is limited to the work done by Dawes [9], who found high levels of ash and protein in three species of seagrasses from the northern Gulf of Mexico.

This study aims to assess the nutritional composition of a species of seagrass (*Syringodium filiforme*) collected in the Términos Lagoon, Campeche, Mexico, and compare its levels against species of high consumption by humans and high commercial value, to evaluate its possible use for human consumption. In Mexico, as in other developing countries, the exploration of alternative uses for seagrasses, particularly protein-rich species, could be beneficial for the development of functional foods.

MATERIALS AND METHODS

Study area

The Términos Lagoon (Figure 1a) is located in the southern region of the Gulf of Mexico between the latitudes 18°27′37″ and 18°47′36″ N and the longitudes 91°14′44″ and 91°53′55″ W, and covers a total area of approximately 2500 km^2, which makes it the second largest coastal lagoon in Mexico. It has an average depth of 3.5 m and is connected to the Gulf of Mexico through two openings: the Puerto Real and the Del Carmen. The contribution of freshwater to the lagoon is due to the presence of three rivers: Chumpán, Palizada and Candelaria [10]. The climate of the region includes three periods: the dry season (from March to May), the rainy season (from June to October) and the season of 'Nortes' (from November to February) [11]. An important component of the coastal ecosystem in the lagoon are the seagrasses, including three species: *Thalassia testudinum* (König), *Halodule wrightii* (Ascherson) and *S. filiforme* (Kützing). *Syringodium filiforme,* commonly known as manatee grass, is distributed in shallow warm waters, grows in an interval between 1 and 3 m deep, and can be found in the sublittoral zone in sandy or silty substratum [12]. This species is provided with rhizomatous cylindrical stems, with 1 or 3 branched roots per node. The apex of the sheath presents an auriculate and ligulate structure, slightly compressed while the lamina is cylindrical. The flowers are protected by two bracts, very similar to the lamina, pedunculated staminate. The ecological importance of these species includes its use as a good stabiliser of the floor where it is distributed, as well as being a source of food for marine animals, such as manatees, and, due to its high levels of antioxidant substances, its medicinal use has been noticed [13].

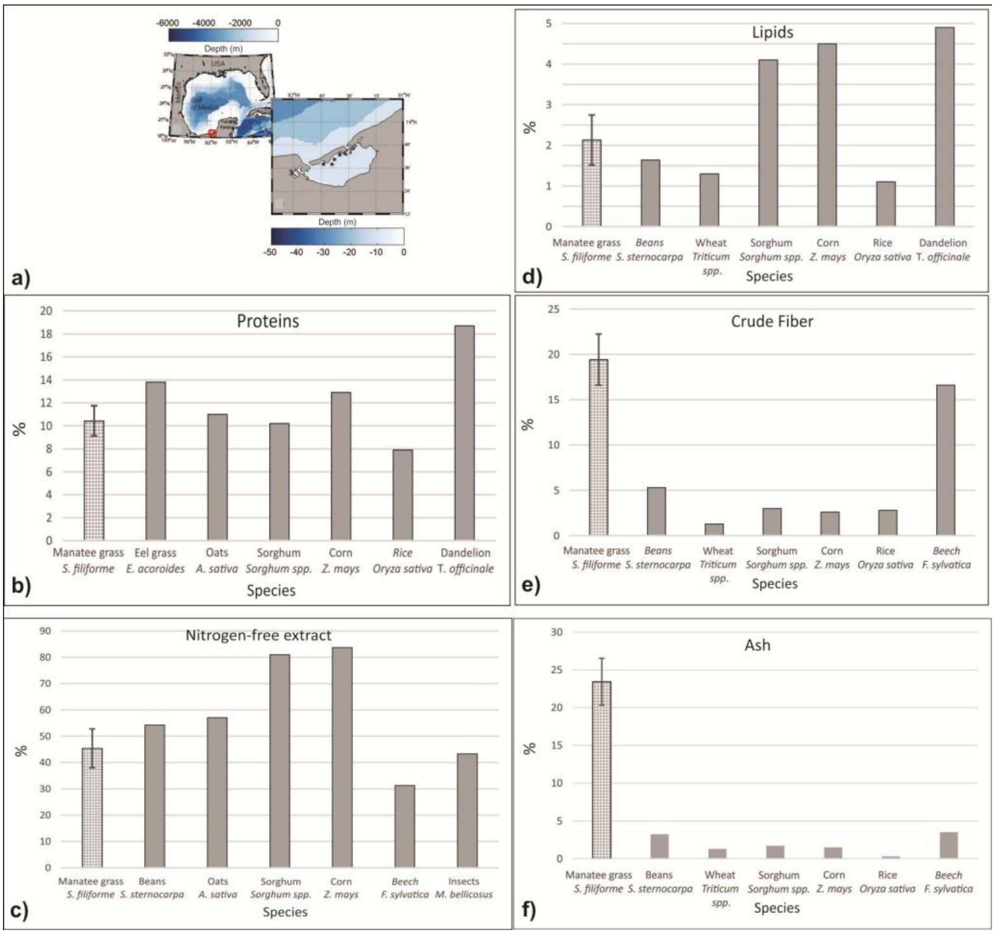

Figure 1. (a) Location of: The Gulf of Mexico, the rectangle in red represents the study area, Términos Lagoon, the symbol "*" represents the sampling sites; **(b)** Percentage of protein (mean ± one S.E.) and its comparison with other species of high human consumption and commercial value reported in the literature; **(c)** Percentage of nitrogen-free extract (mean ± one S.E.) and its comparison with other species of high human consumption and commercial value reported in the literature; **(d)** Percentage

of crude fat (mean ± one S.E.) and its comparison with other species of high human consumption and commercial value reported in the literature; **(e)** Percentage of crude fibre (mean ± one S.E.); **(f)** Percentage of ash content (squared bar) and their comparison with other species of high human consumption and commercial value reported in the literature

Fieldwork

Specimens of *S. filiforme* were collected in October, corresponding to the rainy season. The samples (including leaves and rhizomes) were collected, in triplicate, from the northern region of the lagoon (Figure 1a), using a hand shovel, stored in sealed plastic bags and then transported on ice to the laboratory where they were washed with distilled water to remove mud and sand.

Laboratory analyses

The samples were processed and analysed immediately after their collection. The epiphytes were removed completely by scraping. The leaves and rhizomes, completely clean, were weighed on a Sartorius analytical balance (Göttingen, Germany, precision 0.01 mg) and then dried at 115 °C for 5 h until reaching a constant dry weight.

The nutritional content was evaluated by conducting a proximal chemical analysis, following the methods, protocols and recommendations of the Association of Official Analytical Chemists [14]. The analysis included the determination of crude protein content, nitrogen-free extract (NFE), crude fat, crude fibre and total ash.

For the determination of crude protein and NFE, the Kjeldahl method was applied, with a correction factor of 6.25. This method is characterised by the use of boiling the sample in concentrated H_2SO_4 to oxidatively destroy the organic matter present in each sample and reduce the organic nitrogen in ammonia. The three-step procedure can be summarised as (1) the digestion of the sample in concentrated H_2SO_4 in the presence of a catalysis, which converts the nitrogen contained in the sample into ammonia, forming ammonium sulphate; (2) the distillation of the ammonia released by the addition of NaOH, and (3) the back-titration of the excess of the capture solution. To estimate the nitrogen content, the latter is multiplied by a factor, which is calculated based on the nitrogen content of the proteins. In most vegetable proteins, the average nitrogen is 16%, which means that each unit of nitrogen is contained in 6.25 units of protein [15].

The ether extract or crude fat was measured based on the continuous heat extraction of all the petroleum ether-soluble substances in the dry samples [14].

The crude fibre was estimated by the Weende method [14], in which crude fibre is considered as the indigestible portion of the food, and it is constituted mainly by cellulose, hemicellulose and lignin.

For obtaining the total ash and organic matter, the samples were combusted at 550 °C for 2 h, to oxidise the organic matter, resulting in the ashes, which were considered as the mineral part of the samples [14].

RESULTS AND DISCUSSION

Overall, the nutritional values for the manatee seagrass (*S. filiforme*) evidenced by the proximal chemical analysis were high (Table 1).

Table 1. Nutritional values for different species with high human consumption and high commercial value. [1]This study: [2]Rengasamy et al. [8]; [3]North and Bell [17]; [4]Cruz-Suárez et al. [16]; [5]Watson [19], [6]Cortez and Wild-Altamirano [18]; [7]Ndidi et al. [21]; [8]Shams-El-Din and El-Sherif [20]; [9]Cicnjak et al. [22]; [10]Nwosu [24]; [11]Banjo et al. [23].

Common name	Scientific name	Proteins (%)	Nitrogen free extract (%)	Lipids (%)	Crude fibre (%)	Ash (%)
Manatee grass[1]	***Syringodium filiforme***	**10.43**	**45.37**	**2.13**	**19.43**	**23.43**
Eel grass[2]	*Enhalus acoroides*	13.8	2	1.4	20.3	26.63
Oats[3,9]	*Avena sativa*	11	57.06	*	*	*
Sorghum[4]	*Sorghum spp*	10.2	81.0	4.1	3.0	1.7
Corn[5,6]	*Zea mays*	12.9	83.7	4.5	2.6	1.5
Rice[4]	*Oryza sativa*	7.9	*	1.1	2.8	0.23
Wheat[4]	Triticum spp	10.1	*	1.3	1.3	1.3
Beans[7,10]	*Sphenostylis sternocarpa*	*	54.22	1.64	5.31	3.23
Common dandelion[8]	*Taraxacum officinale*	18.7	*	4.9	*	*
Common beech[9]	*Fagus sylvatica*	*	31.22	*	16.61	3.52
Insects[11]	*Macrotermes bellicosus*	*	43.3	*	*	*

* Values not available

Based on the values observed in all the analyses undertaken and considering the values reported in the scientific literature for other species, it is possible to highlight the potential represented by the use of this species of seagrass as food for human consumption.

The crude protein content observed for *S. filiforme* in this study (Figure 1b, Table 1) was 10.43%. A similar value (13.8%) has been reported for the eel seagrass (*Enhalus acoroides*), which is used for human consumption in some countries, such as, the Philippines. Likewise, oats, as whole grain (*Avena sativa*), and sorghum (*Sorghum* spp.) have documented protein contents of 11.0% and 10.2%, respectively [16, 17], in agreement with our results. Some varieties of corn (*Zea mays*) contain 12.9% protein [18, 19]. Rice (*Oryza sativa*) has 7.9% protein compared with 18.7% for herbs, such as the common dandelion (*Taraxacum officinale*) [20].

The NFE content, consisting mainly of digestible carbohydrates, has been evaluated in several species, including edible insects. In this study, the values observed for *S. filiforme* were high, representing 45.37%. In comparison, literature studies state NFE contents of 54.22% in the African bean (*Sphenostylis stenocarpa*) [21], 57.06% in oats (*A. sativa*) [22], and 81% and 83.7% in sorghum and corn, respectively [16]. Also, some species of beech (*Fagus sylvatica*) are indicated to contain 31.22% NFE [22] while some edible insects (*Macrotermes bellicosus*) have been described as having 43.3% NFE [23] (Figure 1c, Table 1).

This study's target species was low in crude fat, with just 2.13% (Figure 1d, Table 1). Slightly lower levels have been detected in African beans [24] and wheat (*Triticum* spp.) [16], with 1.64% and 1.3%, respectively. Sorghum has less (4.1%) crude fat [16] than corn, with 4.5% but more than rice (*O. sativa*), with 1.1% [16]. Finally, for some herbs, such as the common dandelion (*T. officinale*) values of 4.9% have been reported [20].

The crude fibre content observed for *S. filiforme* in this study was 19.43% (Figure 1e, Table 1), a value much greater than those reported for several species of high human consumption and high commercial value, such as African beans, with 5.31% [24] and wheat, sorghum, corn and rice, with 1.30%, 3.00%, 2.60% and 2.80%, respectively [16]. A species with a similar crude fibre content to that found in this study is the beech (*Fagus silvatica*), with 16.61%. Many components of fibre have been linked to antioxidant effects. The World Health Organisation (WHO) recommends a fibre intake of 22–23 g/1000 kcal of food [25, 26]. Dietary fibre is necessary for digestion, the elimination of waste and the contraction of the muscular walls in the digestive tract [8]. Recently, a diet low in crude fat and rich in fibre, as could be provided by *S. filiforme*, based on the values observed in this study, was associated with a reduced risk of breast cancer [27]. Finally, *S. filiforme* presented a high ash content of 23.43%, considered as the mineral portion of the sample (Figure 1f, Table 1), showing a similar pattern to the crude fibre content, with higher contents than reported in the literature for other species, like African beans (3.23%), wheat (1.3%), sorghum (1.7%), corn (1.5%), rice (0.23%) and beech (3.52%) [16, 22, 24]. To date, it is known that the mineral content of seagrasses is very high relative to that in terrestrial plants, although spinach comes close, with 20.4% [28].

Based on the evidence presented in the figures and table above, the nutritional values found for the manatee seagrass in this study are within the range recognised for many species of high human consumption and high commercial value, thereby supporting the high primary productivity that this species presents. Furthermore, it suggests that manatee seagrass can be explored as food for human consumption, particularly given that its productivity even surpasses other species of high commercial value, such as wheat and corn. In addition, its high nutritional value is similar to that of sorghum, a species characterised by its high protein content, which has been considered as one of the most important sources of protein for human consumption, forming the basis of the diet of millions of people in over 30 countries [29].

Although the information presented in this study suggests the use of this resource for human consumption, it is important to consider the presence of different toxic substances, such as lectins, flavonoids, alkaloids and tannins, which could be present in any part of the plant and can be potentially harmful to the consumer. As such, it is necessary to conduct more studies in this regard. However, as a first approximation, and based on the results shown in this study, it is possible to consider *S. filiforme* as a source of human nutrition. Another important aspect to consider is that like most plant species, the nutritional content of seagrass is affected by external factors, such as geographical location, environmental conditions, and time of year and sampling situations [30]. The geographical position of some countries, coupled with the presence of natural phenomena, has induced a significant lack of food. In the Philippines for example, a country where the presence of El Niño–La Niña phenomena induce the consumption by the population of non-conventional vegetable resources, such as bamboo [31], then, the exploration of alternatives for human food consumption is pertinent.

CONCLUSIONS

Based on the proximal chemical analyses performed on the manatee seagrass, high values of crude protein, NFE, ash (considered as the mineral part), crude fibre, as well as low levels of crude fat were found. In Mexico, as in other developing countries, it is possible to explore new possibilities for the use of seagrasses in the expansion of functional foods for human nutrition, particularly with species that have these characteristics, in order to implement social programs to combat food insecurity. Based on our results, the use of seagrass could complement the protein and mineral levels recommended in the human diet. However, like any other food, it must meet the industrial specifications and official safety regulations for consumers, regarding the microbiological quality and content of heavy metals that seagrasses may contain.

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