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Marine Algae Based-Meal as Substitute Ingredient Feeds for the Fighting Conch *Strombus tricornis* L. (Mollusca, Gastropoda): Body Weights and Histomorphological Studies

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ABSTRACT

Strombus tricornis is a true conch among *Strombidae* species predominately exploited for feeding and jewelry production. Intensive conch culture targets higher growth rates using convenient formulated feed under suitable conditions. Moreover, the efficacy of the digestive system mainly depends on the nutritive value of aqua feed. Currently, nutriment scientists attempt to use marine algae as an alternative protein for aquatic feed. Hence, an assessment was made to compare the inclusion of seaweed and protein sources in *Strombus tricornis* diet using five experimental diets (D). D1, D2 and D3 integrated with *racemosa*, *J. rubens*,and *D. ciliolate*, respectively, while D4 and D5 incorporated with animal and plant protein, respectively. Each diet was run into three replicates of conchs in 60 liters of aquaria at 30- 32°C for three months. The final body weight of *Strombus* conchs simultaneous with histomorphology characteristics of the digestive system and muscles were evaluated for five treatments. Results ensured that seaweed enhanced growth for further increased final body weight. Histomorphological results exhibited normal intestinal epithelium of columnar cells and well-studiated muscle fibers when compared with those of control and commercial diets. In conclusion, algae act as a proper alternative feed for protein sources of *Strombus.*

INTRODUCTION

Strombidae are marine benthic gastropods which constitute a major economic importance in the Caribbean. At a minimum, four species contribute significantly as staple food **(Aranda, 2003)**. *Strombus tricornis* occupied one of the most famous *Strombidae* species. The shells of *Strombus tricornis* are typically found residing on coral carpet and the adjacent sandy areas at water depths ranging from 6 to 30 meters. They are also observed on rock bottom. Additionally, a living juvenile was observed settling in the sand near a coral carpet at a water depth of 20 meters in the Red Sea **(Janssen *et al.*, 2011)**.

Under controlled conditions, several cost gastropods cultures have been successfully established **(Song *et al.*, 2016)**. Methods for queen conch's aquaculture were previously instituted as means of culture conchs for feeding and stocking purposes. Nevertheless, there is a demand to advance husbandry techniques for juveniles enhancement **(Davis & Shawl, 2005)**. While model ways for stocking and calcium demands are well studied, the essential nutritional requirements are not widely recognized **(Stoner & Waite, 1990)**.

In marine culture, feed constitutes the most expensive component for production, and protein sources are particularly costly ingredients **(Jatobá *et al.*, 2014)**. In the development of gastropods and other species, the diet of queen conch should take into consideration the level and efficiency of protein for maximum growth. Accurate evaluation of the protein needs can motivate efficacy of protein utility and minimize expenses of the manufactured feeds **(Garr *et al.*, 2011)**. Among the protein ingredients applied to manufacture diets for marine culture, fishmeal stands out for its rich compositions of vitamins, minerals, amino acid, and palatability **(Chavez *et al.*, 2016)**. Meanwhile, fishmeal is not represented as a renewable ingredient, attributed to an extractive industrial fish farming **(Zhao *et al.*, 2017)**. This has led to the search for alternative protein sources that offer the same nutritional value but at lower costs, thereby allowing for a greater profit margin **(Chiu *et al.*, 2016; Sun *et al.*, 2016)**. Nevertheless, the addition of algae to the fish meal diet exhibited a successful potential for the replacement of fish meals and lipid sources **(Liao *et al.*, 2022)**.

Usage of algae as an additive nutrition has attracted significant regard due to the favorable impact on the body weight **(Ophilia & Ramanujam, 2017)**. The characteristic of microalgae as a fish meal is gaining recognition as a rapidly substitutional candidate in recent aquaculture manufacturing **(Becker, 2007)**. Many algae categories have been estimated for their nutritive benefit and formulated as fish nutrition for increasing fish output **(Sirakov *et al*., 2015)**.

The gastropods mostly survive on brown, green, and red seaweeds **(Hwang *et al*., 2013)**. Correspondingly, marine algae have been used as crucial feed for the breeding of aquatic organisms, including marine cucumber, and mollusks under circumscribed conditions **(Li *et al*., 2020**). Seaweed is a valuable biomass for livestock, showcasing great variations in proteins, minerals, lipids and fibers **(El-Manawy *et al*., 2019)**. Seaweeds enjoy a high mineral level due to the capability for absorption of inorganic substances from outside, and also they are fortified in polysaccharides; nevertheless, they comprise little amount of lipids, polyunsaturated fatty acids in particular **(Misurcova, 2011)**.

Histopathology along with other diagnostic methods is an indicator used in the assessment of the aquatic feed used and their environmental conditions **(Rajeshkumar & Munuswamy, 2011)**. Histological examination of the digestive system is an ideal diagnostic for the nutritional condition of the fish **(Caballero *et al*., 2003)**. Intestine is a primarily organ in food digestion and absorption, and hence monitoring of such organ is much necessitated **(Roberts, 1989)**. Histological analysis is commonly based on semiquantitative scoring system **(Mouton, 2002)**.

Little is known about the efficacy of pellets and unicellular algae for *Strombidae* breeding. At a histological level, feeding attempts using formulated pellets gained growing concern in the meal composition in addition to the function and structure of the digestive gland of *Strombidae* **(Aranda *et al*., 2007)**. In mollusks, the muscles and the digestive glands are constituted main energy reserves **(Berthelin *et al*., 2000)**. However, energy maintains basal metabolism, and organisms functions **(Sokolova *et al.*, 2012)**. The gastropod digestive gland represents the most complicated structure, suggesting variations in feeding habits and diet constituents **(Lopez *et al.*, 2003)**. However, few investigations discussed the histological observations of the digestive tract of *Strombidae*, particularly concerning digestive physiology and the nature of enzymes **(Alyakrinskaya, 2001; Volland *et al*., 2012)**.

To address this, a protocol was constructed to ensure how variable macroalgae could replace commercial protein compositions offered to conch *Strombus tricornis L.* (Mollusca, Gastropoda) using the histological lesions scoring to differentiate between the degree of lesions of different formulated diets.

MATERIALS AND METHODS

1. Ethical approval

This procedure follows the ethical guidelines for the aquatic animals management which is approved by the Local Committee of National Institute of Oceanography and Fisheries (NIOF) in Egypt for Ethical Care and Use of Aquatic Animal to ensure that the procedure is appropriate avoiding any stressors during fish handling with the approval No. (NIOFAQ3I23R035).

2. Experimental fish

Marine mussels, *Strombus tricornis* of 8.95- 11.90cm length weighing 100± 20gm were collected from the Abu Sadaf area (27°17'31.71''N, 33°46'58.70''E) at the environment of marine algae with a sandy bottom by a snorkeling tube at water depths between (0.5- 1.5m) in October 2020 (Fig. 1). Samples were transferred into the laboratory tanks at the National Institute of Oceanography and Fisheries in (27°17'7.80''N, 33°46'19.90'') Hurghada City, the Red Sea Governorate, Egypt.

3. Experimental diets

Randomized complete-blocked design was performed with different diets on recirculating systems. Five feeding treatments were used in the experiment, consisting of marine algae and commercial feeds. Additionally, five formulated rations were prepared to include crude protein, lipid, and total carbohydrate. The collected seaweeds were cleaned with distilled water, dried in shade, ground into a soft powder and stored at room temperature for feeding experiments and chemical analysis.

Diets from 1 to 3 were incorporated with different macroalgae which were identified based on their morphological characteristics taxonomy in consistent with **Sahoo (2001)**. Accordingly, in diet 1, conchs were fed with green seaweed, specifically the species of *Caulerpa racemosa* var. gracilis (Zanardini) Weber-van Bosse from Chlorophyta. Diet 2, *strombus cornis* were supplemented with *Jania rubens* (Linnaeus) *J.V. Lamouroux* from Rhodophyta. While in diet 3, fish meal was incorporated with brown algae represented by *Dictyota ciliolata* Sonder ex Kützing from Phaeophyta, suggesting feeding on red algae.

Commercial diet of the animal sources (D4) was substituted to contain an increased level of fish meal, whereas the diet of the plant sources (D5) was substituted to contain an increased level of soybean, as expressed by the manufacturer's guides in Table (1).

Fig. 1. General shape of the *Strombus tricornis* under water the marine environment

Table 1. Protein composition (%) in the commercial diets

Ingredient %	Commercial diets	
	Animal diet	Plant diet
Fish meal	66.0	0.0
Soybean meal	0.0	46.0
Yellow corn	11.0	11.0
Corn gluten	6.0	6.0
Wheat bran	14.0	14.0
Rice bran	14.0	14.0

4. Analytical characterization of feed constituents

Prior to feeding, intended diets were subjected to analysis for crude protein content, following the demonstrated method of **Lowry *et al.* (1951)**. Crude lipid concentrations were primarily measured using petroleum ether extraction, and the ash content was determined in feed stuff according to the guidelines of the **AOAC (2000)**. A natural source of calcium from the sepia shell was used, where it was collected, dried, and milled, and was added by 1 to 2% to each diet.

5. Experimental design

In the experiment, seventy five (75) healthy well acclimatized gastropod *Strombus tricornis* with an average body weight (100± 20gm) were randomly distributed into 5 treated groups. These five treated groups included green algae, red algae, brown algae, animal diet, and plant diet, respectively. Treatments were done into three replicates. Each group consisted of 15 specimens in a glass tank with a three-tank capacity of 60L (L50×H40×W30 cm^3) of seawater. These tanks were connected to a direct pipeline, submerged underwater pumping system to transfer saline water from the sea to the aquatic laboratory.

During the experiment, the daily feeding weight of food was set at 10 grams of diet (10% of body weight of conch), comprising 9 grams of diet and 1 gram of natural source of calcium from the squid shell. Feeding time was set from 9- 10AM daily, and siphoning and cleaning of the tank were daily done to remove waste, and leftover food.

Gastropod was exposed to different concentrations of diets for a period of three months, continuously. Water was daily changed, and the salinity, water temperature, and pH of water measured. They ranged between (40- 42‰), (30- 32c), and (7.80- 8.20), respectively. Conchs *Strombus tricornis* in all supplemented groups were daily monitored for any mortalities and abnormalities in their behavior. After the feeding experimentation has finished, final body weights of the treated conchs were calculated. Moreover, tissue samples were selected for the histological examinations.

6. Tissue sampling

After the three-month experimentation period concluded, organs including the gut, digestive glands and muscles of *Strombus tricornis* were dissected from treated *strombus* conchs. Parallel sea gastropods samples served as a standard control. Subsequently, the collected organs preserved in suitable fixative solution for histological monitoring.

7. Histological examination

Specimens from the selected organs were fixed in 10% neutral buffered formalin, sequentially dehydrated in methanol, and then embedded in paraffin wax after purification in xylene. For tissues sections, approximately about 5 microns were prepared using a microtome for hematoxylin and eosin (H&E) staining. Subsequently, they were microscopically imaged following the method of **Bancroft and Gamble (2002)**. This was performed to compare the potential effect of different diets on the morphology of the digestive tract and musculatures of *Strombus tricornis*.

8. Statistical analysis

Analyzed data are presented in mean ±standard deviation using one-way analysis of variance by SPSS software.

RESULTS

1. Feed characterization

The proximate ingredients in diets formulated with different protein sources is shown in Table (2). Correspondingly, the total protein values (g/ kg) of the formulated diets in algae diets (D1, D2 and D3) were 10.2± 1.33, 20.31± 2.1, 15.31± 1.33, respectively, whereas the protein values in D4 and D5 were 50.0± 1.4 and 56.0± 1.3 of protein diets. Crude lipid level values (g/ kg) were 3.51± 1.21, 1.21± 1.34 and 0.451± 0.12 in D1, D2 and D3, respectively; however in protein diets, the values were 8.0± 1.3 and 0.55± 0.032, respectively.

Total carbohydrate concentration values (g/ kg) in D1, D2 and D3 were 55.11± 1.12, 35.31± 2.4 and 52.251± 3.4, respectively. In contrast, the diets of protein origin were 15.2± 0.82 and 18.45± 132. Eventually, the values of ash content (g/kg) were 31.21± 3.2, 41.71± 2.3 and 32.31± 2.5 in green, red and brown diets, respectively, while animal and plant diets exhibited values of 27.0± 0.32 and 25.0± 0.56, respectively.

Table 2. Proximate compositions of the formulated diets

Diet / **Ingredient (g/ kg)**	Diet 1 (*Racemosa*)	Diet 2 *(J. rubens)*	Diet 3 (*D.ciliolate)*	Diet 4 (Animal)	Diet 5 (Plant)
Crud protein	10.2± 1.33	15.31± 1.33	20.31± 2.1	50± 1.4	56± 1.3
Crud lipid	3.51± 1.21	0.451± 0.12	1.21± 1.34	8± 1.3	0.55± 0.032
Total carbohydrate	55.11± 1.12	52.251± 3.4	35.31± 2.4	15.2± 0.82	18.45± 132
Ash	31.21± 3.2	32.31± 2.5	41.71± 2.3	27± 0.32	25± 0.56

2. Mortality and final body weights

In terms of mortalities, according to the statistical data, mortalities percentage was only detected among animal and plant supplemented groups. It was 13.3 and 6.6%, respectively.

Regarding the body weights, as shown in Fig. (2), seaweeds supplemented *Strombus tricornis* exhibited marked increase in the final body weights, reaching 205.3± 6.39gm for *J. rubens,* 180.98± 14.4gm for *D. ciliolate* and 180.78± 14.3gm for *racemosa,* when compared with the *Strombus tricornis* weights under animal and plant diets, which were 176.44± 25.7 and 171.14± 9.8gm, respectively.

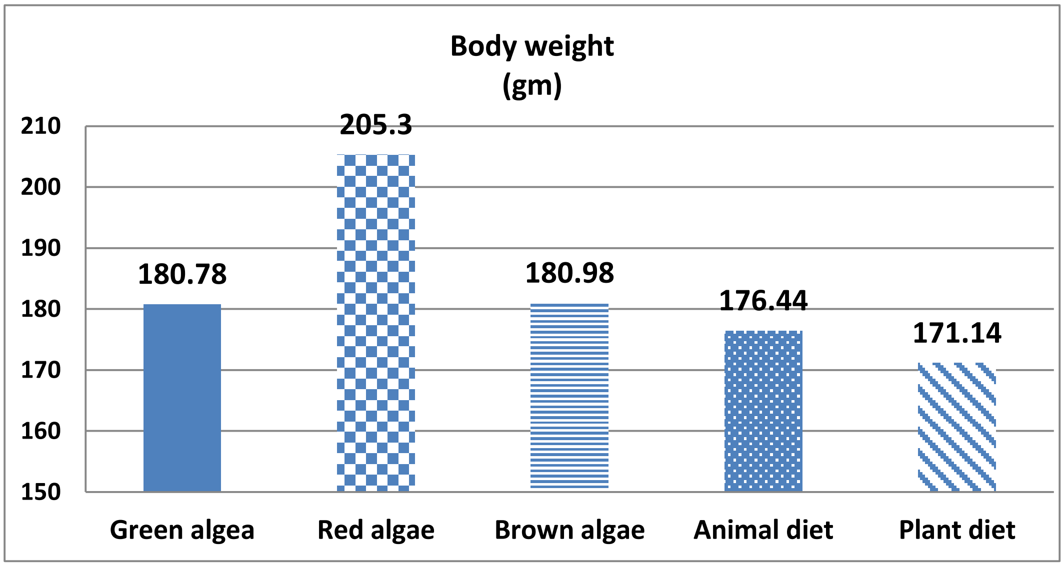

Fig. 2. Effect of the different algal and protein diets on the body weights of *Strombus tricornis*

3. Histological results

3.1. Macroscopic findings

Necropsy revealed that gut, digestive glands and muscles of the control *Strombidae* exhibited apparently normal appearance. Likewise, treated groups appeared within normal shape, color and consistency.

3.2. Microscopic lesions

Table (3) and Figs. (3, 4, 5) show the results of the histopathological examinations which displayed ameliorative effect of marine macroalgae on histomorphology of the digestive organs and muscles of *Strombus tricornis* conchs when compared with histomorphological characteristics of commercial protein diets.

3.2.1 Intestine.

Histological sections of intestine of control *Strombus tricornis* showed degenerative changes with vacuolation of the epithelial lining villi (Fig. 3a). On the other hand, *Strombus tricornis* treated with green algae exhibited normal architecture of the intestinal layers mainly composed of well-developed mucosa lined with columnar epithelial cells and intact submucosa with loose connective tissues (Fig. 3b). Moreover, intestine of *Strombus tricornis* supplemented with red and brown algae showed fully developed intestinal morphology (Fig. 3c, d). In group 5, treated with animal protein, a prominent degree of cytoplasmic vacuolation was observed, indicating a degeneration of the intestinal tissues (Fig. 3e). Moreover, *Strombus tricornis* treated with plant protein suffered from degenerative changes of the epithelial lining but in mild form (Fig. 3f).

3.2.2 Digestive gland.

Histological sections of the control digestive glands of *Strombus tricornis* exhibited poor development of the digestive cells with vacuolated cells deficient in brown inclusion bodies (Fig. 4a). Digestive glands of *Strombus tricornis*, treated with green, red and brown algae showed a typical arrangement of the digestive cells with a columnar epithelium. Moreover, vacuolated cells were frequently observed, showing vacuolated cytoplasm with elongated brown inclusion bodies (Fig. 4b, c, d). *Strombus tricornis* fed with animal protein revealed focal inflammatory infiltration consisted of the erythrocytes and lymphocytes (Fig. 4e). Digestive glands of *Strombus tricornis* of group 6, treated with plant protein, showed normal histology of the digestive cells (Fig. 4f).

3.2.3 Muscles.

Histological sections of the muscles of control *Strombus tricornis* revealed mild congestion in the blood vessels and degeneration with less striations of the muscles fibers (Fig. 5a). Muscles of *Strombus tricornis* of group 2, treated with microalgae supplements green, red or brown type, exhibited a well developed striated muscles with normal striation (Fig. 5b, c, d). While, in the case of *Strombus tricornis* of group 5, a mild hemorrhagic inflammation was observed, characterized by a limited infiltration of red blood cells (Fig. 5e). Meanwhile, muscles of *Strombus tricornis*, when treated with plant protein, showed normally coordinated muscles fibers with a slight congestion of the blood vessels (Fig. 5f).

Table 3. Histological lesions scoring based on degree of the histological lesions

Group / Lesion	Control	*Racemosa*	*J. rubens*	*D.ciliolate*	Animal protein	Plant protein
Intestine						
Epithelial vacuolation	+	-	-	+	++	+
Hemorrhage	-	-	-	-	+	-
Inflammation	-	-	-	-	+	+
Digestive gland						
Brown inclusion bodies	-	+++	+++	+++	++	+
Digestive cells vacuolation	-	+	+	+	++	-
Mononuclear infiltration	-	-	-	-	++	+
Erythrocytes infiltration	-	-	-	-	+	+
Muscles						
Degenerative changes of muscles	-	-	-	-	+	++
Congestion of blood vessels	-	-	-	-	+	++

Absent, (-), mild (+), moderate (++), and severe (+++)

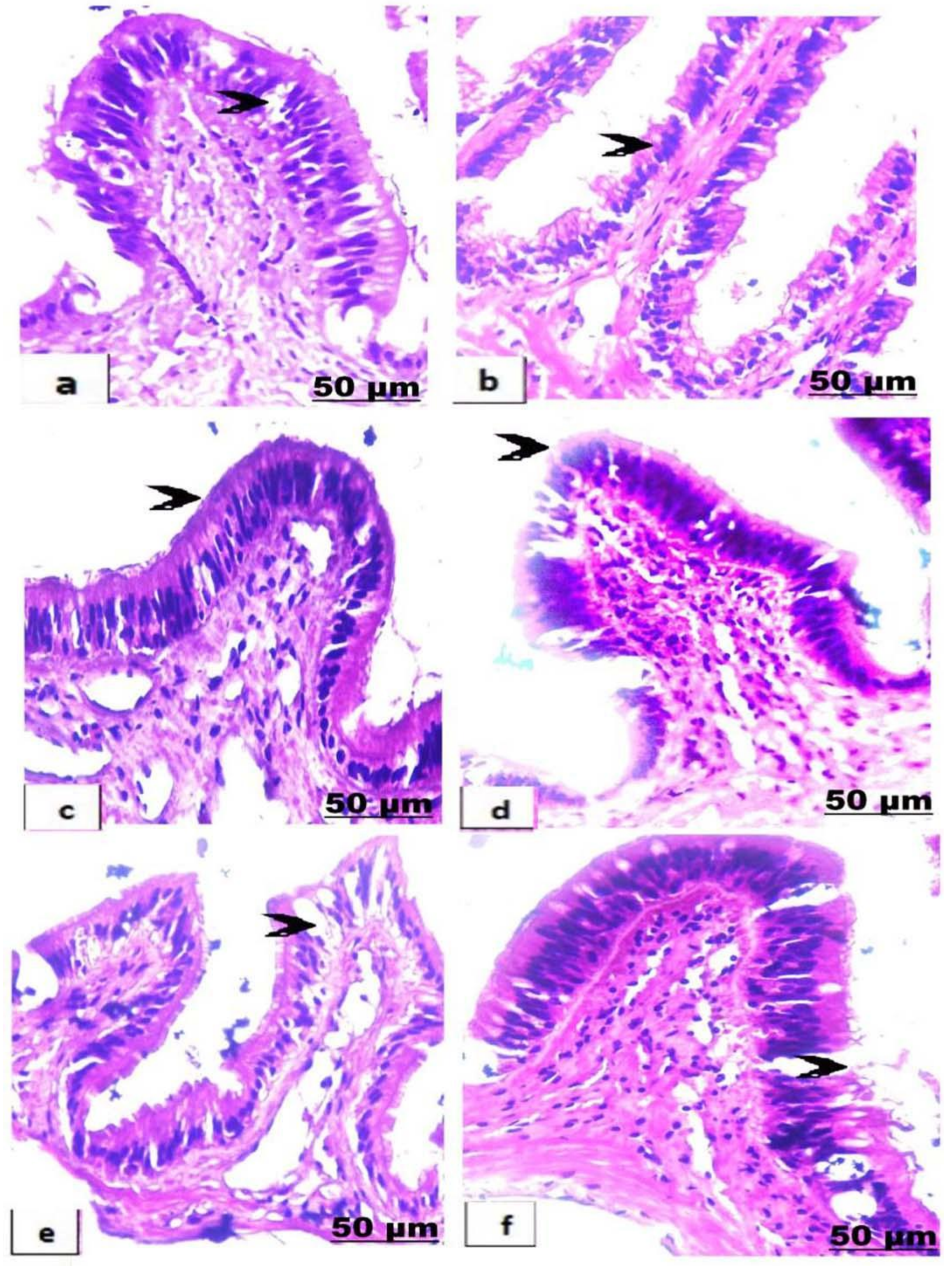

Fig. 3. Transverse sections of intestine of control and treated *S. tricornis* stained with H & E showing: a) Intestine of control showing vacuolation of the epithelial lining intestinal villi, b) Intestine treated with green algae showing intact intestinal epithelium, c) Intestine treated with red algae showing well developed intestinal tissues, d) Intestine treated with brown algae showing mild vacuolated intestinal tissues, e) Intestine treated with animal protein showing remarked vacuolation of the intestinal epithelium, and f) Intestine treated with plant protein showing slight degenerative changes of the epithelial cells (Scale bar= 50µm)

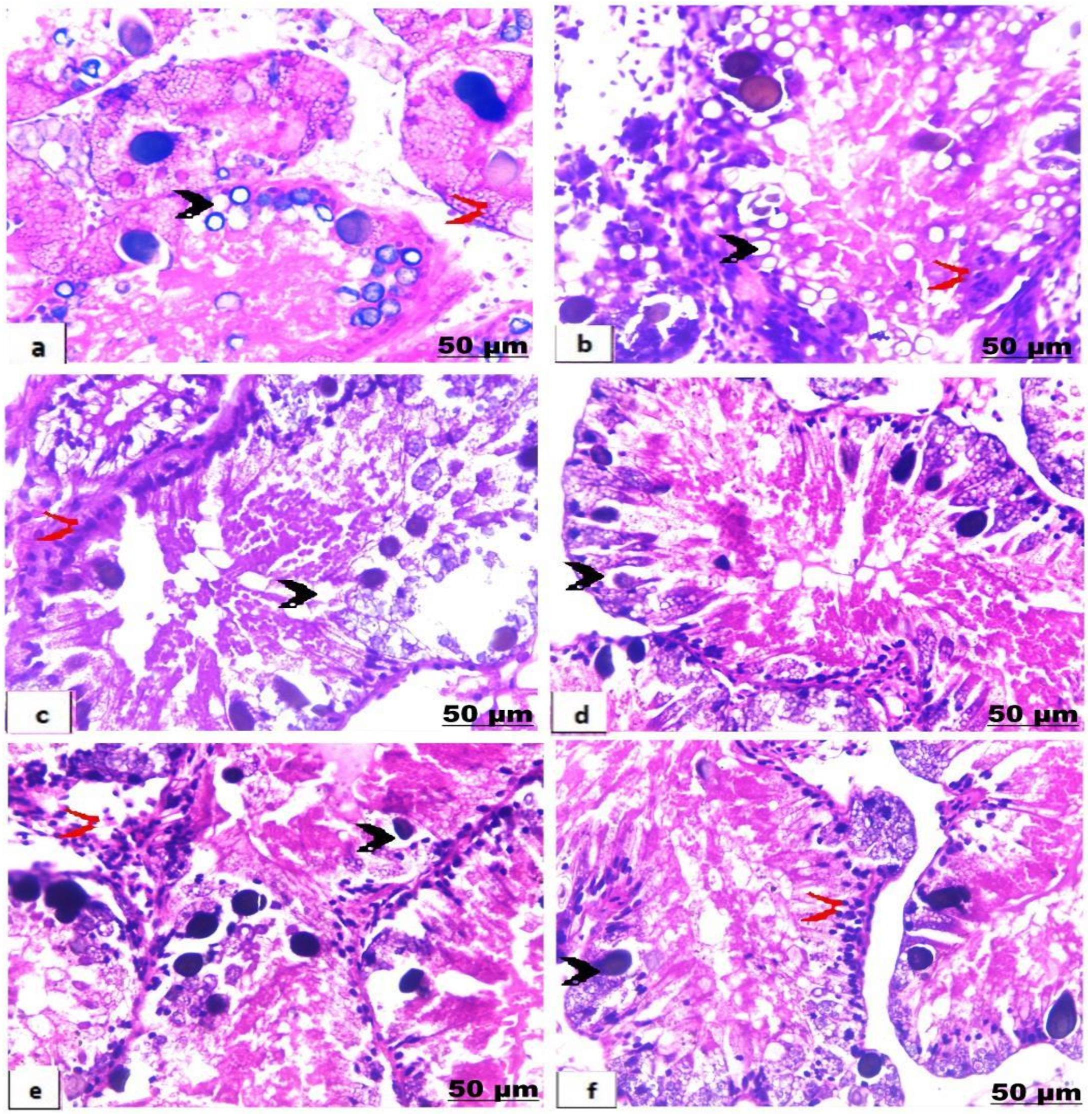

Fig. 4. Transverse sections of digestive glands of control and treated *S. tricornis* stained with H & E showing: a) Digestive glands of control *S. tricornis* showing poorly developed digestive and vacuolated cells; b) Digestive glands treated with green algae showing well developed digestive and vacuolated cells with brown inclusion bodies; c) Digestive glands treated with red algae showing normal organized digestive and vacuolated cells; d) Digestive gland treated with brown algae showing normally arranged vacuolated cells; e) Digestive glands treated with animal protein showing focal infiltration of the erythrocytes (red head), besides lymphocytes infiltration (black head), and f) Digestive glands treated with plant protein showing healthy digestive glands (Scale bar= 50µm)

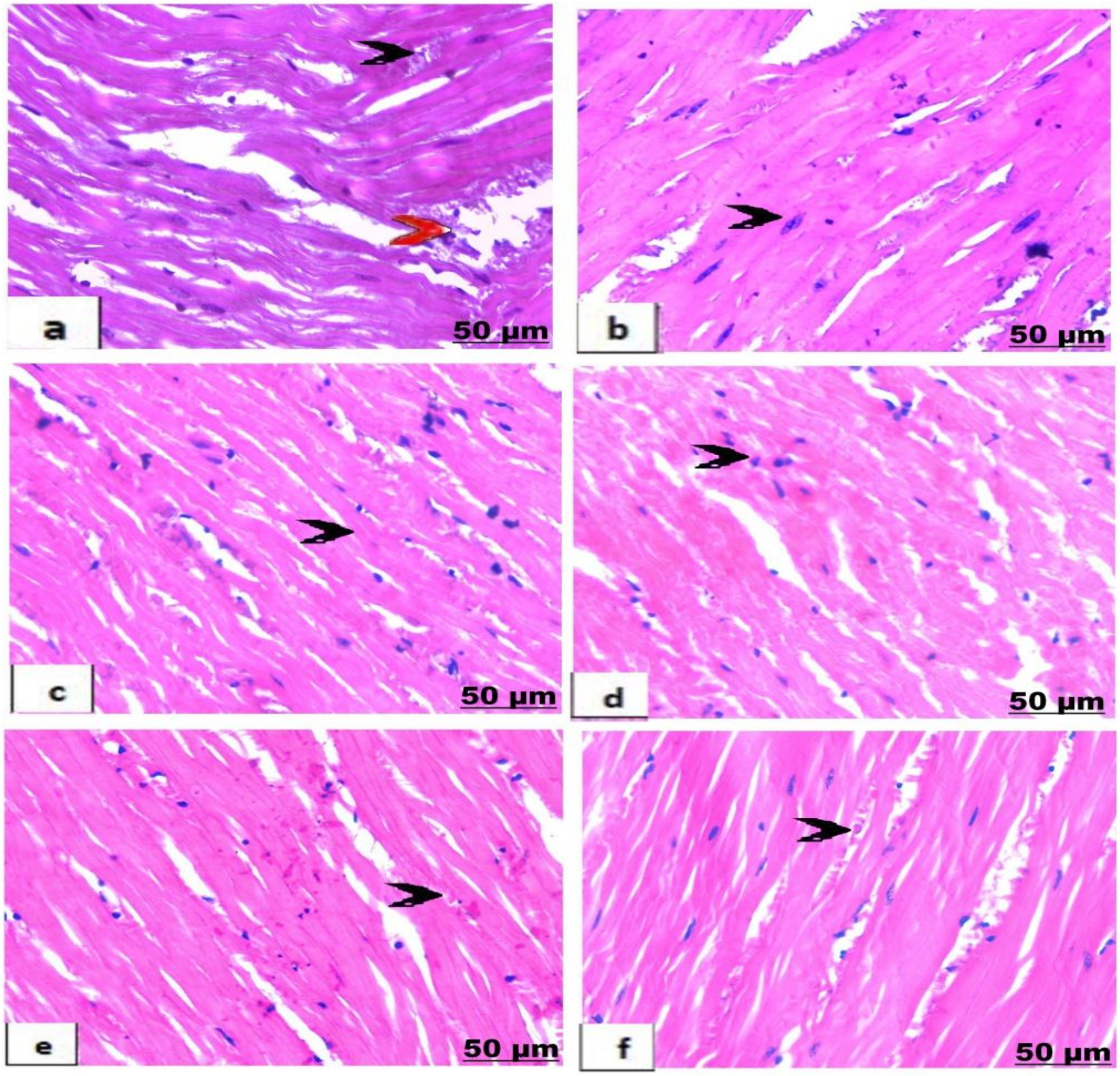

Fig. 5. Transverse sections of muscles of control and treated *S. tricornis* stained with H & E showing: a) Muscles of *S. tricornis* of control showing congestion in the blood vessels (black head), as well as degeneration of some muscles fibers; b) Muscles treated with green algae showing well developed striated muscles; c) Muscles treated with red algae showing normal striation of muscles; d) Muscles treated with brown algae showing well organized muscles fibers; e) Muscles treated with animal protein showing minimal infiltration of the red blood cells, f) Muscles treated with plant protein showing normal striation of the muscles fibers with congested blood vessels (Scale bar= 50µm)

DISCUSSION

The cultivation of marine, shellfish and algae is a critical source of food production **(FAO, 2010)**. Moreover, it has assisted to improve harvestable stocks condition of some marine wealth. Sustainable aquaculture of *Strombidae* needs harvest of broodstock reared by using appropriate feed **(Stoner & Waite, 1991)**. In aquaculture, growth depends on the availability of protein sources notably the fishmeal. Aquaculture meals require rising in the daily body gain. In aqaufeed, fishmeal predominantly serves as the primary source for nutritive protein, minerals, vitamins, and essential fatty acids **(Naylor *et al.*, 2009)**.

Intensive conch aquaculture is deficient in formulated feed for attaining a proper growth rate at an equal or a higher than that of the wild stock. Under natural conditions, conchs' graze on a composite macroalgae and microbenthic diets **(Serviere-Zaragosa *et al*., 2009)**. There is no available information on the desired nutrient schedule for Strombus species' diet **(Garr & Acosta, 2011)**. To investigate the potential of formulated algae as a nutrient substitute for protein diet, a protocol was established to study its effects on the histological profile of *Strombidae tricornis*.

Strombidae are frequently associated with continual microphagous nutrition **(Fretter & Graham, 1962)**. However, many studies have mentioned that some Strombus species are herbivorous graze on hard and soft algae **(Stoner & Waite, 1991)**. The mode of feeding varies for microphagous and deposit-feeders. Additionally, the digestive gland undergoes cyclic modifications primarily correlated with food availability and processing **(Henry, 1984)**.

Recently, fish nutritionists have been exploring alternative feedstuff ingredients that can provide the same nutritional value at a lower cost, and this trend is becoming increasingly striking **(Bin Dohaish *et al*., 2018)**. Among the potential alternatives, algae are promising constituents in aquafeeds, hence they improve the growth performance in aquatic species **(Allen *et al*., 2019)**. Algae as an available source for human and animal food have gained growing attention recently **(Lorenze & Cysewski, 2000)**. Compared with other protein compositions, algae are enriched with essential fatty acids and proteins. Moreover, they serve as valuable ingredients in meals, contributing to enhanced growth, improved physiological status, increased resistance to diseases, and stress reflection **(Adissin *et al*., 2019; Ayala *et al*., 2020)**.

Seaweed culture permits continual availability of macroalgae species and assures that the essential nutritive contents are relatively consistent **(Capo *et al*. 1999, 2002; Barile *et al*., 2004)** and are possibly boosted **(Shipgel *et al*., 1999)**. Marine macroalgae is categorized to three main types; red, green and brown. It is considered as a main food supplement for proteins, lipids, minerals, polysaccharides and enzymes **(Wei *et al.*, 2013)**. Algae are a valuable source for some vitamins, such as A, B, C, E, folic acid, nicotinic acid, biotin, and pantothenic acid **(Becker, 2004)**. Substantially, macroalgae are enriched in iron and gamma linoleic acid **(Belay, 2002)**, chlorophyll and carotenoids pigments **(Al-Harthi & El-Deek, 2012)**. The red algae species Rhodophytas, *Gracilaria ferox,* and *A. subulata*, as well as green algae species the *Ulva* spp., from a controlled environment, were combined to create a mixed seaweed feed, fostering higher yields in *Aplysia californica* **(Capo *et al*., 2002)**.

In the present study, we investigated the utilization of seaweeds as an alternative source of protein for *Strombus tricornis* conchs by evaluating their body weights and the histological profile of intestine, digestive glands and muscles. Supplementation of the *Strombus tricornis* with *racemosa, ciliolate* and *J. rubens* algae had a positive impact on the body weight with a better histomorphology of the digestive organs and muscles, while protein diets exhibited some histological changes despite having an improvement in body weights was observed. Similar results were confirmed by **Bin Dohaish *et al.* (2018)**, who reported that a diet incorporating the blue-green alga *S. platensis* improved the kidney histoarchitecture of tilapia. In contrast, the diet with soybean protein exhibited consecutive cellular alterations in the renal tissues. The presence of *S. platensis* in the diet induced improvements in the growth and histoarchitecture of tilapia, attributed to its increased nutritional value. *Spirulina* is distinguished by its high concentration of vitamins, minerals, phycocyanin, and antioxidant characteristics **(Estrada *et al*., 2001)**. *Spirulina platensis* offered a positive role on the kidney architecture of tilapia which might be due to the bioactive contents in alga implicated in an attenuation of inflammation **(Bin Dohaish *et al*., 2018)**. The predominance of such contents verified detectable anti-inflammatory, hepatoprotective, anti-arthritic, and neuroprotective effects against various diseased conditions **(Rimbau *et al*., 1999)**.

In comparison with soybean, algae cover a significant protein source and fishmeal substitution attributed to own rare level of tannins, phytic acid, and trypsin inhibitor as anti-nutrient factors **(Kokou *et al*., 2015)**. Seaweeds used an animal feed addition comprised brown *Ascophyllum nodosum* species. Tasco®, marine plant can intensify the health of animals and improved gut microbiota, and growth performance **(Evans & Critchley, 2013)**. The addition of brown *Ascophyllum nodosum* seaweed to broiler feed resulted in improved intestinal criteria, characterized by well-developed villi. This suggests an increase in the digestive and absorptive area, leading to enhanced nutritive utilization. Hence, brown algae reserve a useful effect on growth performance, and intestine development without triggering adverse effects **(Abou El-naga & Megahed, 2018)**. Moreover, red *Porphyra dioica* alga utilized as feed substituent for marine *Oncorhynchus mykiss* pose subsequent improvements on growth, feed quality and protein efficacy. Bioactive pigments in algae surely increased carcass protein **(Soler-Vila *et al*., 2009)**.

Raw soy-based feed had a negative impact on the digestive system and an increased tendency to enteritis in carnivorous fish. It was attributed to an increase of fiber content, carbohydrates, nutritional factors, and amino acids **(Rašković *et al*., 2011)**. However, it has been previously reported that abundant consumption of the plant protein confers a protective effect against chronic degenerative pathology through cholesterol regulation and inhibition of hepatic phospholipid metabolism **(Krajcovicova Kudlachova *et al*., 2005)**. Herein, an increase in the final body weights of *Strombus cornis* was observed in protein diets of animal sources compared to initial weights. **Bautista-Teruel *et al*. (2001)** and **Tung and Alfaro (2012)** confirmed that formulated diets of animal proteins sources positively affect tissue growth and development in mollusks.

Furthermore, adverse histological consequences in tilapia fed the commercial protein diet with plant content might be linked to the inclusion of soybean in the diet **(Bin Dohaish *et al*., 2018)**. Those lesions excited by the antinutritional factors of soybean **(Fuentes-Appelgren *et al*., 2014)**. Soybean protein intensively utilized in aquafeeds and subsequently altered growth and morphology in fish **(Sahlmann *et al*., 2013)**. Soybean possesses diverse anti-nutritional factors that influence quality, utility, and digestion of soybean protein **(Herkelman *et al*., 1992)**, inducing pronounced digestive and metabolic issues **(Sun *et al*., 2005)**. In soybean, protease inhibitor was able to disturb the enzymatic activity responsible for proteolysis process. The resultant amino acids from protein degradation are converted to ammonia, which is then transformed into urea by the liver. Additionally, increased blood urea level caused sudden renal histological aberrations **(Schrier *et al*., 2004)**.

CONCLUSION

Based on the previous histological observations, conchs which were fed diets containing *C. racemosa, D. ciliolate and J. rubens* exhibited an increase in body weight and maintained intact, fully developed histological structures in the intestines, gigestive glands, and muscles. This was characterized by an improvement of the intestinal villi with columnar epithelial lining, proper health of the digestive glands, and normally striated muscles fibers. On the other hand, conchs provided with protein diets experienced histological alterations in the cellular architecture of the digestive tissues and muscles fibers. These alterations were characterized by congestion of the blood vessels, degenerative changes with cytoplasmic vacuolation, and interstitial inflammation with infiltrates of lymphocytes and erythrocytes. Accordingly, we could conclude that algae supplementation confers improved effect on growth and histology of *Strombus tricornis* conchs in comparison with proteins supplemented diets. Algae can be effectively utilized to replace protein ingredients, enhancing the commercial production of marine conchs culture at various dietary levels.

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