

Full Length Research Paper

Nutritional composition of *M. senegalense* in order to increase the value of this macroalgal resource for economic development

Abdoulaye C. Macky¹, Baaba G. Diouf^{2,4*}, Patrick H. Ousmane^{2,3}, Leopold Abdou Sembene³ and Youssou Keita Cisse¹

¹Département de Biologie végétale- Laboratoire de Botanique et de Biodiversité. Faculté des Sciences et techniques, Université Cheikh Anta Diop de Dakar, Sénégal.

²Laboratoire de Electrochimie et des Procédés, École Supérieure Polytechnique, Université Cheikh Anta Diop, B.P 5085 Dakar Fann, Sénégal.

³Laboratoire des Biotoxines et Contrôle des Aliments, Institut de Technologie Alimentaire (ITA) Route des Pères Maristes, B.P 2765 Dakar, Sénégal.

⁴Centre d'Etudes sur la Sécurité des Aliments et le développement des Molécules fonctionnelles (CESAM-RESCIF) - Université Cheikh Anta Diop de Dakar, Sénégal.

Accepted 01 October, 2016

Macroalgae are used in diverse global regions. *Meristotheca senegalense* J. Feldmann, a macroalga species found in a Senegalese bay, was the subject of this study focusing on the chemical and mineral composition. The present study was done in order to evaluate the potential of this macroalgal resource for biomass development and contribution to the economy in Senegal. The results of this study showed that *M. senegalense* J. Feldmann was relatively a good source of nutrients including fiber ($6.67 \pm 0.7\%$) and protein ($6.37 \pm 0.8\%$). Mineral analysis also showed significant concentrations of magnesium (216.87 ± 12.9 mg/100 g), calcium (81.6 ± 17.5 mg/100 g), iodine (31.16 ± 1.5 mg/kg) and iron (28.13 ± 2.15 mg/100 g). However, zinc and copper 3.31 ± 0.26 and 2.43 ± 0.13 mg/100 g respectively were found at relatively low concentrations. Interestingly, the vitamin B12 content was significant with a content of 20 ± 1.0 mg/kg, potentially allowing for the use of the alga as a supplemental. The nutrient concentrations reported for *M. senegalense* J. Feldmann suggests that its cultivation and harvest can be a source of diversification in the activities of fishermen. In terms of food consumption, the results also showed that the red alga used in this study can be added to human diets as supplementation and might also be F

Key words: *Meristotheca senegalense*, nutrient composition, macroalgae, supplementation, food diversification.

INTRODUCTION

There are 218270 known macro and microalgae varieties of which 36238 have been identified at the species level

(John, 1994). However only about 665 of the known species of marine macroalgae are used for food or

*Corresponding author. E-mail: di.baba@gmail.com



Figure 1. Map of Cap-vert peninsula (Dakar Region) showing Ngor bay position (Modified from Google Earth 04/2015).

animal feed, and extracted for individual chemical components (Lobban and Harrison, 1994; Pereira, 2016). Components from industrial extraction of macroalgae include: hydrocolloids, nutraceuticals, minerals and food color. According to Mouritsen (2013) and Pereira (2016), the primary mineral components in seaweeds were iodine, calcium, phosphorus, magnesium, iron, sodium, potassium, and chlorine with trace elements such as zinc, copper, manganese, selenium, molybdenum and chromium. The mineral composition varies significantly from one seaweed species to another depending on oceanic residence time, seasonal variations, environmental and physiological conditions, and the processing method of mineralization. *Meristotheca senegalense* has been harvested for approximately three decades (Pérez, 1997; McHugh, 2002; John et al., 2004). It was originally isolated in Dakar between Ngor and Ouakam bays and initially characterized by Faye et al. (2004) and named *M. dakarensis* and was subsequently renamed *M. senegalense*. Previous studies on *M. senegalense* showed the presence of the phycocolloid iota carrageenan (Fostier et al., 1992) containing a potentially promising pharmacological glycolipid biomolecule with anti HIV properties previously extracted from *Cyanobacterium* (Diop and Samb, 2004).

This species of algae was previously exported as raw material to Japan (Pérez, 1997; McHugh, 2002) where *M. senegalense* (McHugh, 2002), *M. papulosa* (Faye et al., 2005; Rao et al., 2007; Pereira, 2016) and *M. procumbens* (Rao et al., 2007; Pereira, 2016) were used for human consumption (Pérez, 1997; Rao et al., 2007;

Mouritsen, 2013; Pereira, 2016). Unfortunately the mineral composition of *M. senegalense* was unknown at this time. The exploitation of this marine resource was recently restricted for exportation as a harvested biomass by the Senegalese government. However due to malnutrition faced by some segments of the population of Senegal and elsewhere, diversification of sources of essential micronutrients appears as one of the solutions next policy strategies and enhancement of certain fruit and vegetables neglected (Ayessou et al., 2009, 2011, 2014; Gueye et al., 2014). Thus, strengthening nutritional balance requires the identification of new food resources. Accordingly, the purpose of the present study was to determine the nutritional composition of *M. senegalense* in order to increase the value of this macroalgal resource for economic development through the local use of the biomass which is still underexploited in Senegal.

MATERIALS AND METHODS

Plant materials

M. senegalense samples were collected in Dakar peninsula Ngor bay located at N 14° 44'715; W017° 30' 857 (Figure 1). Samples were collected early March (the beginning of the cold season) until late June (beginning of the warm season) from crops grown on the mariculture station nets.(Figure 2) This time interval corresponded to the period during which the natural fields of the species were harvested for biomass traded by local coastal populations. For biochemical analysis, three batches of *M. senegalense* samples were targeted. To insure preservation, samples were first naturally dried in shade with adequate ventilation. Prior to analysis samples

were washed in distilled water and dried at 70°C in an oven according to Afnor's method NF V 03-707 (Afnor, 1982) for 48 h before grinding with a mortar pestle.

Major macronutrient analysis

Analyses of lipid and protein content were carried out according to the procedure described according to AFNOR standards (Afnor, 1982). Samples were dried in an oven at 105°C for two hours, cooled and then weighed to determine moisture content. Lipid extraction was performed using a Soxhlet extractor with diethyl ether as the solvent (NFV 03-905 standard). Nitrogen determination was performed using Kjeldhal method (NF 03-050 standard) and the protein content was calculated by using a coefficient factor of 5.7. Fiber content was determined in sample through AFNOR standards V76-101. Samples were hydrolysed with acid solution and then with basic solutions. Then it's mineralizing during 3 h incineration at 550°C.

Ascorbic acid

Ascorbic acid content of the samples was determined according to the method of Dhuique et al. (2007). Ten grams of *M. senegalense* was homogenized in ice-cold metaphosphoric acid solution (4% in distilled water) to extract the ascorbic acid. The mixture was centrifuged at 1000 X g for 15 min with a second extraction repeated after removing supernatant. Supernatants were pooled before determining the total ascorbic acid content. The analysis was performed using a Thermo Scientific HPLC 1000 SCM (Thermo Fisher Scientific France, Illkirch) with an RP 18 Licrospher 100 column (4.6 × 250 mm; 5 μm, Merck, Darmstadt, Germany). The separation used a mobile phase consisting of a 0.01% isocratic sulfuric acid solution (Sigma-Aldrich, Saint-Quentin Fallavier, France) with an injection volume of 10 μl. Quantification was performed using a UV 3000 Spectra (254 nm). Quantification and identification of the peaks were done using an external calibration curve using a concentration range from 10 to 200 mg/l of L-Ascorbic acid solution (A5960 BioXtra, ≥99.0%, crystalline (Sigma) standards (200 to 10 mg.L⁻¹) with a 0.01 % limit of detection.

Vitamin A

To determine Vitamin A content samples were extracted with a mixture of ethanol/hexane (4:3 v/v), with CaCO₃ and 0.1% butylhydroxytoluene (added as antioxidant). *M. senegalense* (0.5 g) samples were mixed with 20 ml of the extraction buffer followed by centrifugation at 15000 X g for 15 min at 4°C. A second extraction was repeated using the same conditions after collecting the supernatant. All supernatants were pooled and evaporated to dryness under nitrogen. After evaporation to dryness, samples were solubilized in 1 mL of a dichloromethane/Tert-Butyl methyl ether/methanol mixture. Separations were carried out by gradient elution using an Agilent HPLC 1100 with water (solution A)/methanol (solution B)/Tert-Butyl methyl ether (solution C) as follows: Initial conditions 40 %A/60 % B; 0-5 min, 20% A/80% B; 5-10 min, 4%A/81% B/15% C; 10-60 min, 4% A/11% B/85% C; 60-71 min, 100% B 71-72 min, and back to the initial conditions for reequilibration. Samples were quantified at 350, 400, 450 and 470 nm wavelengths. Comparisons were carried out using authentic standards as reported by Dhuique et al. (2007) with a limit of detection (LOD) of 0.035 mg/100 g and a limit of quantification (LOQ) of 0.119 mg/100 g per sample.

Mineral determination

Samples were mineralized by incineration at 500°C and desiccated by adding fluorhydric acid at 40% (Sigma-Aldrich, Saint-Quentin Fallavier, France) and then evaporated to dryness. Sodium, potassium, calcium, magnesium, phosphorus, copper, zinc and iron were quantified using an ICP-AES (inductively coupled plasma atomic emission spectrometry) Varian Vista spectrophotometer containing a charge coupled device for detection (Agilent France, Massy). Mineral standards used in this assay (Ca, K, Mg, Fe, Zn, Cu) were obtained from Fisons Scientific Equipment (Loughborough, England).

Vitamin B12

Extraction of vitamin B12 was carried out in acetate buffer (pH 4.0) containing pepsine [50 mg.ml⁻¹ (4500 U.ml⁻¹)]. Partial purification was achieved using Amberlite XA D-2 followed by elution with 80% (v/v) methanol. Activated charcoal facilitated removal of impurities in the extract and in the further purification of vitamin B12. The purified fraction containing methyl cobalamin was analyzed by HPLC using a silica C18 column with water/methanol 50/50 (pH 4.5) as a mobile phase, and a UV detector.

Iodine

Iodine was assayed by "Aqualan" (Bordeaux, France) using the standard method EN 15111/ICP-MS with a VARIAN Spectrometer ICP-VISTA coupled to a mass spectrometer.

Quality control and statistical analysis

HPLC limits of detection (LOD) of vitamin C, β-carotene, and vitamin B12 were determined using a 5 point external calibration systematically performed before each series of analyses. The spectrophotometer limits of detection (LOD) used for mineral determination was a 5 point calibration and analysis of control samples whose mineral contents were known. All analyses were carried out in duplicate and the data were analyzed using SAS software (version 8.1 2000; SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

The results from Table 1 show that the algae *M. senegalense* is very low on lipid content (0.08 mg /100 g) and rich in carbohydrates especially with a dry weight fiber content of 6.67%. The protein content was 6.38% and the minerals were relatively abundant most notably magnesium (216.87 mg/100 g), calcium (81.6 mg/100 g) and iron (28.13 mg/100 g). Moreover, *M. senegalense* also contained a significant concentration of iodine (31.16 mg/kg) zinc (3.31 mg/100g) and copper (2.43 mg/100g). Vitamin B12, an essential hydrosoluble vitamin was found at a concentration of 20 mg/kg. However, the vitamin A and vitamin C content were relatively low 0.7 mg/kg of sample and < 10 mg/kg respectively.

In this study, sample averages were obtained during a complete season and showed large variances for calcium (17.5 mg/kg) and magnesium (12.9 mg/kg) due to the minima and maxima values (64 and 99 for Ca; 203 and 228.5 for Mg). These variations could be related to

Table 1. Average chemical composition of *Meristotheca senegalense*

Components	Average (n=3)	Components	Average (n=3)
Lipid (mg/100 g)	0.08± 0.1	Zn (mg/100g)	3.31 ± 0.26
Protein (%)	6.38± 0.8	Cu (mg/100g)	2.43 ± 0.13
Fibers (%)	6.67± 0.7	Iodine (mg/kg)	31.16 ± 1.5
Ca (mg/100 g)	81.6 ± 17.5	Vitamin B12 (mg/kg)	20 ± 1.0
K (mg/100 g)	9.25 ± 2.58	Vitamin C (mg/kg)	< 10
Mg (mg/100 g)	216.87 ±12.9	Vitamin A (mg/kg)	0.7± 0.06
Fe (mg/100 g)	28.13± 2.15		

Table 2. Comparative study between *M. senegalense* and other macroalgae species.

Species*	Protein (%)	Lipid (%)	Fibers (%)	Ca (mg/100 g)	Fe (mg/100 g)	Zn (mg/100 g)	Cu (mg/100 ng)	Vit. B12 (mg/kg)
<i>M. senegalense</i> ¹	5.6 -7.2	2-8.10 ⁻⁵	6 -7.5	64-99	25.7- 29.8	3.1- 3.6	2.3-2.5	20
<i>Ulva lactuca</i> ²	10-25	0.6-1.6	29-55	840	66	-	-	600
<i>Laminaria digitata</i> ^{2,3}	8-15	1	36-37	1005	3.2-9	1.77	< 0.5	0.05
<i>Undaria pinnatifida</i> ²	12-23	1.0-4.5	16-51	680-1380	1.54-30	0.94	0.18	0.36
<i>Chondrus crispus</i> ²	11-21	1-3	10-34	420-1120	1.54-30	7.14	< 0.5	60- 400
<i>Palmaria palmata</i> ²	8-35	0.7-3	29-46	560-1200	50	2.86	0.37	0.9
<i>Porphyra tenera</i> ²	28-47	0.7-1.3	12-35	390	10-11	2-3	< 0.63	-
<i>P. umbilicalis</i> ²	29-39	0.3	29-35	330	23	-	-	2.9
<i>P. yezoensis</i> ^{2;3}	31-44	2.1	30-59	440	13	10	1.47	0.52

*Results expressed according to the dry wet; ¹this article; ²Pereira (2011). ³Pèrez (1997).

seasonal aspects of the samples which are linked to the physiological state of *M. senegalense* during Sample collection was in April, May (cold season) and June (beginning of the warm season).

M. senegalense was compared to other edible seaweeds (Table 2). The results show that *M. senegalense* contains less fiber and calcium compared to other species; whereas, the vitamin B12 contents of different edible seaweeds were highly variable. When considering seafood as an important source of iodine both red and brown algae are generally richer in iodine than green algae (Fleurence and Guéant, 1999). According to Teas et al. (2004) *Rhodophyceae* contained 10 to 100 mg/kg of iodine similar to the content of

Palmaria palmata, while species like *Porphyra umbilicalis* and *Undaria pinnatifida* had iodine contents of 17.3 and 22 to 30 mg/kg respectively. The results of this study show that *M. senegalense* is a good source of iodine with an higher average concentration (31.16 mg/kg) than the species mentioned above. In the past years important actions were taken by world organizations, such as World Health Organization, to fight against iodine deficiency. The recommended concentration of iodine in iodized salt was fixed at 30 mg/kg. Therefore, *M. senegalense* could be a valuable dietary source of iodine. The specie used in this study could be used to fill the gap of iodine

concentration in many foods which WHO and other organizations have suggested as an alternative source of iodine. In this context, *M. senegalense* should be promoted as a new local food. In fact edible seaweeds present many advantages such us the quality of their fatty acids content (Khotimchenko and Levchenko, 1997), traces metals such us Fe, Zn, Cu (Robledo and Pelegrin, 1997) or iodine content (Teas et al., 2004; Zava and Zava, 2011). In addition, some reports have shown quality protein content in some species including *Chlorophyta* and *Rhodophyta* (Galland-Irmouli et al., 1999; Fleurence and Guéant, 1999).

Although *M. senegalense* is considered as a rich source of iodine, the FDA and other world dietary guidance programs warn that consumption of excess iodine rich seaweeds could be dangerous for health (Brownlee et al., 2012; Leung and Braverman, 2014). An example of the potential health risk was reported by Brownlee et al. (2012), when seaweed was used in a study composed of lactating mothers in Japan and Korea. They found that the high concentrations of iodine in seaweed were transmissible from mother to infant through breast milk which could result in neonatal iodine toxicity and subsequent hypothyroidism or hyperthyroidism. However, *M. senegalense* could be very valuable in new foods which are rich in iodine.



Figure 2. Plant of *Meristotheca senegalense* collected during May 2010 at Ngor Bay. Scale bar = 5 cm.

Currently new types of foods are been developed using *M. senegalense* as a source of some important nutrients such calcium, magnesium and iron as well as iodine.

The increase of the local consumption of this endemic seaweed in spite of exportation will also induce development of local markets.

Conclusion

Like other seaweed, *M. senegalense* could be an important source of nutrients, iodine, minerals and vitamin B12. These results also show that these red algae can be added to the human diet and diversify world food sources however, further studies are needed in order to boost the added value of *M. senegalense*. Farming of *M. senegalense* could promote diversification of fishing activities reducing pressure on other marine resources and contributing to sustainable food production.

Conflicts of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors would like to thank first program of the

Ministry of High Education and Scientific Research of Senegal Government for funding this research and Dr. Applegate at Purdue University for editing the paper.

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