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ORIGINAL RESEARCH

Variations in the proximate composition of the sea cucumber, *Isostichopus* sp. aff *badionotus*

Katrina Medina-Lambraño . Ernesto J. Acosta-Ortíz . Adriana Rodríguez-Forero

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Abstract Holothurians or Sea cucumbers are animals belonging to the phylum Echinodermata, which in recent decades have become important, mainly because they are considered in Asian countries as a high-quality food product, with pharmaceutical properties and high economic value. This has led to the overexploitation of this resource in several countries, including Colombia. Several studies worldwide affirm that sea cucumbers have a high nutritional content. However, there is not much information on the species of commercial interest exploited in the Colombian Caribbean Sea. Therefore, the aim of this study was to evaluate the variation of the proximate composition of sea cucumber, *Isostichopus* sp. aff *badionotus* in the Colombian Caribbean region of Santa Marta, depending on the collection area, climatic season and maturity stage. Wild sea cucumbers were collected from Rodadero and Taganga Bays, and its muscle was processed. The protein, moisture and ash contents were determined in the ranges of 3.33-7.21%; 89.17-93.26%; 3.1-3.97%, respectively. Significant differences were observed amongst months and the collection area in relation to these values, nevertheless, fat percentage (0.03 to 0.07%) did not register significant differences. The GSI varied significantly between the collection area and months (0.06 and 10.44%). Nutritional quality of the muscle of *Isostichopus* sp. aff *badionotus* is similar to that obtained in other sea cucumbers of interest marketed worldwide.

Keywords Caribbean Sea . Nutritional value . Seasonal variation . Sea cucumber

Introduction

The high economic value of sea cucumbers, coupled with the high demand of Asian markets, led many Asian countries to overfish their local species, leading to the expansion of this fishery worldwide, including the Colombian Caribbean in order to meet market demands (Purcell 2010). Several studies worldwide state that sea cucumber has a great commercial and economic impact in Asian countries because of their medicinal, nutritional and cultural values (Purcell et al. 2018; Purcell et al. 2012). Its nutritional content has been well studied (Tanikawa et al. 1955; Zaboukas et al. 2006; Zhong et al. 2007; Wen et al. 2010; Ridzwan et al. 2014; Vergara and Rodríguez 2016; Widianingsih et al. 2016), however, those, inhabitants of the Caribbean Sea have minor concerns. In Colombia, sea cucumber fishing is not a traditional fishery, however, many fishing communities have seen in this activity an additional source of income, encouraged by traders mostly of Asian origin (Rodríguez et al. 2013). The first reports of fishing for sea cucumbers in

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Colombia date back to 2006 in the area of Bahía Portete, in La Guajira, also catches have been reported in the Santa Marta City (Taganga Bay) (Gracia-Clavijo et al. 2011; Rodríguez et al. 2013). According to FAO fisheries statistics (FAO 2020), 51.247 tons of sea cucumber have been marketed in 2018, 17367 tons of which was imported from the Asian countries.

The high demand for this resource originates in the traditions and culture of Asian countries, where sea cucumbers are considered a gastronomic delicacy of high nutritional value and with medicinal properties (Conand 1981; Toral-Granda et al. 2008), which is why several studies affirm that the sea cucumber trade has generated a great commercial and economic impact. This has motivated the development of several studies in relation to its nutritional content.

However, in the Colombian Caribbean Sea despite the fact that for more than 20 years there has been illegal, unregulated and unquantified fishing of several species of Sea cucumbers, mainly of the genus Isostichopus due to its high value (Gracia-Clavijo et al. 2011; Purcell 2012; Rodríguez et al. 2013; Purcell et al. 2018; FAO 2020), research on species with economic potential including *Isostichopus* sp. aff *badionotus*, has been few, focusing mainly on aspects related to ecology, reproductive biology and culture (Agudelo and Rodríguez 2015; Acosta et al. 2020). While research in relation to their proximate composition has been really scarce (Pastrana et al. 2016; Vergara and Rodríguez 2016; Hernández et al. 2017). Although the chemical composition of seafood is influenced by factors such as area of capture, habitat, climatic season, food availability and reproductive stage among other (Zaboukas et al. 2006; Diniz et al. 2012; Dubischar et al. 2012), these factors have not been considered in the studies conducted so far in relation to the proximal composition of sea cucumbers native to the Colombian Caribbean. Therefore, the development of this research is aimed at deepening the nutritional composition of *Isostichopus* sp. aff *badionotus* in Colombian Caribbean Sea to establish its variation with respect to seasonality, catch area and gonodosomatic index.

Materials and methods

Study site

The collection of sea cucumbers was carried out in two bays in the Santa Marta region, Taganga Bay (11°16' 07.42" N – 74° 11' 37.16" W) and Rodadero Bay (11°12' 27.40" N - 74°13' 47.44" W), from December 2016 to November 2017. This region is characterized by presenting a semi-arid tropical climate, with a dry season from December to March, the rainy season from June to November and the transition season from April to May with average water temperatures of 24.3 °C to 33.3 °C in the rainy season and 21.8°C at 33.4 °C in the dry season (Díaz et al. 2000; CIOH 2013) (Fig. 1).

Sampling and proximal chemical analysis

During the study, between 8 and 10 sea cucumbers were collected monthly by snorkeling with the help of artisanal fishermen from each Bay. However, in Taganga Bay it was not possible to collect specimens in July, August, October and November due to unusual weather events (strong winds, rains, tropical storm Bret, mini tsunami, hurricane Kryan and tropical storm Harvey).

Sea cucumbers were transported in tanks with seawater at an average temperature of 15 °C to the facilities of the Aquaculture laboratory of the Universidad del Magdalena. In the laboratory, the individuals were photographed and weighed (Ohauss electronic balance, 0.1g precision). Then they were sacrificed with a cold thermal shock, attending Good Animal Welfare Practices (National Institutes of Health, Office of Animal Care and Use 2009). The dissection was performed with a ventral cut in the anus-mouth direction and the weight of the body wall without internal organs (W) and the weight of the gonad (Wg) were recorded and the gonadosomatic index (GSI) was calculated with the following formula:

$$GSI = (Wg / W) \times 100\%.$$

From the middle portion of the body wall of each individual, between 40 to 50 g of muscle were extracted for the performance of the analyzes of chemical composition as described by the Association of Official Analytical Chemists (AOAC 1990). Crude protein (N 6.25) was measured according to the micro-

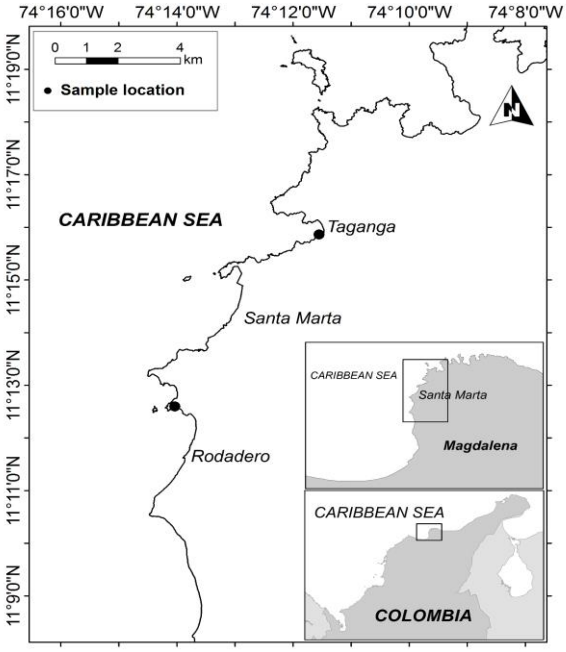


Fig. 1 Study area, Taganga Bay and Rodadero Bay. Box in inset A is magnified in inset B; box in inset B is magnified in the main panel. Source: Information base INVEMAR.

Kjeldahl method; fat by diethyl ether extraction in a Fosstech analyzer after HCl^- hydrolysis; moisture by drying in conventional oven and ash by combustion for 15 h at 550 °C. Each analysis was carried out in triplicate.

Statistical analysis

One-way ANOVA tests were performed to determine whether one or more of the components of the proximate analysis (protein, fat, ash and moisture) is affected by variables such as months of the year, climatic season and/or area of capture. The homogeneity and normality of the data were tested using Levene's test and the Kolmogorov-Smirnov test, respectively. The relationship between the gonadosomatic index and the components of the proximal analysis was performed through a two independent samples comparisons test. Significance was set at $P < 0.05$. Statistical analyses were performed with Statgraphics Centurion vs. XVII.

Results

Protein levels of sea cucumber muscle captured in the Taganga Bay showed significant differences ($P > 0.05$), in June with respect to December to March and September, with values of 4.04% and 7.01% (Table 1). For the ash contents there were statistically significant differences ($P > 0.05$), amongst the groups of months. September showed differences with respect to January, June, and December, with values ranging between 3.31% and 3.91%. In May, differences were observed with respect to January to March (3.48% and 3.91%) and between April and February (3.66% to 3.91%) (Table 1) (Fig. 2). However, there were no significant differences ($P > 0.05$) in fat values in any of the sampled months whose records ranged between 0.04% and 0.06% (Table 1) (Fig. 2). Finally, in the moisture contents, significant differences were found ($P <0.05$) in June in relation to January to March, May, September and December (89.22% - 91.62%) (Table 1) (Fig. 3).

In sea cucumbers captured in the Rodadero Bay, protein values ranged between 3.33% and 7.21% and statistical differences were observed ($P <0.05$), in June in relation to January to May, July, September to November and December. There was a difference in April with relation to August (Table 1) (Fig. 4). For ash contents there were significant differences ($P <0.05$), in November in relation to January to July and December. In these months, data were between 3.1% and 3.9%. Significant differences were also observed

Table 1 Proximal chemical composition (mean ± standard deviation) of sea cucumber (*Isostichopus sp. aff badionotus*) muscle during one year of sampling (December 2016 to November 2017), in both collection areas. N = 189.

SEASON	Month	Proximate Composition of sea cucumbers							
		% Protein		% Fat		% Ash		% Moisture	
		Taganga	Rodadero	Taganga	Rodadero	Taganga	Rodadero	Taganga	Rodadero
DRY SEASON	December	5.21 ± 1.07^{b}	5.11 ± 1.20^{b}	0.05 ± 0.02	0.04 ± 0.03	3.71 ± 0.11^{b}	3.75 ± 0.12^{bdj}	91.03 ± 1.07^{b}	91.11 ± 1.16d
	January	4.55 ± 0.96^{b}	4.17 ± 1.35^{b}	0.05 ± 0.03	0.07 ± 0.02	3.77 ± 0.21^{bd}	3.83 ± 0.17^{bdfj}	91.62 ± 0.88^{b}	91.93 ± 1.40^{b}
	February	4.71 ± 1.03^{b}	3.48 ± 1.61^{b}	0.05 ± 0.02	0.03 ± 0.02	3.91 ± 0.15^{bdf}	3.9 ± 0.25^{bdfgjk}	91.33 ± 1.01^{b}	92.59 ± 1.56^{b}
	March	4.78 ± 0.99^{b}	4.61 ± 0.95^{b}	0.05 ± 0.03	0.04 ± 0.02	3.80 ± 0.11^{bd}	3.97 ± 0.18^{bdf}	91.37 ± 0.96^{b}	91.39 ± 1.06^{b}
TRANSITION SEASON	April	5.74 ± 1.78	3.33 ± 1.32^{bc}	0.06 ± 0.03	0.03 ± 0.02	3.66 ± 0.15^{be}	3.73 ± 0.13^{bdj}	90.54 ± 1.85	92.91 ± 1.34^{b}
	May	5.12 ± 1.61	3.80 ± 1.79^{b}	0.04 ± 0.03	0.06 ± 0.02	3.48 ± 0.18^{bc}	3.73 ± 0.21^{bdj}	91.35 ± 1.55^{b}	92.41 ± 1.75^{b}
	June	7.01 ± 1.13^{a}	7.21 ± 1.18^{a}	0.05 ± 0.02	0.04 ± 0.03	3.71 ± 0.17^{b}	3.57 ± 0.34^{bdhl}	89.22 ± 1.02^{a}	89.17 ± 1.13^{a}
	July		4.70 ± 1.88^{b}		0.04 ± 0.03		3.58 ± 0.31^{bdh}		91.67 ± 1.86^{b}
RAINY SEASON	August		5.39 ± 0.89^{d}		0.06 ± 0.02		3.28 ± 0.13^{hi}		91.28 ± 0.91^{b}
	September	4.04 ± 1.15^{b}	3.42 ± 1.11^{b}	0.04 ± 0.02	0.06 ± 0.02	3.31 ± 0.08^{a}	3.26 ± 0.21^{c}	92.61 ± 1.19^{b}	93.26 ± 1.06^{bc}
	October		3.43 ± 1.19^{b}		0.05 ± 0.03		3.42 ± 0.09^{e}		93.10 ± 1.28^{b}
	November		4.21 ± 1.34^{b}		0.04 ± 0.02		3.1 ± 0.18^{a}		92.66 ± 1.25^{b}
Max value		7.01 ± 1.13	7.21 ± 1.18	0.06 ± 0.03	0.07 ± 0.02	3.91±0.15	3.97 ± 0.18	89.22 ± 1.02	93.26 ± 1.06
Min value		4.04 ± 1.15	3.33 ± 1.32	0.04 ± 0.03	0.03 ± 0.02	3.31 ± 0.08	3.1 ± 0.18	92.61 ± 1.19	89.17 ± 1.13

[abc] Values in the same column with different superscripts are significantly different (P <0.05).

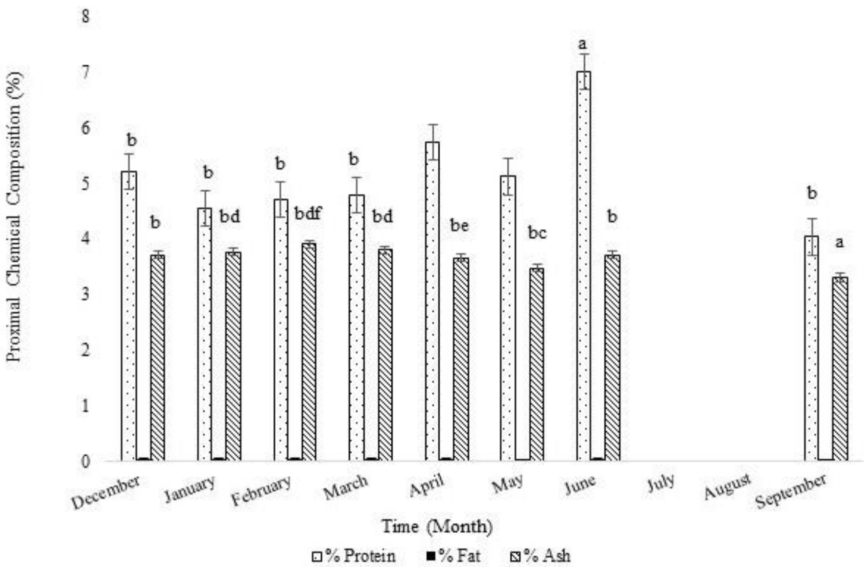


Fig. 2 Proximate analysis of sea cucumber muscle *Isostichopus* sp. aff *badionotus*, in percentages of crude protein, fat and ash, during the sampling months in the Taganga area. Frozen samples, N= 72.

between September and January to July and December (3.26% to 3.9%). October showed differences with respect to January to March, registering data between 3.4% and 3.9% there were also differences in the values of ash (3.57% to 3.9%) in March in relation to June, July and August. In August, ash contents showed statistical differences with respect to January, February, April, May and December (3.3% to 3.9%). In addition, there was a difference between February and June for ash contents with values between 3.9% to 3.57%. There were no significant differences ($P > 0.05$) in the fat analysis in the sampled months (Table 1) (Fig. 4). Finally, for the moisture contents, there were significant differences ($P < 0.05$) in June as regards January to May, July, August, November, October, and September and amongst September and December (Table 1) (Fig. 5).

One hundred seventeen sea cucumbers were obtained in the Rodadero Bay and seventy-two in the Taganga Bay. Between the zones, the values of the proximal analyzes of the cucumbers showed statistically significant differences in proteins, moisture and ash contents ($P < 0.05$). For protein contents, the values varied between 2.75% and 4.27% for Rodadero Bay, while for Taganga, the values were 3.23% to 4.17%

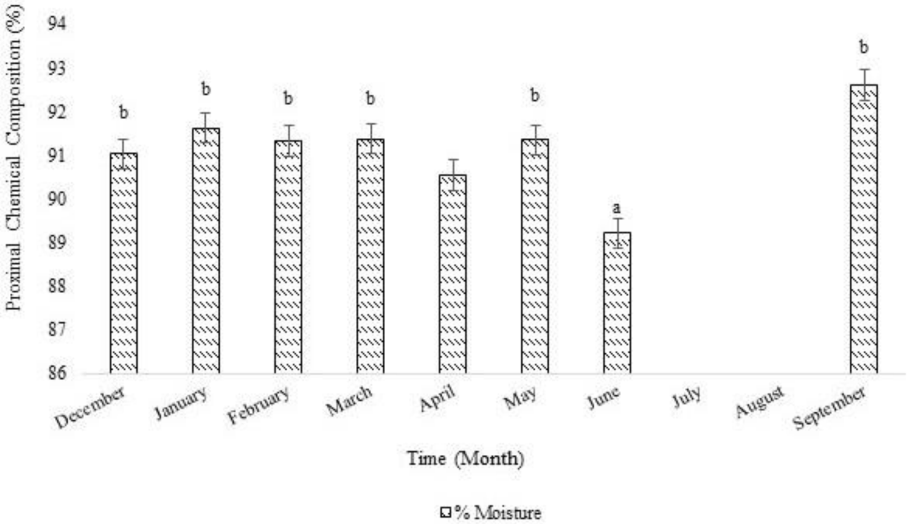


Fig. 3 Proximate analysis of sea cucumber muscle *Isostichopus* sp. aff *badionotus*, in percentages of moisture, during sampling months in the Taganga area. Frozen samples, N= 72. abc Values in the same bar with different superscripts are significantly different (p <0.05).

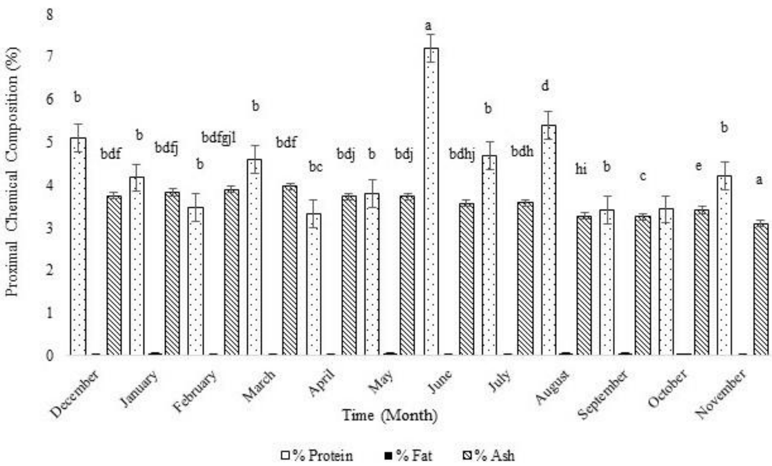


Fig. 4 Proximate analysis of sea cucumber muscle *Isostichopus* sp. aff *badionotus*. Variation in percentages of crude protein, fat and ash, during the sampling months in the Rodadero area. Freezing samples, No. 117. abc Values in the same bar with different superscripts are significantly different (p <0.05).

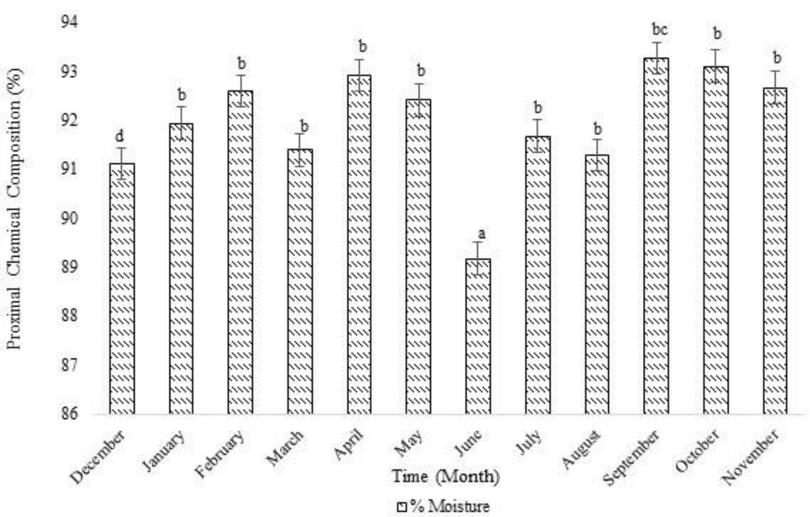


Fig. 5 Proximate analysis of sea cucumber muscle *Isostichopus* sp. aff *badionotus*, in sampling months in the Rodadero area. Frozen samples, N= 117.

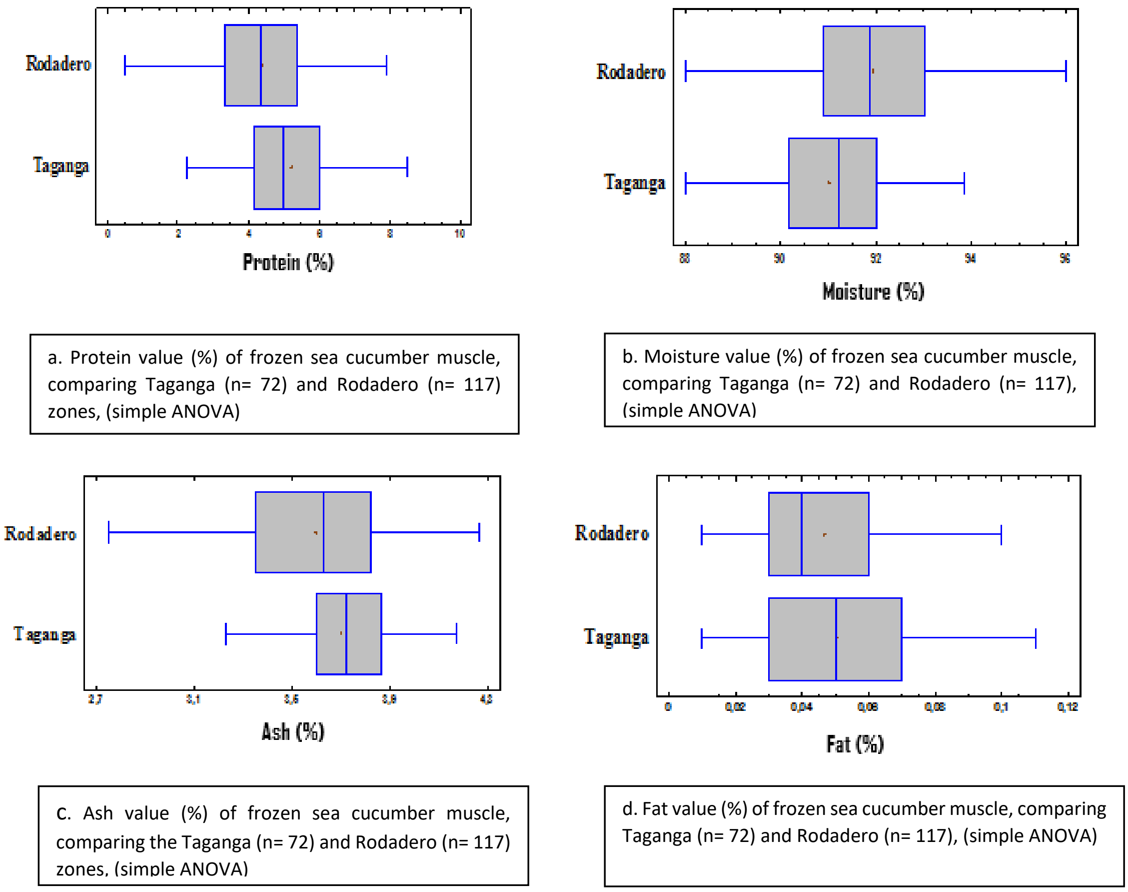
(Fig. 6a). In the case of moisture content, the values ranged between 88.02% and 95.99% in the Rodadero and from 88.0% to 93.87% in Taganga (Fig. 6b). In the case of ash contents, the values for Rodadero were found asbetween 2.75% and 4.27%, and between 3.23% to 4.17% for Taganga (Fig. 6c). Finally, fat content of sea cucumbers did not show significant differences ($P > 0.05$), presenting values varied in 0.01% to 0.1% (Fig. 6d).

Determination and relationship of the gonadosomatic index with the proximal analysis

For the determination of the gonadosomatic index, the body weight of the eviscerated cucumber was performed, which fluctuates in ranges from 83.5 to 231.84 g. The average gonad weight values of cucumbers from Taganga were 182.2 g and from Rodadero 150.6g; the lowest data (83.5 g), was obtained in the Rodadero (September), and the highest (231.84 g) was recorded in Taganga (March). Regarding the result of the gonadosomatic index, significant differences were observed from average GSI (%) ($P < 0.05$), between the study areas, with a range of 0.06% to 10.44%. Higher percentage value was registered in sea cucumbers captured in August in the Rodadero and the lowest in February in Taganga (Table 2).

For Taganga Bay, significant differences ($P < 0.05$) were presented in the GSI (%) of sea cucumbers in regard to September vs. January, February, May and June (Table 2). In the Rodadero, there were significant differences ($P < 0.05$) between October in relation to January to June, November and December. There were also differences in September related to December, January, March and November. August also presented a significant difference with respect to the months from January to June, November and December and between July and March (Table 2).

There were significant differences ($P < 0.05$) in the relationship between GSI and protein, with values for GSI ranging from 0.06% to 4.37% for Taganga and from 0.73% to 10.44% for Rodadero. Likewise,



a. Protein value (%) of frozen sea cucumber muscle, comparing Taganga (n= 72) and Rodadero (n= 117) zones, (simple ANOVA)

b. Moisture value (%) of frozen sea cucumber muscle, comparing Taganga (n= 72) and Rodadero (n= 117), (simple ANOVA)

c. Ash value (%) of frozen sea cucumber muscle, comparing the Taganga (n= 72) and Rodadero (n= 117) zones, (simple ANOVA)

d. Fat value (%) of frozen sea cucumber muscle, comparing Taganga (n= 72) and Rodadero (n= 117), (simple ANOVA)

Fig. 6 Proximal chemical composition (mean ± standard deviation) of sea cucumber (*Isostichopus sp. aff badionotus*) muscle in two stations

Table 2 Gonadosomatic index (mean ± standard deviation) of sea cucumber *Isostichopus* sp. aff *badionotus* from Taganga and Rodadero. N=110.

Month	GSI (%)	
	Taganga	Rodadero
December	2.22 ± 2.20	1.88 ± 0.94^{bdf}
January	0.67 ± 0.68^{b}	1.64 ± 1.43^{bdf}
February	0.06 ± 0.10^{b}	1.39 ± 1.76^{bf}
March	0.55 ± 1.08	0.64 ± 0.88^{bdfh}
April	0.42 ± 0.42	2.25 ± 1.99^{bf}
May	1.2 ± 0.64^{b}	0.49 ± 0.57^{bf}
June	0.57 ± 0.26^{b}	3.34 ± 1.70^{bf}
July		5.97 ± 2.68^{g}
August		10.44 ± 4.69^{e}
September	4.37 ± 3.12^{a}	6.91 ± 3.05^{c}
October		9.39 ± 5.30^{a}
November		1.18 ± 0.50^{bdf}

^{abc} Values in the same bar with different superscripts are significantly different ($P <0.05$).

the protein content of sea cucumber for Taganga was between 4.04% to 7.01% and for Rodadero was from 3.42% to 7.21%. Based on these results, a similar behavior was shown in Fig. 7 and in Fig. 8 between the months of December to May for both Bays. However, in June in both Bays, GSI of sea cucumbers increases exponentially.

Discussion

Proximal analysis of *Isostichopus* sp. aff *badionotus*

The proximal analysis of species determines their proximal chemical composition; this will depend on their physiological conditions, food, life cycle, weather seasons, maturity status and habitat (Purcell 2010; Diniz et al. 2012; Pastrana et al. 2016; Vergara and Rodríguez 2016). In this study, the results registered for *Isostichopus sp.* aff *badionotus* are close to the ranges reported by other species of sea cucumbers such as *Stichopus japonicus*, *Parastichopus californicus* and *Parastichopus parvimensis* (Tanikawa et al. 1955; Chang-Lee et al. 1989; Wen et al. 2010; Omran 2013; Oedjoe 2017), and for the same species, registered by Vergara and Rodríguez (2016).

The values presented in *Isostichopus* sp. aff *badionotus* shows muscle quality as a possible ingredient in the diet nationwide and worldwide, when compared to traditional meat foods (like pork, chicken or beef). The native cucumber can be offered as a healthy food, for food security, as gourmet food, or for use in the medical, pharmaceutical or cosmetic industry. Several authors (Zhong et al. 2007; Li et al. 2009; Mehmet et al. 2011; Diniz et al. 2012), have verified the quality and nutritional contribution of sea cucumber in Asian and Mediterranean diets, whose values are close to those obtained here. It should deepen in regard to fatty acids, amino acids, vitamins and minerals to complement nutritional assessment of Caribbean Sea cucumber species.

The protein content in fresh sea cucumber muscle presented similar values to those reported by Tanikawa et al. (1955), for dry *Stichopus japonicus* (3.31%) and also by Chang-Lee et al. (1989), (6.78%), in *Parastichopus parvimensis* (5%) and *P. californicus* (6%), as well as the fresh values, of *Isostichopus* sp. aff *badionotus*, found by Vergara and Rodríguez (2016), (2.74% and 6.63%) and by Hernández et al. (2017) (3.12%), which are the same species, but whose name has been changing while its genetic origin was verified (Vergara et al. 2018). These values are not very far from being related to those reported in fresh by Aydin et al. (2011) in *H. polii*, *H. tubulosa* and *H. mammata* (7.88% to 8.82%). On the other hand, the data obtained in this study are located below to those reported by Wen et al. (2010), for *S. herrmanni*, *Thelenota ananas*, *Thelenota anax*, *Holothuria fuscogilva*, *Holothuria fuscopunctata*, *Actinopyga mauritiana*, *Actinopyga*

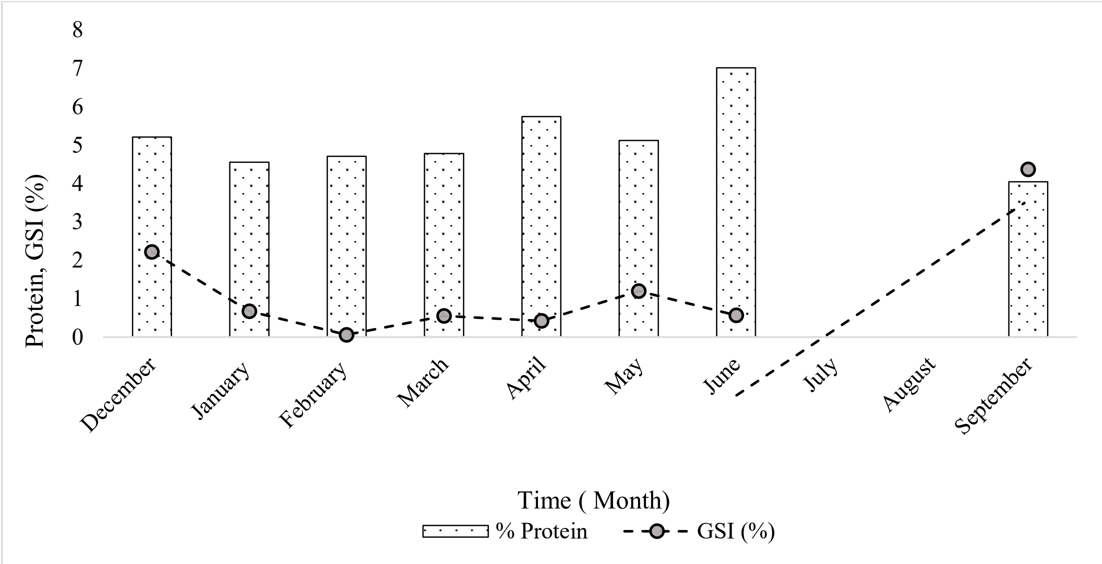


Fig. 7 Gonadosomatic Index (%) and protein content of sea cucumber *Isostichopus* sp. aff *badionotus*, during sampling in Taganga Bay. N= 71. Protein, n=39 GSI. Frozen muscle samples.

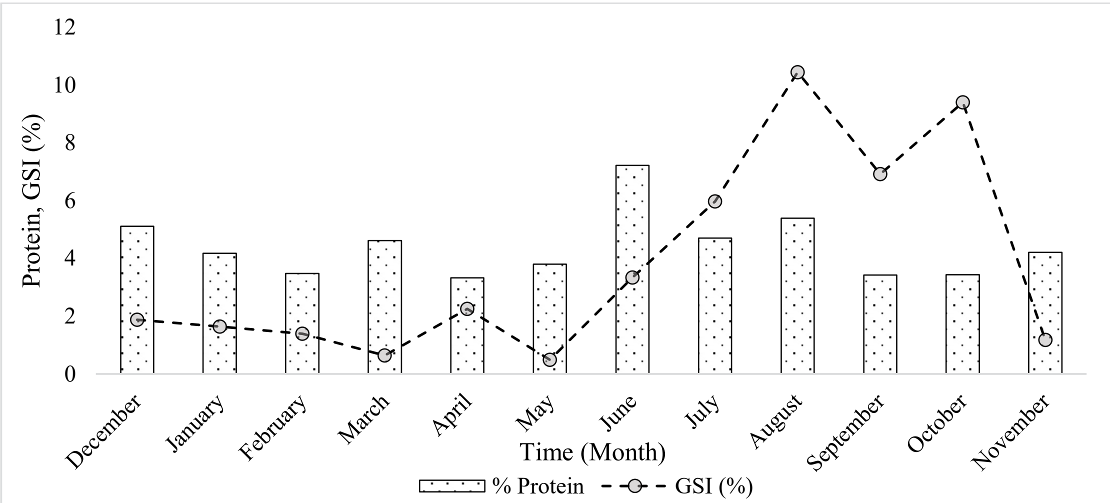


Fig. 8 Gonadosomatic Index (%) and protein content of sea cucumber *Isostichopus* sp. aff *badionotus*, during sampling in the Bay of Rodadero. N= 117 protein, n=39 GSI. Frozen muscle samples

caerulea and *Bohadschia argus* with ranges between 40.7% - 63.3% in dry samples. Also for Omran (2013), for *Actinopyga mauritiana*, *Holothuria scarba*, *Bohadschia marmorata*, *Holothuria leucospilota* (43.23% - 48.27%), in fresh sample; by Hernandez (2015), for *Isostichopus fuscus* (21.02%) in fresh; by Widianingsih et al. (2016), for *Paracaudina australis* (20.22%), in fresh sample, and by Oedjoe (2017), for *Holothuria nobilis*, *Holothuria scabra*, *Holothuria atra*, *Holothuria edulis*, *Holothuria impatiens*, *Holothuria leucospilota*, *Actinopyga lecanora*, *Bahaschia argus* (39.08%), in dry samples.

Past research demonstrated that seasonal changes influence the nutritional contents of sea cucumbers (Chang-Lee et al. 1989; Ginger et al. 2001; Aydin et al. 2011; Hernández 2015; Pastrana et al. 2016; Vergara and Rodríguez 2016; Widianingsih et al. 2016). In this way, the animals sampled reflected fluctuations in percentages of protein content in two Bays with peaks in Rodadero in December, June, August, November and in Taganga in December, April, May, June, showing the highest increase for both zones in June, which is a rainy season. However, Taniwaka et al. (1955) reported that the protein content of *Stichopus japonicus* varied from January to August, while Vergara and Rodríguez (2016) mentioned similar values to those obtained in this study. Of course, a tropical species cannot be compared to a temperate species. These variations can be influenced by multiple factors such as weather conditions, life cycle, sexual maturity, food availability and source, collection areas and physiological characteristics of the individual (Wen et al. 2010; Diniz et al. 2012; Vergara and Rodríguez 2016; Widianingsih et al. 2016).

Regarding the sampling areas, Gámez-Ramírez (2012) states that the average granulometric fractions of sediment (gravel, sand and sludge) in Rodadero Bay have smaller sizes (percentage values) in Rodadero Bay than in the Taganga Bay. Probably, the smaller particles present in the Rodadero Bay would facilitate their capture, consumption and digestion by cucumbers in that area and thus explain their better proximal value compared to those studied in Taganga Bay. In turn, the mouth of the Gaira River which ends into that Bay, brings abundant organic matter that could have a positive impact on the food consumption of cucumbers. Studies on sediments, chlorophyll, and minerals from both areas, as well as the stomach content of sea cucumbers will contribute to confirm these in this hypothesis.

Agudelo and Rodríguez (2015) reported that the reproductive seasons of sea cucumbers are from July to October in the Colombian Caribbean Sea. These months match with the maximum protein value found in the cucumbers sampled in this research. This is explained by the use of nutrients in the reproductive season, to improve the eggs quality during their laying period. It should also stand out that the nutritional value of the feeding of a marine organism will determine the success in the reproduction and its normal embryonic development (Álvarez 2006). And this may be related to the end of the transition season and most of the rainy season. Despite the importance of knowing these changes in the composition and reproduction of native cucumbers, studies related to proximate composition and reproduction are very scarce on the Caribbean Sea.

Then again, fat content of sea cucumbers did not show significant variations amongst sampled the areas and months. The content ranges were slightly below to those reported by Vergara and Rodríguez (2016) and by Hernández et al. (2017), with the same species (0.35% and 0.09%) and far apart when related to those reported by Tanikawa et al. (1955) in fresh *Stichopus japonicus* (0.56% to 2.3%) by Chang-Lee et al. (1989), in the *P. parvimensis* and *P. califomicus* (0.3%), and by Wen et al. (2010) for S. *herrmanni*, *T. ananas*, *T. anax*, *H. fuscogilva*, *H. fuscopunctata*, *A. mauritiana*, *A. caerulea* and *B. argus* which report fat content between 0.3% to 10.1%. On the other hand, Aydin et al. (2011) reported fat contents of 0.09%, 0.15% and 0.18%, for *H. tubulosa*, *H. polii* and *H. mammata*, while Omran (2013) reports 4.6% to 5.66% for *A. mauritiana*, *H scabra*, *B. marmorata* and *H. leucospilota.* Widianingsih et al. (2016) reported fat content as 1.42% for *P. australis* and Oedjoe (2017) reported values from 1.01% to 1.19% for *H. nobilis*, *H. scabra*, *H. atra*, *H. edulis*, *H. impatiens*, *H. leucospilota*, *A. lecanora* and *B. argus*, which differ from those obtained in the current study.

Taking into account the foregoing, Alvarez (2006) states that the fat content either acquired by food or by other means, are the main reason for the reproduction and composition of eggs in fish, from which, authors as Wen et al. (2010) state that low fat contents occur more frequently in abyssal species. Taniwaka et al. (1955) confirm that variations in fat content are reflected by the development of the gonads and feeding conditions. In this study, there were no variations in the values of fat present in the muscle of the sea cucumbers, however, the highest values were in January, May and September for the Rodadero and in April for Taganga, which indicates that there is no relationship with their spawning season because this species spawns during the second half of the year.

Ridzwan et al. (2014) state that variations in the fat content of sea cucumber are linked to the season and habitat. In the Colombian Caribbean Sea, the weather seasons are: Dry season from December to March, the rainy season from June to November and the transition season from April to May (CIOH 2013). The results of the present study showed the highest percentage of fat in the rainy season and the lowest in the dry season for Rodadero Bay. While in Taganga Bay, the highest values were presented in the dry season. This indicates that the season of the year influences the fat content present in this Caribbean Sea cucumber.

Widianingsih et al. (2016) suggest that most sea cucumbers and other marine species contain high values of moisture and low in protein. In this study, the moisture content was in the range of 89.17% to 93.26%, which are considered high values for this species. These values are similar to those reported by Vergara and Rodríguez (2016), and Hernández et al. (2017) with the same species (84.89% and 86.92%), also with those reported by Chang-Lee et al. (1989), in *P. parvimensis* and *P. califomicus* (89% to 92.6%) by Tanikawa et al. (1955), with average value of 89.08% in fresh muscle for *Stichopus japonicus* and below those reported by Omran (2013) for *A. mauritiana*, *H. scarba*, *B. marmorata* and *H. leucospilota* (81.41%

and 85.17%), by Widianingsih et al. (2016), for *P. australis* (74.92%), for Oedjoe (2017) for the species *H. nobilis*, *H. scabra*, *H. atra*, *H. edulis*, *H. impatiens*, *H. leucospilota*, *A. lecanora* and *B. argus* with average moisture content of 78.10%, and for Hernández (2015), for *Isostichopus fuscus* (42.05%). The moisture content percentages found in native sea cucumber should be related to the time of the year, weather seasons, geographical variations or feeding behavior (Chang-Lee et al. 1989; Ginger et al. 2001).

Finally, the ash content ranged from 3.1% to 3.97%; these values being almost equal to those found by Vergara and Rodríguez (2016) and Hernández et al. (2017) for the same specie (3.16% to 3.81%), by Chang-Lee et al. (1989) in *P. parvimensis* and *P. califomicus* (3%) and by Oedjoe (2017) for *B. argus* (3.07%). These variations are above the values reported by Taniwaka et al. (1955) for *Stichopus japonicus* (1.61% in fresh); by Widianingsih et al. (2016) for *P. australis* (2.5%), as well as these values are below those reported by Hernandez (2015) for *Isostichopus fuscus* (5.43%), by Omran (2013) for *B. marmorata* (6.03%), *H. leucospilota* (4.3%), by Wen et al. (2010) for *S. herrmanni*, *Thelenota ananas*, *T. anax*, *Holothuria fuscogilva*, *H. fuscopunctata*, *Actinopyga mauritiana*, *A. caerulea* and *Bohadschia argus* (15.4% to 39.6%), and by Aydin et al. (2011) for H. *polii*, *H. tubulosa* and *H. mammata* with a range between 5.13% and 7.85%. The ash content, according to Taniwaka et al. (1955), may be linked to the high content of spicules presented in their body. In this sense, the ash content was obtained from the muscle without removing the spicules, so we consider that this influenced the ash percentages for *Isostichopus* sp. aff *badionotus*.

Gonadosomatic index

Knowledge of the stages of gonadal maturity is of great importance because these are associated with wild population management and protection (Saborido 2008). In Colombia there are studies related to the gonadal stage of sea cucumber *Isostichopus* sp. aff *badionotus*, however, this species and other Caribbean Sea cucumbers continue to be exploited regardless of management or conservation plans. Some studies suggest that holothurians such as *Isostichopus fuscus* reproduce annually between July and September; also *Isostichopus* sp. aff *badionotus* has an annual development cycle. This reproductive cycle is maybe related to the surface temperature of the sea, causing the spawning of the sea cucumbers when temperatures are frequently higher than the annual average (Herrero et al. 1999; Vergara et al. 2015). Likewise, Ramos et al. (2017), found a negative correlation between gonadosomatic index of *Holothuria floridana* in the relationship with the temperature and the salinity.

The sea cucumber GSI values for two study areas were found in the ranges of 0.06% to 10.44%, showing the lowest value (0.06%) in February (rainy season) for Taganga Bay and the highest (10.44%) in August (dry season) for Rodadero Bay. Our results supported those reported by Herrero (1994) for *Isostichopus fuscus* (44%) and *Neothyone gibbosa* (6.61%) during July to September. Likewise, Fajardo et al. (2008) reported for *P. parvimensis*, maximum GSI values of 5.5% and 11% in April (2000-2001) and March (2001), while low values with 2% in June and July (2000-2001). Palazón (2001) reported a decrease in gonadosomatic index for *Isostichopus badionotus*, between September to October, while at state by Morgan (2000) *H. scabra* GSI values reached between 20% and 22%, which are far from those reported in this study.

In relation to the above, the reproductive success of sea cucumber will depend largely on its habitat and the season, but also of the use of the nutrients that will be an essential source for its reproduction (Saborido 2008). In the same way, tropical sea cucumbers increased their GSI index between May to June in the two zones, while the protein content decreased dramatically. Alvarez (2006) states that this is due to the use of nutrients in the breeding season of tropical sea cucumbers, to have a better egg quality. It is noteworthy that the lack of this type of knowledge together with the absence of resource management plans, in species like sea cucumber of great ecological and economical importance, enhances the status of vulnerability and threat of the species. In view of our results, we open the space for new research, focused on a better use of this resource based on its reproductive cycle.

Colombian Caribbean *Isostichopus* sp. aff *badionotus* is a potential resource for sustainable use, since it presented similar conditions in its proximal composition in relation to other widely marketed sea cucumber species, thus being an important nutritional resource for the region. The proximal chemical composition of this tropical sea cucumber varied in seasons and according to the collection areas in the protein, moisture and ash contents, while the fat concentration did not vary. In the case of Taganga and Rodadero, the values of proteins and ashes were inverse: the highest in protein were obtained in the rainy season and the lowest in the dry season, by contrasts for ashes, lower values were observed in the rainy season and higher in the dry season. Likewise, the highest and lowest moisture content values for the Rodadero Bay occurred in the rainy season, while in the Taganga Bay the highest value was evidenced in the dry season and the lowest in the rainy season. The gonadosomatic index confirms the sexual maturity from August until the end of November. Its reproductive season is characterized by low protein levels and high moisture content and high GSI values. The ratio of the percentage of protein and the GSI (%), varies according to the reproductive status of the species from June in the two zones studied.

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Conflict of interest The authors declare that they have no conflict of interest.

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