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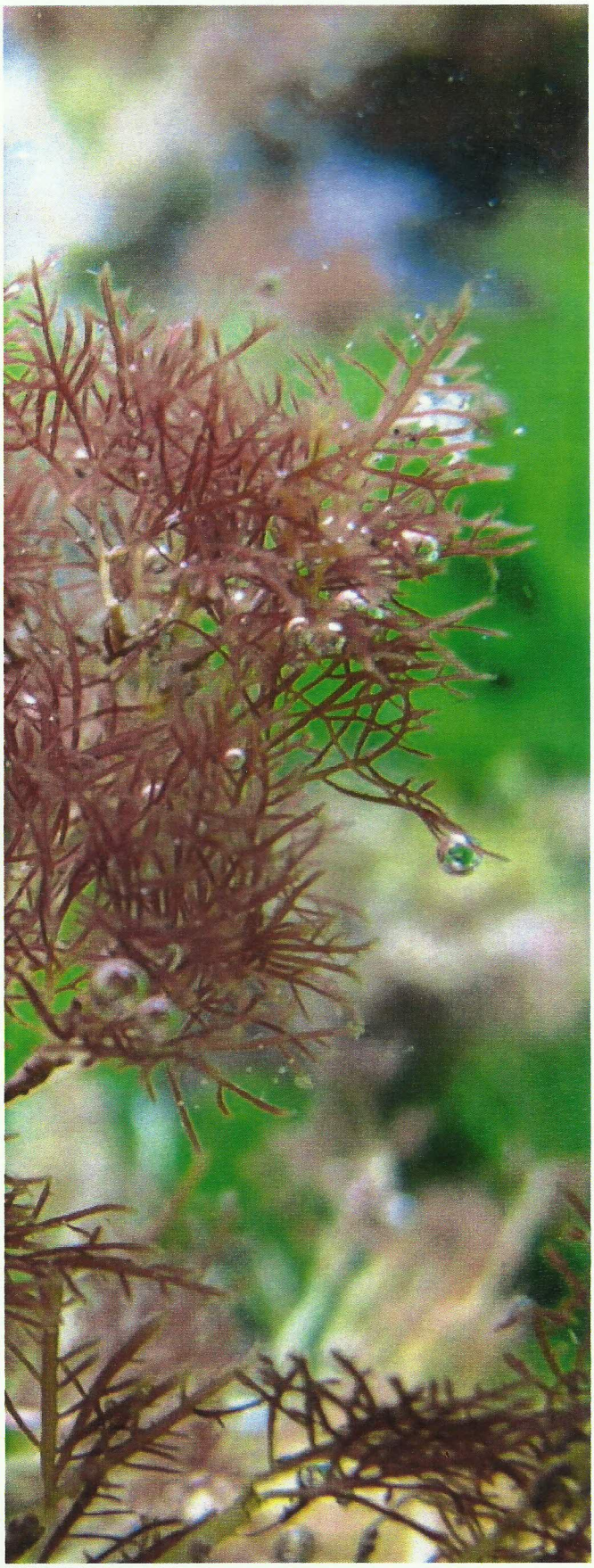

The mineral composition value of selected Azorean macroalgae with beneficial impact on human cardiovascular health

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Abstract

In view of the current increasing demand of macroalgae for human consumption, due to its high nutritional and health-promoting value, this study determines the ash content and investigates the macromineral composition in seven selected Azorean macroalgae (the Chlorophyta Ulva compressa and Ulva rigida, the Ochrophyta Fucus spiralis and the Rhodophyta Gelidium microdon, Osmundea pinnatifida, Porphyra sp. and Pterocladiella capillacea) in order to estimate its potential impact on human cardiovascular health. The ash content of the studied macroalgae (dry weight basis) ranged from 10.7±0.2% (P. capillacea) to 38.6±0.7% (O. pinnatifida), which is higher than that of the most common vegetables. Thus, these macroalgae can contribute with essential microelements to human and animal nutrition. Regarding the macromineral composition, as compared to some common foods, the results revealed that F. spiralis, G. microdon, O. pinnatifida and P. capillacea presented a well-balanced Ca/Mg ratio (approx. 1:1) and consequently a potential positive effect on heartbeat regulation and myocardial infarction protection. The results also revealed that all studied macroalgae presented a low Na/K ratio (< 2) and, consequently, a potential human hypotensive effect. Thus, the results suggest that a regular consumption of the studied Azorean macroalgae, either directly or through food supplements, may have a protective effect on cardiovascular diseases, the world´s most common cause of Human death.

Keywords: Edible macroalgae; ash; macrominerals; dietary Ca/Mg ratio; dietary Na/K ratio; heartbeat rate; myocardial infarction; hypertension; cardiovascular health.

Taking into account that in recent decades, consumer awareness increased regarding the influence of diet on health and well-being and that worldwide demand for macroalgae, as a natural source of functional ingredients, is growing, several reports on the biochemical composition of edible macroalgae have been published. Published sources are lack of information on the amount of some important nutrients and their potential use. For example, the dietary intake ratios of Ca/Mg and Na/K are rarely highlighted, despite its importance on cardiovascular health.

It is well known that the heart muscle is composed of billions of cells working as an electrochemical generator. Thin fibers on the outer surface of the heart cells are stimulated by Ca and then relaxed by Mg, which produce an electrical charge that pushes Ca to the opposite side of the cell. Thus, Ca helps to produce the heartbeat and Mg regulates it. This complementary activity of Ca and Mg can only be achieved if these minerals are provided to our body in balanced amounts (Seelig and Heggtveit, 1974; Rosanoff, 2010). According to previous physiological studies (for example,

Matyushin and Samartseva, 1972; Anderson *et al.*, 1975), during a heart failure, some Mg is moved out of the cell resulting in an influx of Ca into the cell and a drastic unbalance in the Ca/Mg ratio. Thus, the heart muscle will show a 20-30% decrease in Mg and a 4 fold increase in myocardial Ca, which disturbs the potential energy of the affected muscle. It is also well known that Mg supplements are one of the most effective type of therapy to protect myocardial integrity during cardiac arrest (Almoznino-Sarafian et al., 2009) and can also cause vasodilatation and lower hypertension (Singh et al., 1976; He *et al.*, 2010). Besides the Ca/Mg ratio, another important mineral ratio in dietary food is the Na/K. In fact, it is also well known that the intake of sodium chloride and diets with a high Na/K ratio have been related to the higher incidence of hypertension (Cook *et al.*, 2009), one of the major causes of cardiovascular diseases. Food with low Na/K ratio can therefore help balance high Na/K ratio diets.

Macroalgae are abundant and structuring organisms on the coastal areas of the Azores Islands located in the middle of the Atlantic Ocean, and known as environmentally healthy habitats. Traditionally, the Azorean population has gathered macroalgae either as food (for example, *F. spiralis, Porphyra sp., Laurencia, Osmundea* and *Ulva*) or for agar production (for example, *G. microdon* and *P. capillacea*) (Paiva *et al.*, 2016).

The aim of the present study was to determine the ash content and to investigate the macromineral composition in seven selected Azorean macroalgae (SAM) in order to (1) estimate its potential effect on the correction of the unbalanced Ca/Mg ratio and, consequently, on the impact of heartbeat regulation and myocardial infarction, and (2) evaluate its potential impact on hypertension by Na/K ratio value.

Materials and methods

Fucus spiralis Linnaeus, *Gelidium microdon* Kützing, *Osmundea pinnatifida* (Hudson) Stackhouse and *Pterocladiella capillacea* (S.G. Gmelin) Santelices & Hommersand samples were collected in January of 2013, in "ETAR da Pranchinha" *(F. spiralis, G. microdon* and *O. pinnatifida*) and in "Praia do Pópulo" (*P. capillacea*). *Porphyra* sp. C. Agardh was collected in January of 2007, in "Ihéu de São Roque". *Ulva compressa* Linnaeus and *Ulva rigida* C. Agardh were collected in April of 2013, in "Forno da Cal". All these macroalgae samples (Figure 1) were from the intertidal zone of the coast of São Miguel Island (Azores Archipelago, Portugal), and were stored dried at a cold temperature. Voucher specimens were deposited in the Herbarium AZB – Ruy Telles Palhinha of the Department of Biology at the University of Azores.

The total inorganic material (ash) of the SAM samples was determined as described by Paiva *et al.* (2014)

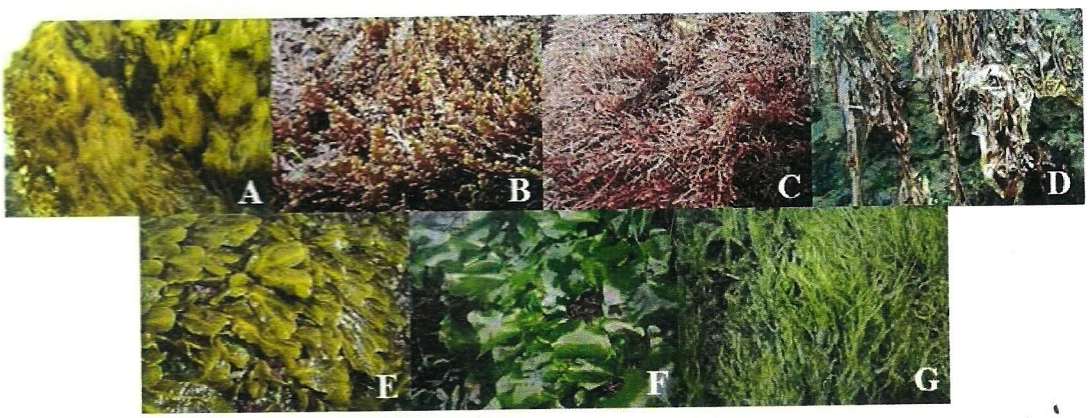

Figure 1 - Selected Azorean macroalgae. A. Gelidium microdon; B. Osmundea pinnatifida; C. Pterocladiella capillacea; D. Porphyra sp.; E. Fucus spiralis; F. Ulva rigida; G. Ulva compressa. (Photos by Azorean Biodiversity Group - Azores University).

samples was determined as described by Paiva *et al.* (2014), and its minerals content was determined by ionic chromatography on an universal cation exchange free-metal column (10 cm x 4.6 mm i.d., 7 µm particle size) from Alltech Associates (Deerfield, IL, USA) as described by Paiva *et al.* (2014, 2016).

Results and discussion

The ash content (dry weight basis) in SAM (see Table 1) presented the highest value in *O. pinnatifida* (38.6%) followed by *Porphyra* sp. (28.2%), *F. spiralis* (22.3%), *G. microdon* (20.7%), *O. pinnatifida* (38.6%) followed by *Porphyra* sp. (28.2%), *F. spiralis* (22.3%), *G. microdon* (20.7%), *U. rigida* (20.6%) and *U. compressa* (18.0%), and the lowest in *P. capillacea* (10.7%), and was within the ranges previously reported for marine algae and algal food products (8–44%) (Rupérez, 2002; Paiva *et al.*, 2018). Rupérez (2002) reported similar values for the edible *Fucus vesiculosus* (30.10%) and *Porphyra tenera* or Nori (20.59%) from Pontevedra (Spain). These values were higher than those reported by USDA (2001) for land plants (5–10% dry weight), due to the extraordinary ability of macroalgae to accumulate minerals present in the water (Rupérez, 2002). Thus, incorporating edible algae or products derived from them in human and animal nutrition may contribute with important microelements, such as Fe, Zn, Cu, Se and I (Matanjun *et al.*, 2009), which are low or absent in some land vegetables.

Concerning the macromineral composition, Table 1 shows that the Ca, Mg, K and Na content is generally higher in SAM than that in some common foods (McCance et al., 1993). For the Ca/Mg ratio, the values in SAM ranged from 0.15 to 1.07. It can be noted that *G. microdon* (0.59), *F. spiralis* (0.72), *O. pinnatifida* (0.98) and *P. capillacea* (1.07) revealed a well-balanced Ca/Mg ratio (approx. 1:1) than some common foods and, consequently, a potential positive effect on heartbeat regulation and myocardial infarction protection. Rupérez (2002) reported the range of 0.57 to 1.53 for the Ca/Mg ratio of several edible brown and red macroalgae, presenting the *F. vesiculosus* the well-balanced ratio (0.94).

As mentioned above, most of the SAM showed higher Na content than that in some common foods (Table 1).

Table 1 - Ash (g/100 g dry weight) and macromineral content (mg/100 g dry weight)a in selected Azorean macroalgae compared to some common whole foods (adapted from Paiva et al., 2014, 2016, 2017).

Macroalgae and Foods	Minerals				Mineral ratios		Ash
	Na	K	Ca	Mg	Na/K	Ca/Mg	
Fucus spiralis	1429.0±4.2	975.9±3.5	118.1±0.4	163.2±0.7	1.46	0.72	22.3±0.4
Gelidium microdon	433.1±2.6	1239.0±3.0	74.7±0.2	127.0±0.4	0.35	0.59	20.7±0.2
Osmundea pinnatifida	2669.2±9.3	1464.2±4.5	411.5±2.7	418.6±2.1	1.82	0.98	38.6±0.7
Porphyra sp.	2382.6±7.8	2481.1±10.8	124.5±0.5	396.4±2.9	0.96	0.31	28.2±0.5
Pterocladiella capillacea	635.6±3.3	2369.5±10.5	174.0±1.5	162.7±1.3	0.27	1.07	10.7±0.2
Ulva compressa	1322.5±3.2	693.3±2.3	242.6±1.2	1594.1±3.1	1.91	0.15	18.0±0.2
Ulva rigida	576.1±2.3	817.5±3.8	324.9±1.9	1775.1±4.7	0.70	0.18	20.6±0.3
Brown rice[b]	28.0	1160.0	110.0	520.0	0.02	0.21	-
Whole milk[b]	55.0	140.0	115.0	11.0	0.39	10.45	-
Cheddar cheese[b]	670.0	77.0	720.0	25.0	8.70	28.80	-
Sirloin steak[b]	49.0	260.0	9.0	16.0	0.19	0.56	-
Bananas[b]	1.0	400.0	6.0	340.0	0.003	0.02	-
Peanuts[b]	2.0	670.0	60.0	210.0	0.003	0.29	-

[a] Values are mean ± SD (n = 3). [b] Values for whole foods from McCance et al. (1993) in mg/100g weight.

common foods (Table 1). Nevertheless, Na/K ratios were low in all SAM (0.27–1.91), specially the *P. capillacea* (0.27), *G. microdon* (0.35) and *U. rigida* (0.70). Rupérez (2002) also reported low Na/K ratios, below 1.5, for several edible brown and red macroalgae (0.33–1.34). These results are interesting from the nutrition point of view, since the diets with a high Na/K ratio have been related to the incidence of hypertension. Thus, SAM could have a potential human hypotensive effect.

Conclusions

The balanced Ca/Mg and Na/K mineral ratios found in selected Azorean macroalgae suggested that their regular consumption may improve heartbeat regulation and have myocardial infarction protection (particularly P. capillacea, O. pinnatifida and F. spiralis), and can also reduce hypertension (particularly *P. capillacea, G. microdon* and *U. rigida*) with undoubtable beneficial impact on human cardiovascular health. In addition, the high ash content (particularly in *O. pinnatifida* and *Porphyra* sp.) can also contribute with essential microelements to human and animal nutrition that are low or absent in some of the common nutritional land vegetables.

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