Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(1): 379 – 396 (2024)
www.ejabf.journals.ekb.eg

Proximate Composition and Quality Properties of some Egyptian Sea Cucumber Species

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ARTICLE INFO

Article History:
Received: Dec. 26, 2023
Accepted: Jan. 19, 2024
Online: Jan. 27, 2024

Keywords:
Sea cucumber,
TVBN,
TMA,
TBA,
TBC

ABSTRACT

The current study aimed to evaluate the proximate composition and quality properties of eight Egyptian sea cucumbers *(Bohadschia argus, H. arguinensis, H. mammata, H. poli, H. sanctori, H. tubulosa, H. forskali* and *Stichopus regalis)* collected during October 2023 from the Mediterranean Sea in Alexandria Governorate. Proximate composition, pH value, total volatile basic nitrogen (TVB-N), trimethyylamine (TMA), thiobarbituric acid value (TBA), water activity, fatty acids, total bacterial counts (TBC), and sensory quality aspects of sea cucumbers samples were determined. The results revealed that significant differences in chemical composition, physicochemical, microbiological and sensory analysis were observed between species ($P< 0.05$). The moisture, protein, fat, ash, carbohydrate, and energy values of the analyzed sea cucumbers samples ranged between 79.11- 87.58%, 7.78- 9.35%, 0.19- 1.95%, 0.65- 6.50%, 0.18- 6.34%, and 34.36- 52.39Kcal/ 100g, respectively. While, the pH value, water activity, TVBN, TMA TBA, and TBC ranged between 8.01- 8.87, 0.911- 0.973aw, 12.08- 13.87mg/ 100g, 1.09- 1.75mg/ 100g, 0.11- 0.16mg MDA/ kg, and 3.11- 3.94cfu/ g, respectively. The results demonstrated that there were significant differences between sea cucumber species in chemical composition, physicochemical, microbiological, and sensory quality aspects, while these values didn't exceed the maximum permissible limits, moreover, these species are deemed safe for human consumption. However, further research is essential to be carried out in the future to reveal the potential biopharmaceutical value and development of functional foods from the species under study.

INTRODUCTION

Sea cucumbers are an important fishery resource worldwide, where they are either consumed raw, dried or boiled in many tropical and subtropical countries **(Purcell, 2014)**. Sea cucumber is a nutritious seafood with high protein and low lipid content, in addition

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to being rich in gluten, nitrogen, and iodine. It considered as one of the most popular Chinese seafood dishes. Moreover, it is used in medicinal purposes. Sea cucumbers were also found to have beneficial impact for impotent individuals **(Ran, 1993; Wen *et al.*, 2010)**. Hence, Asian markets are in search of new target species, mainly from the Mediterranean Sea **(Gonzalez-Wangüemert *et al.*, 2016)**. On the other hand, the use of sea cucumber as a human food source has been strongly linked to Asia for hundreds of generations, as the continent that most imports, consumes, and exports this product **(Ferdouse, 2004)**.

The *Holothuroidea,* or sea cucumbers, are an abundant and diverse group of worm-like and usually soft-bodied echinoderms. They are found in nearly every marine environment. There are about 1400 living species of sea cucumber in a variety of forms. Some of these are about 20cm in length though adults of some diminutive species may not exceed a centimeter, while one large species can reach lengths of 5m (*Synapta maculata*) **(Kerr, 2000)**. At present, 66 species of sea cucumbers are commercially exploited worldwide **(Purcell, 2010)**.

Egypt is giving a special attention to sea cucumbers resources and fishery through different projects. It is important that their results and reports are disseminated. The socio-economy of sea cucumber fisheries also deserves a special attention in the Middle East region **(Ahmed & Lawrence, 2007)**. The average sea cucumber production in Egypt from 1994- 2005 was recorded at 502.7 tonnes and 3.4% percentage of total world production (**Toral-Granda *et al.*, 2008)**, while, the aquaculture industry has rapidly grown. The farmed sea cucumber output of 2021 reached 222,700mt in China **(CFSY, 2022)**. It is well known that, sea cucumber contains high concentrations of protein, vitamins (Vitamin B1, B2), minerals (calcium, magnesium, iron and zinc) and some special bioactive substances, such as phenolics, triterpene glycosides, free radical scavengers, and unsaturated fatty acids **(Vladimir & Alexandra, 2005; Bordbar & Saari, 2011)**.

Some studies have been conducted on the nutritional composition of some sea cucumbers **(Saito *et al*., 2002; Kasai, 2003; Cakli *et al*., 2004; Warnau *et al*., 2006; Zhong *et al*., 2006; Lavitra *et al*., 2009; Purcell *et al*., 2009; Aydin *et al*., 2010; Wen *et al*., 2010; Aydin *et al*., 2011; Sicuro *et al*., 2012; Salarzadeh *et al*., 2012; Yahyavi *et al*., 2012; Bechtel *et al*., 2013; Careaga *et al*., 2013; Omran, 2013; Fawzya *et al*., 2015; Haider *et al*., 2015; Yu *et al*., 2015; Gao *et al*., 2016; Tunca *et al*., 2016; Mecheta *et al*., 2020)**. However, there are still limited data and non- sufficient studies on the Egyptian varieties related to quality characteristics, proximate composition, physicochemical, microbiological and sensory quality. Therefore, this study aimed to analyze and compare the proximate composition, physicochemical, microbiological, and sensory quality properties of some Egyptian sea cucumber species collected from the Mediterranean Sea coast in Alexandria Governorate during October 2023 to evaluate their quality.

MATERIALS AND METHODS

Sea cucumbers collection, identification and preparation

Eight species of sea cucumbers *(Bohadschia argus, H. arguinensis, H. mammata, H. poli, H. sanctori, H. tubulosa, H. forskali* and *Stichopus regalis)* were collected during October 2023 from two sites along the Egyptian Mediterranean Sea coast, Alexandria Governorate, El-Montaza shore (Lat: 31.2700293, Long: 29.992348) and Miami Island shore (Lat: 31.2368499, Long: 26.0572625). Then, samples were immediately transferred in an ice box within 3 hours to the Fish Processing and Technology Lab., National Institute of Oceanography and Fisheries (NIOF), at El-Kanater El-Khairia city, Qaliubia Governorate. Uppon arrival, sea cucumbers samples were firstly scientifically classified and identified by two scientists specialized in biology and invertebrates based on morphological characters and spicules examination. Afterward, the body walls of sea cucumbers samples were separated from the viscera (all internal organs), and they were thoroughly washed with distilled water to remove sand and dirt. Subsequently, the samples were packed in plastic bags and stored at -18°C prior analysis. All chemicals were of analytical grade and were purchased from Sigma-Aldrich, GmbH Taufkirchen, Germany. Although there are many recommendations concerning the handling of sea cucumbers, no ethical code has been established. In our study, we were careful to ensure that all specimens were treated with respect and empathy, using an ethically responsible research.

Analytical methods

The moisture and ash contents were determined by drying at 105°C and the combustion of dry samples for 16 hours at 500°C until constant weight, respectively **(AOAC, 2000)**. The protein content was determined using Kjldahl method as reported by **AOAC (2000)**. Crude fat was determined following the extraction method of **Bligh and Dyer (1959)**. Carbohydrates were calculated by the difference in the sum of the values of fat, ash, moisture, and protein content. The energy value, expressed as kcal/ 100 g edible part, was estimated using **FAO (1989)** factors: 9.02 and 4.27kcal/g for fat and protein, respectively. The water activity of sea cucumbers samples was measured by using water activity instrument **(Schiraldi *et al.*, 1996)**. Trimethylamine nitrogen (TMA-N) was analyzed according to the guidelines of **AOAC (2002)**. Total volatile basic nitrogen (TVB-N), thiobarbituic acid (TBA) and the pH value were analyzed **(Pearson, 1991)**. Total bacterial count were determined as per the guidelines of **Downes and Ito (2001)**. Sensory tests of sea cucumbers were evaluated according to the outlines of **Fey and Regenstein (1982)** after boiling sea cucumbers samples at 100°C for 5min and prepared under high-pressure for 10min to be ready-to-eat, as reported by **Hou *et al.* (2014)**.

Statistical analysis

All analyses were repeated in triplicate. Results were expressed as mean values ± standard deviation (SD) and one-way analysis of variance (ANOVA) were carried out using a statistical analysis system (SPSS Version 12). Differences in the concentration between species were tested with ANOVA, followed by multiple-comparison test (Tukey HSD). Differences were considered to be significant when $P< 0.05$.

RESULTS AND DISCUSSION

Morphometric analysis of sea cucumbers samples

Biometrical measurements of sea cucumbers samples collected from the Mediterranean Sea during October 2023 are represented in Table (1). The mean values of both weights and lengths ranged between 60.96- 113.62g and 10.23- 20.09cm, respectively. The highest mean value of weight (113.62g) was recorded for *B. argus*, while the lowest value (60.39g) was recorded for *S. regalis*. On the other hand, the highest mean value of length (20.09cm) was recorded for *B. argus*, while the lowest value (10.88) was that of *H. poli*.

Table 1. Biometrical measurements (average ± STDEV) of sea cucumbers samples collected from the Mediterranean Sea during October 2023

Sea cucumbers species	Weight (g)	Length (cm)
B. argus	113.62±34.20	20.09±5.52
H. arguinensis	81.59±26.39	12.73±2.22
H. mammata	102.70±19.83	16.83±1.21
H. poli	60.96±14.03	10.88±1.87
H. sanctori	74.58±9.34	14.65±1.10
H. tubulosa	70.17±13.28	13.17±0.95
H. forskali	63.82±25.93	10.23±0.19
S. regalis	60.39±13.64	10.89±1.23

The relationship between length and weight differs between species, depending on the shape and strength of the body **(Cone, 1989)**. Furthermore, this is also due to food availability, species biology, growth rates and fishing pressure **(González-Wangüemert *et al*., 2018)**. However, the length and weight can also be influenced by over-harvesting, where larger animals are mainly caught **(Sales *et al*., 2021)**.

Proximate composition of sea cucumbers samples

It is well known that the chemical composition of sea cucumbers varies according to the species, age, tissue, habitat, and season **(Gonzalez-Wanguemert *et al.*, 2018b)**. The proximate composition of sea cucumbers samples collected from the Mediterranean Sea during October 2023 are shown in Figs. (1- 6). The moisture content ranged from 79.11 to 87.58%, protein content from 7.78 to 9.35%, crude lipid from 0.19 to 1.95%, ash content from 0.65 to 6.50%, carbohydrate content from 0.18 to 6.34%, and energy from 34.36 to 52.39Kcal/ 100 g, respectively.

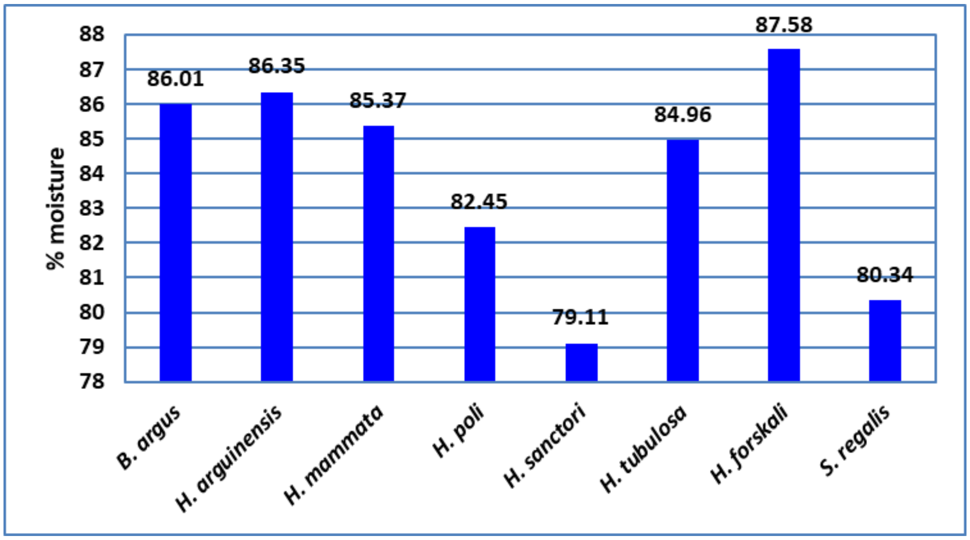

Fig. 1. Moisture content of sea cucumbers samples

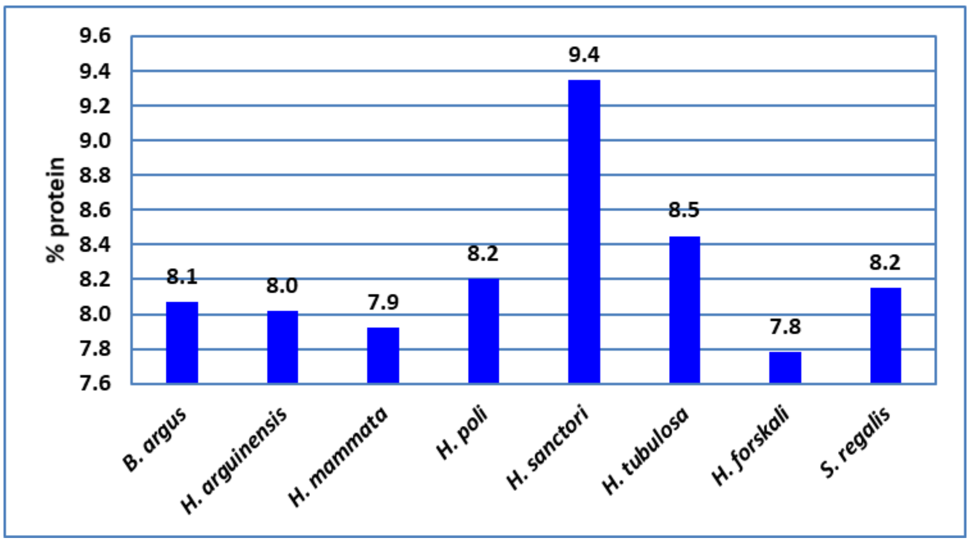

Fig. 2. Protein content (% wet weight basis) of sea cucumbers samples

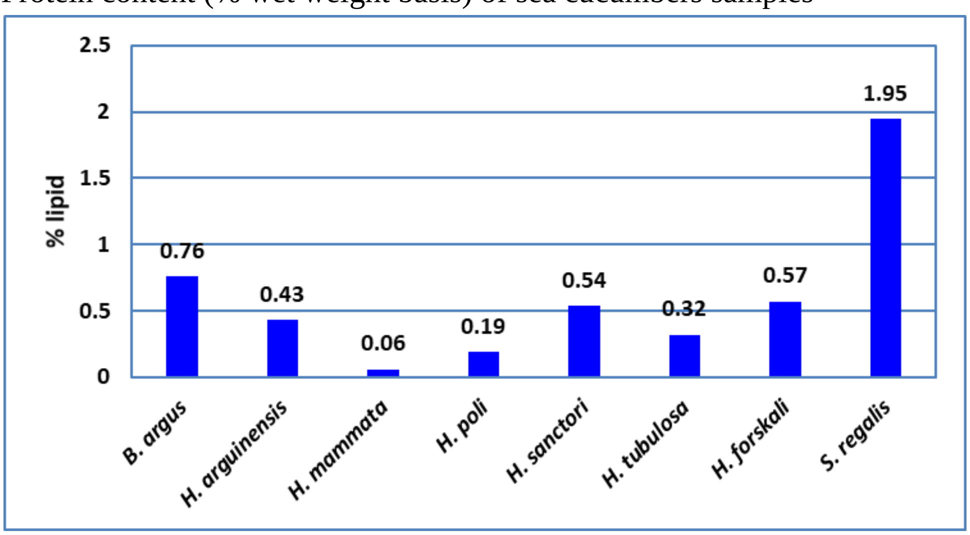

Fig. 3. Lipid content (% wet weight basis) of sea cucumbers samples

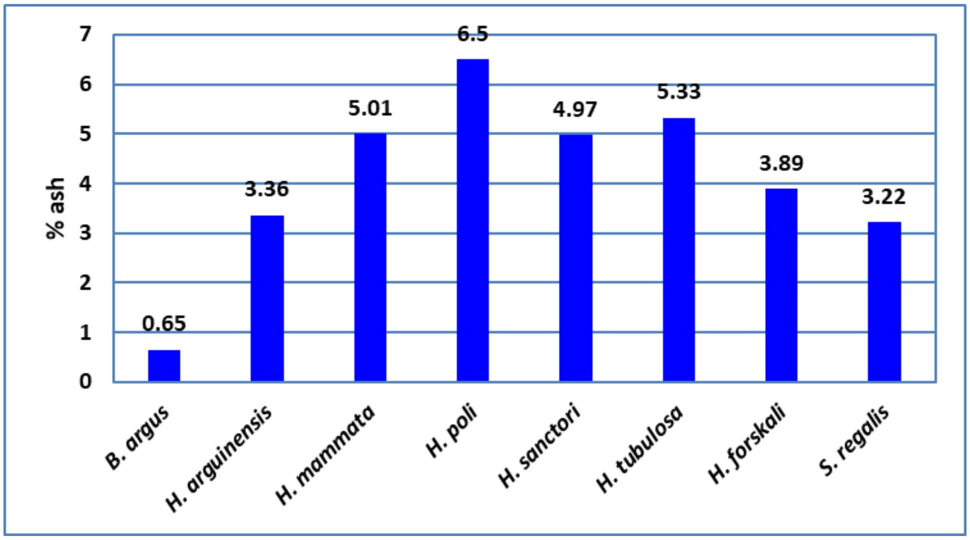

Fig. 4. Ash content (% wet weight basis) of sea cucumbers samples

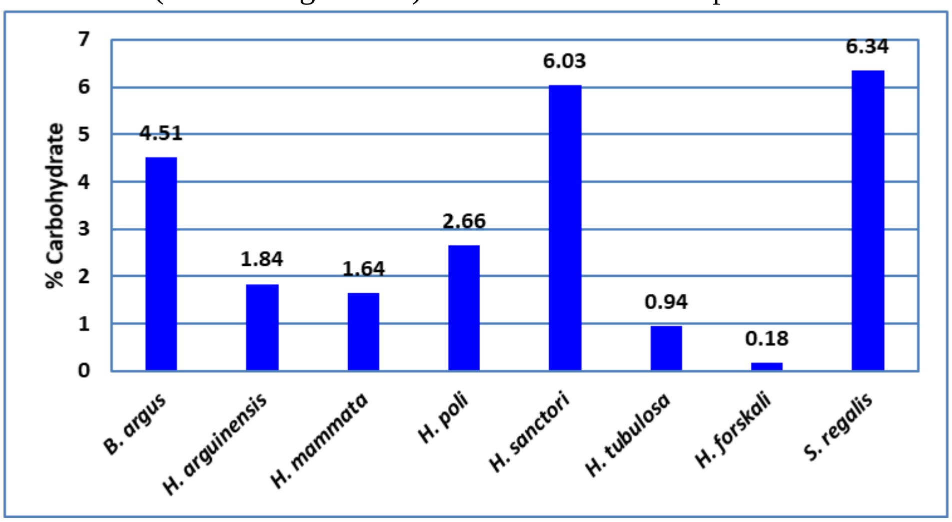

Fig. 5. Carbohydrate content (% wet weight basis) of sea cucumbers samples

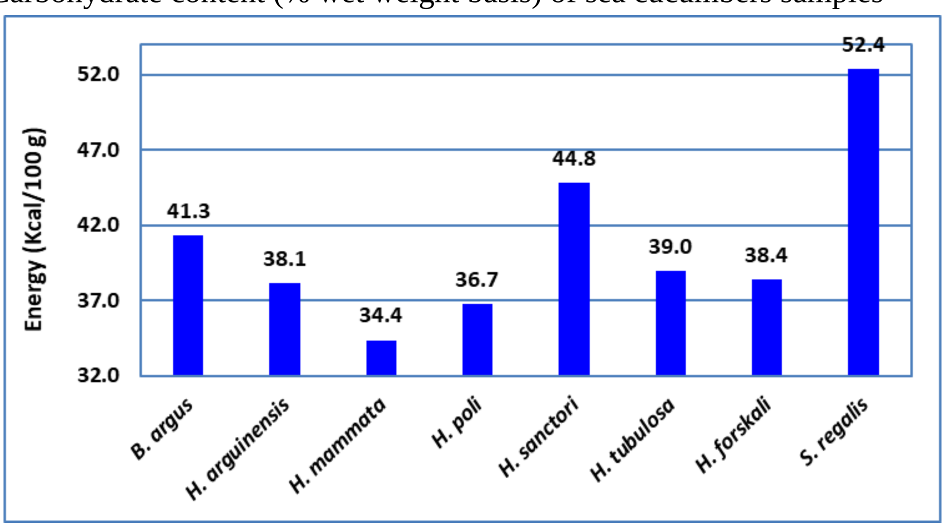

Fig. 6. Energy content (kcal/ 100 g) of sea cucumbers samples

The highest moisture content (87.58%) was found in *H. forskali*, while the lowest (79.11%) in *H. sanctori* (Fig. 1). Remarkably, moisture content has a major impact on the quality of processed sea cucumbers products and their storage conditions. In adition, it has a major impact on the sensory properties, and subsequently the marketing of these products varies as explained by **Salindeho *et al*. (2021)** who reported that, low moisture content will have an impact on the length of sea cucumbers during storage durability, increasing dry product, then durability will be longer. On the other hand, the moisture content affect the texture of the final product. If the moisture content is too high, then the texture of dried sea cucumbers become mushy and not compact, thus affecting consumer acceptance of such products. Drying including fumigation to eliminate water contained in food explains that the longer the drying time, the lower the moisture content in food.

The highest protein content (9.40%) was found in *H. sanctori*, while the lowest (7.80%) in *H. forskali* (Fig. 2). Sea cucumbers are products with high protein, as well as other fishery products. Protein is a nutrient that is essential for the body since it serves as a source of energy, and regulatory builder substance **(Salindeho *et al*., 2021)**.

The highest crude lipid content (1.95%) was found in *S. regalis*, while the lowest (0.06%) in *H. mammata* (Fig. 3). Fat has numerous important functions, among others as a source of energy that is more effective than carbohydrates and protein, lubricating joints and other critical functions. The differences in nutrient content in cucumbers are attributed to differences in sea cucumber species and biological conditions, such differences can also be due to the availability of food in the waters and sea cucumber species itself **(Salindeho *et al*., 2021)**.

The highest ash content (6.50%) was found in *H. poli*, while the lowest (0.65%) in *B. argus* (Fig. 4). A higher ash content contained in a food indicates a greater mineral content. Sea cucumber contains mineral substances, such as chromium, ferum, cadmium, manganese, nickel, cobalt and zinc, phosphorus, magnesium, calcium, iodine, iron, and copper **(Salindeho *et al*., 2021)**. The high ash content of sea cucumber is probably due to the presence of abundant microscopic elements of the skeleton, called ossicles, present in the body wall of the sea cucumber. Ossicles are formed inside cell vesicles and are composed mainly of calcium carbonate **(Smiley, 1994)**.

The highest carbohydrate content (6.34%) was found in *S. regalis*, while the lowest (0.18%) in *H. forskali* (Fig. 5). Carbohydrates constitute a group of chemically defined substances, with a range of physical and physiological properties and health benefits for consumers. Their main function is to provide energy, and they play an important role in the structure and function of cells, tissues, and organs **(Gerschenson *et al.*, 2022)**. Additionally, **Shan *et al.*, (2019)** reported that the quality of carbohydrate can impact the overall food quality and health outcomes.

The highest energy content (52.40kcal/ 100g) was found in *S. regalis,* while the lowest (*H. forskali* kcal/100g) in *H. mammata* (Fig. 6). The components are deemed to be the most relevant to the development of a carbohydrate food quality scoring system including energy density (kcal/ 100 g), **(Shan *et al.*, 2019)**.

Generally all species had a high protein and low fat content**.** There are several factors that can influence the moisture content of organisms, such as environmental, geographical variations, behavior, feeding, and the collection time of the year **(Chang-Lee *et al.*, 1989)**. The obtained results are similar to those previously reported by different authors from the Mediterranean countries. **Wen *et al.* (2010)** reavaled that, moisture, protein, fat. and ash values of eight species of sea cucumbers samples ranged between 1.2- 15.1%, 40.7- 63.3%, 0.3- 10.1%, and 15.4- 39.6%, respectively. In this context, **Aydın *et al*. (2011)** reported that, moisture, protein, fat, and ash contents of *H. tubulosa*, *H. polii* and *H. mammata* ranged between 81.24 and 85.24%, 7.88 and 8.82%, 0.09 and 0.18%, and 5.13 and 7.85%, respectively. Additionally, **Sicuro *et al*. (2012)** stated that, *H. tubulosa*, *H. polii* contains (16.19 and 22.03%) dry matter, (44.58 and 36.99%) protein, (0.71 and 0.55%) lipid, and (46.43 and 48.22%) ash on dry weight basis, respectively. **Mecheta *et al.* (2020)** found that, the moisture, protein, lipid, and ash of *Holothuria poli, H. tubulosa, H. arguinensis,* and *H. sanctori* ranged between 64.55- 67.76%, 49.26- 69.34%, 2.57- 5.53%, and 31.58- 47.31%, respectively. **Sales *et al*. (2021)** investigated moisture, fat, protein, ash, and energy values of the two holothurian species in summer and winter. *H. arguinensis* showed higher mean values for protein (9.2g/ 100g), ash (5.3g/ 100g), and fat content (0.05g/ 100g) than *H. forskali* (8.1g/ 100g, 3.3g/ 100g, 0.01g/ 100g, respectively). The proximate composition of fresh sea cucumbers differs by species, catching season and feeding patterns **(Bordbar *et al.*, 2011)**. Furthermore, **Aydin *et al.* (2011)** reported that the seasonal variation could have influenced of the chemical composition of sea cucumber. In the other hand, the fluctuation of the protein content in sea cucumbers may be influenced by environmental factors, the life cycle of species, the seasonal variation, and the physiological characteristics.

Physicochemical and microbiological quality of sea cucumbers samples

Physicochemical and microbiological quality of sea cucumbers samples collected from the Mediterranean Sea during October 2023 are presented in Figs. (7- 12). The pH value, water activity, TVBN, TMA, TBA, and TBC of sea cucumbers samples ranged between 8.01- 8.87, 0.911- 0.973aw, 12.08- 13.87mg/ 100g, 1.09- 1.75mg/ 100g, 0.11- 0.16mg MDA/ kg), and 3.11- 3.94cfu/ g, respectively.

Significant differences in physicochemical and microbiological quality of sea cucumbers samples were observed between species ($P< 0.05$). The obtained results showed that, the highest pH value (8.01) was found in *H. sanctori*, while the lowest (8.87) in *H. mammata***.** The highest water activity value (973aw) was found in *H. tubulosa*, while the lowest (0.911aw) was in *B. argus***.** Moreover, the highest TVBN value (13.87mg/ 100g) was found in *H. arguinensis*, while the lowest (12.08mg/ 100g) was in

*H. forskali***.** Furthermore, the highest TMA value (1.75mg/ 100g) was found in *H. sanctori*, while the lowest (1.09 mg/100g) was in *B. argus*.

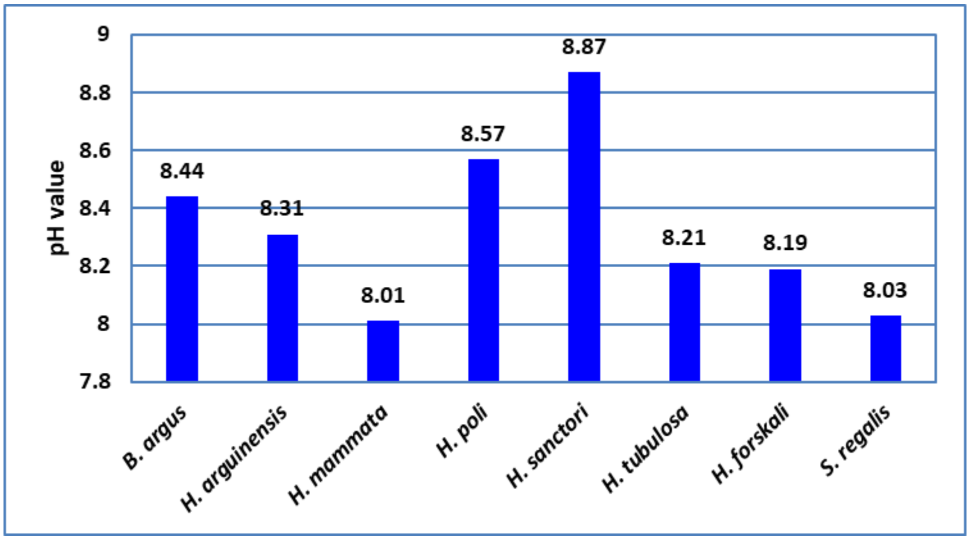

Fig. 7. The pH value of sea cucumbers samples

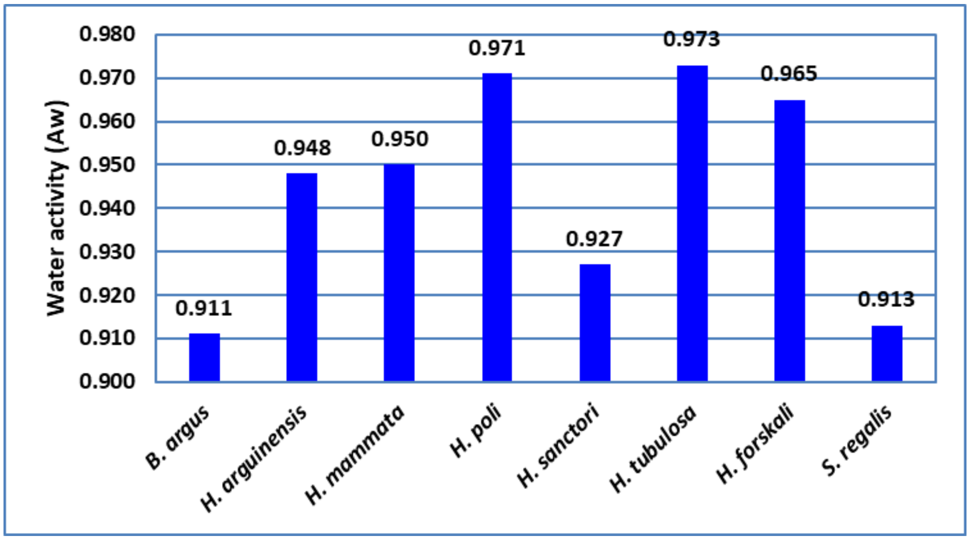

Fig. 8. Water activity (aw) of sea cucumbers samples

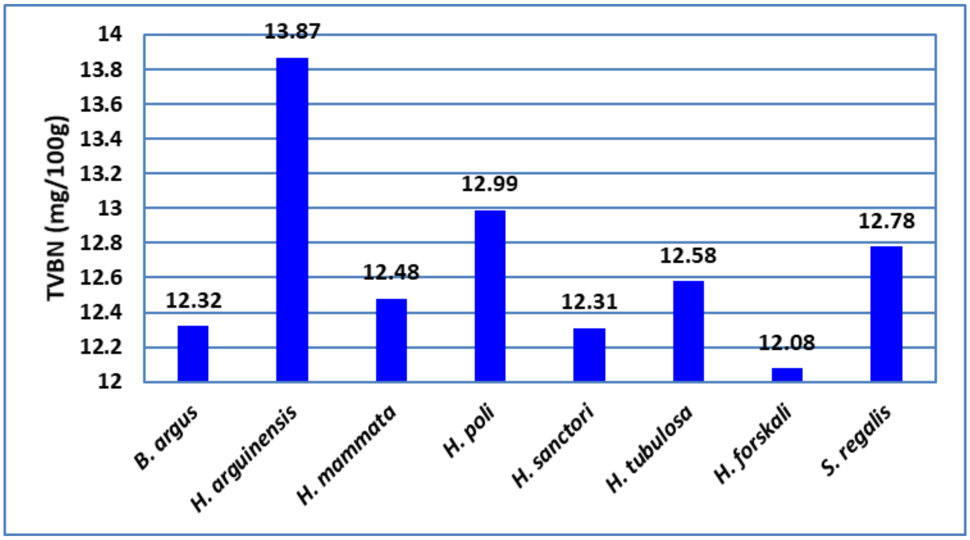

Fig. 9. TVBN (mg/ 100g, ww) of sea cucumbers samples

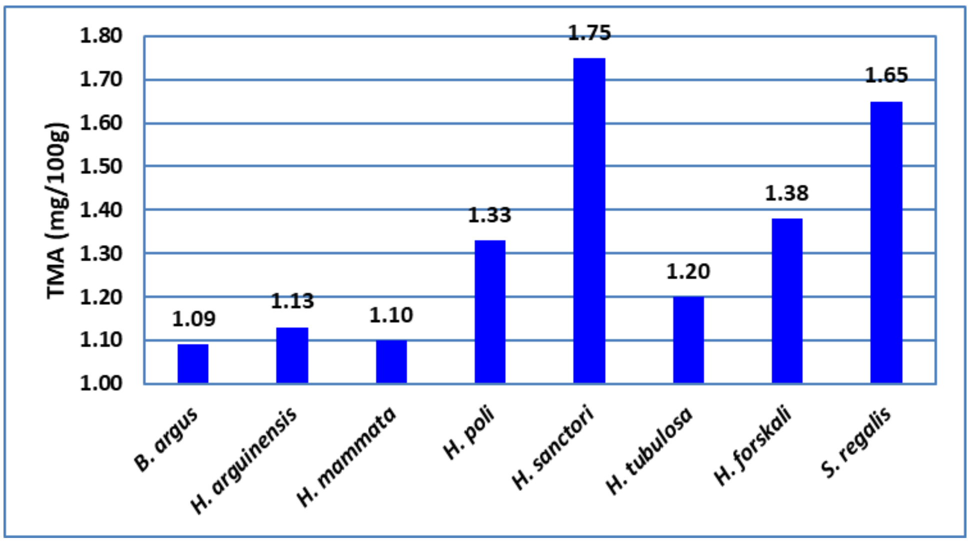

Fig. 10. TMA (mg/ 100g, ww) of sea cucumbers samples

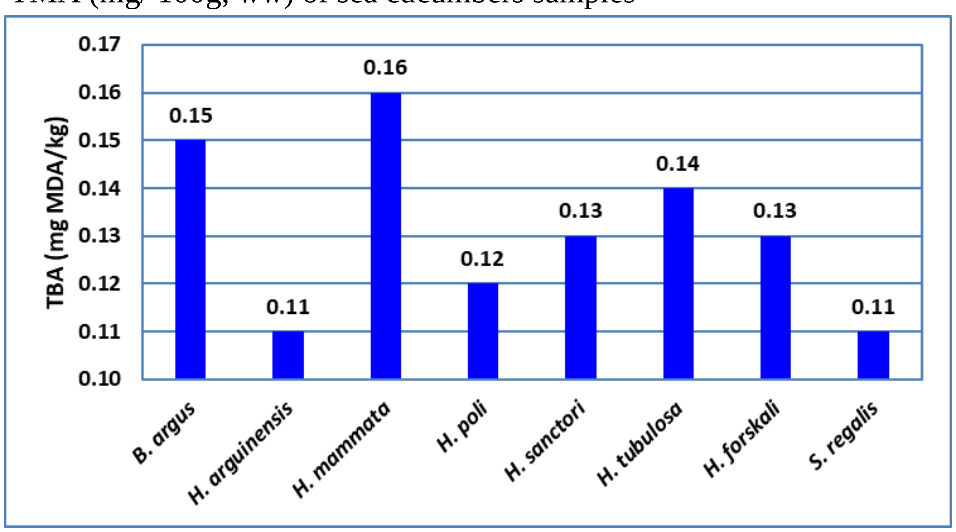

Fig. 11. TBA (mg MDA/ kg, ww) of sea cucumbers samples

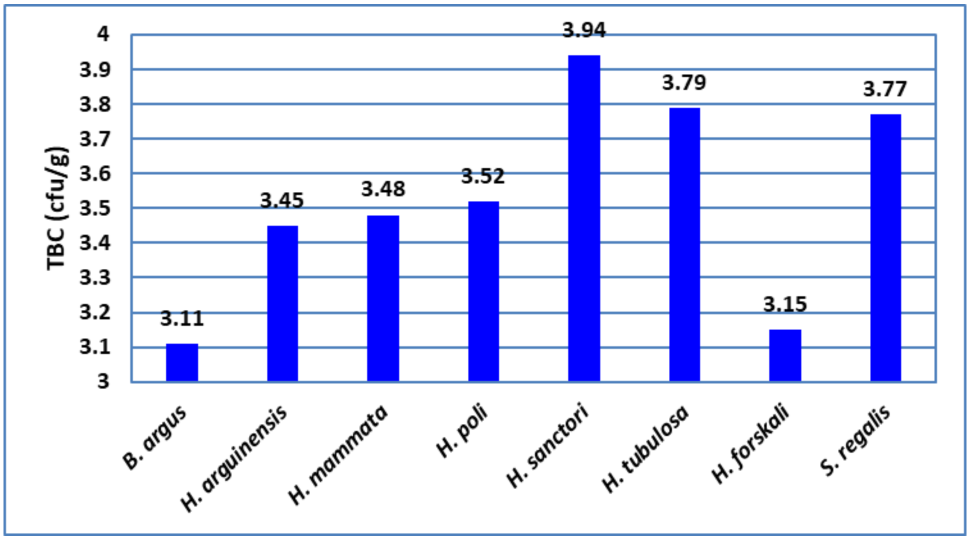

Fig. 12. TBC (cfu/ g) of sea cucumbers samples

The highest TBA value (0.19mg MDA/ kg) was found in *B. argus*, while the lowest (0.11mg MDA/ kg) was in *H. arguinensis***.** The highest TBC value (3.94cfu/ g) was found in *H. sanctori*, while the lowest (3.11cfu/g) was in *B. argus*. Similar results were recorded in previous studies on sea cucmber. **Cakli *et al.* (2004)** reaveled that, fresh *H. tubulosa* had 8.45± 0.31 of pH value, 18.90± 0.99mg/ 100g of TVB-N, 4.11± 1.25mg/ 100g of TMA-N, and 0.18± 0.08mg malonaldhyde/ kg of TBA value. Moreover, **Li *et al*. (2022)** reported that, TVB-N levels increased to the top of 13.405± 0.917mg/100g at the end of the storage period for *Apostichopus japonicus.* **Xiong *et al.* (2020)** evaluated the biochemical, chemical, and textural changes of sea cucumber *Stichopus japonicus* body wall (SJBW) during iced storage at 0, 2, and 4 days, and they reported that, TVB-N (mg/ 100g) increased from 4.030.28 to 12.68± 0.56 during the same time. The changes of pH was possibly attributed to the dissolution of the production of volatile basic components and the accumulation of lactic acid by decomposition of glucose, caused by the degradation of protein by endogenous enzymes **(Ocano-Higuera *et al.*, 2006)**.

The content of total volatile base nitrogen can be used to judge the freshness of animal food. A high TVB-N value means that fish are severely deteriorated. A TVB-N value of 35mg/ 100g is considered the upper limit for acceptability for the fishery products, beyond this limit, the product is considered as spoilt **(Chaparro-Hernandez *et al.*, 2015; Qiao *et al.*, 2017; Lorentzen *et al.*, 2020; Zhang *et al.*, 2022)**. The TVB-N analysis is commonly used as an evaluation method for monitoring quality in aquatic products during iced storage **(Li *et al.*, 2017)**. Additionally, the trimethylamine (TMA) is a marker used for monitoring the quality of seafood since it is the primary component of the "fishy" odor **(Herath *et al*., 2019)**.

Sensory evaluation of boiled sea cucumbers samples

The organoleptic test is a testing technique using human senses as the main tool for measuring the receptivity of the product. Sensory evaluation has an important role in the development of new products in the food industry. Consumer acceptance is based on the process of sensing the five senses, namely the stimulation or reaction to the object namely pempek sea cucumbers. The impression or response of the panelists to the sea cucumber pempek is the result of the panelists' sensing **(Swiader & Marczewska, 2021)**.

Sensory evaluation of different boiled sea cucumbers samples collected from the Mediterranean Sea during October 2023 are shown in Fig. (13). The obtained results showed that, the highest color value (7.75) was found in *H. arguinensis*, while the lowest (6.45) was in *H. sanctori*. The highest tenderness value (7.96) was found in *H. arguinensis*, while the lowest (7.00) was in *H. sanctori*. The highest juiciness value (7.91) was found in *H. arguinensis*, while the lowest (7.01) was in *H. sanctori*. The highest taste value (7.52) was recorded in *S. regalis*, while the lowest (7.00) was in *H. sanctori*. The highest flavor value (6.87) was assessed in *H. arguinensis*, while the lowest (6.01) was in *H. mammata*. The highest overall acceptability value (6.47) was found in *H. tubulosa*, while the lowest (6.00) was in *S. regalis*.

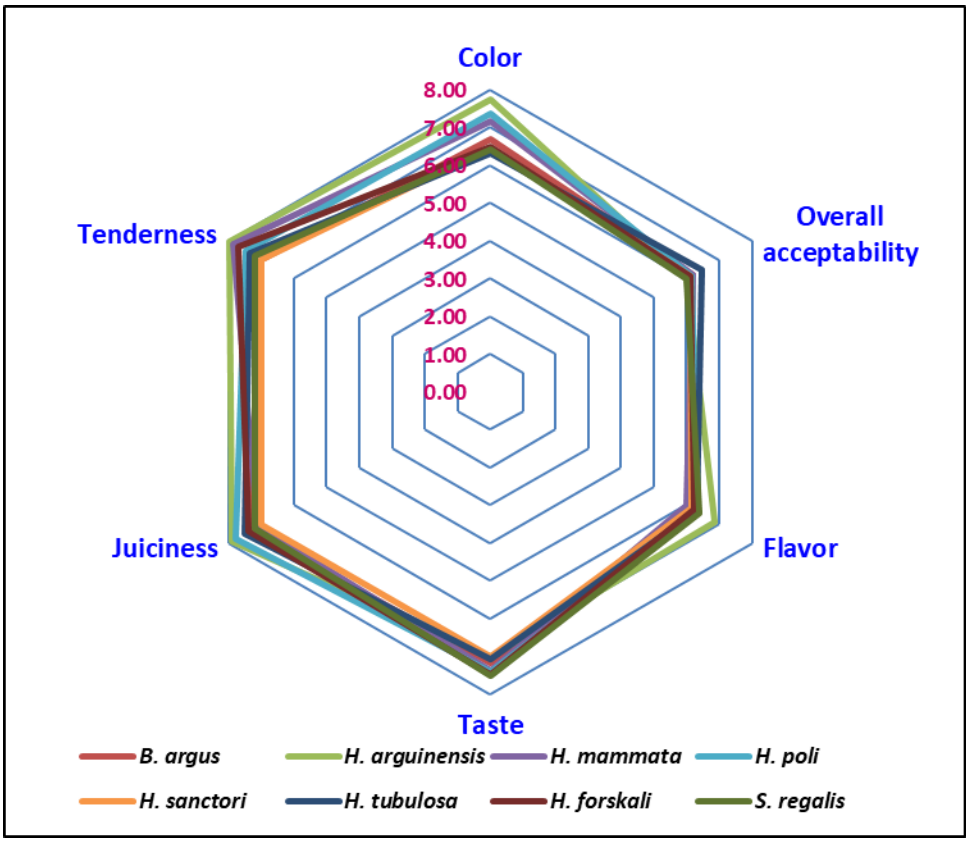

Fig. 13. Sensory evaluation of different boiled sea cucumbers samples collected from the Mediterranean Sea during October 2023

Hou *et al*. (2014) determined the sensorial quality changes of ready-to-eat boiled sea cucumbers stored under 5, 10, and 15˚C, and they found that the sensory quality decreased gradually. The decline of quality reflected in the smell and the surface viscosity; the two index declined quickly during the whole storage. Furthermore, **Li *et al.* (2022)** monitored the sensory quality of sea cucumber after storage and boiling. Compared with the fresh group of sea cucumbers, the sensory scores of sea cucumbers in the frozen group and air group significantly decreased on the first day ($P< 0.05$). After 7 days of storage, the highest sensory score was 69.56± 3.15 in the oxygen group, and the lowest score was 57.67± 1.15 in the freezing group. **Ohoiwutun *et al.* (2022)** postulated that, the level of preference for the appearance of pempek sea cucumbers at the Watuar location was 8.3% and in the Tutrean location was 8.27%, the smell of sea cucumber pempek at Watuar and in Tutrean locations was 8%, the taste of sea cucumber pempek at the Watuar location was 8.3% and in the Tutrean location was 8.2%, and the texture of the sea cucumber pempek at the Watuar location was 8.03% and in the Tutrean location was 8.17%.

CONCLUSION

The results demonstrated that there were significant differences between sea cucumber species in chemical composition, physicochemical, microbiological, and sensory quality aspects, while these values didn't exceed the maximum permissible limits, moreover these species are deemed safe for human consumption. However, further research is essential to be carried out in the future to reveal the potential biopharmaceutical value and development of functional foods from this species.

Ethics statement

Since sea cucumbers are invertebrates, ethical review and approval were waived for this study. The content of this article does not involve human or animal research in the institutional review board statement.

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