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Monthly variations of total lipids content and some biological parameters of rock oyster (*Saccostrea cucullata*) in the Northern coasts of the Gulf of Oman

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The present study was conducted to assess the monthly variations of total lipids content and some biological parameters of rock oyster in the Northern coasts of the Gulf of Oman (Iranian coast) from October 2017 until March 2018 in relation to environmental conditions. According to the results, the maximum and minimum lengths were recorded in December and February, respectively. The highest amounts of weight, dry and wet weight, and condition index were recorded in autumn. There was also a significant difference between the months and the regions for these parameters ($p < 0.05$). The highest amount of total lipids was observed in March (3.1±1.84) with a significant difference relative to October and November and the lowest amount one was observed in October (2.15±1.6). Also, there was a significant relationship between the total lipids and the temperature. Moreover, there were higher amounts of total lipids in *Saccostrea cucullata* in winter compared to those in autumn. In general, one of the reasons for the differences in length, weight and total lipids at different stations over different months can mainly be explained by the reproduction season, nutritional conditions, and environmental factors such as temperature and salinity.

[**Keywords**: Biology, Gulf of Oman, Invertebrate, *Saccostrea cucullata*]

Introduction

As one of the major sources of food, marine organisms have beneficial effects on human health in many products isolated from the marine organisms after clinical trials[1]. Bivalve mollusks mainly contain significant amounts of digestible proteins, essential amino acids, bioactive peptides, unsaturated fatty acids, astaxanthin and other carotenoids, vitamin B12 and other vitamins. They also have some minerals including copper, zinc, and inorganic substances such as phosphate, sodium, potassium, selenium, iodine, and other nutrients essential for the health of consumers. However, due to filter-feeding mode of feeding, they are greatly exposed to ambient pollutants in the habitat leading to diseases in them.

In recent years, however, coastal development has aggravated the degradation of marine ecosystems and depleted marine resources including bivalve mollusks as a result of inadequate management. This could endanger the health and sustainable exploitation of resources. Besides, it is crucial to identify the distribution patterns of bivalves and the environmental conditions along with other ecological indicators for the conservation and management of bivalves.

The study of Sajjadi & Eghtesadi[2] on the nutritional value of bivalves and the evaluation of biometrical parameters by researchers such as Zare *et al*.[3] and Ramadhaniaty *et al*.[4] are among numerous studies conducted on the bivalves. However, no comprehensive study has yet been conducted on the total lipids and some of the population parameters of the rock oyster *Saccostrea cucullata* along the northern coasts of Gulf of Oman. Therefore, this study aimed to evaluate the changes in some population parameters (length, weight and condition index) and in total lipids of *Saccostrea cucullata* and also to evaluate the effect of environmental factors on such temporal changes.

Materials and Methods

From October 2017 to March 2018, 20 bivalves (*Saccostrea cucullata*) per month were manually collected from each station during the 6 months (360 samples in total) from the intertidal zone of Iranian coast in Sistan and Baluchestan province. They were collected from three stations (Tis, Beris and Darya-Bozorg), the hammer and chisel were used for the isolation of samples (oysters)[3]. The locations of sampling stations are listed in Table 1 and Figure 1. The samples were first placed in a wet sack and were then transferred to the Marine science Laboratory of Chabahar Maritime and Marine Sciences University in a large basket.

Biometric study of oyster specimens

The height, length and width parameters of the oysters were measured by Galtsoff[5] method using a caliper with a precision of 0.01 mm. The weight of the samples was measured by a digital scale (SF400) with a precision of 0.01 g, monthly.

Wet and dry weight and condition index

Initially, the whole wet weight of each oyster was calculated (g) and then, the soft tissue inside the shell was removed and the inner and outer surfaces of the shell were thoroughly washed to obtain the wet weight of the oyster shells. Afterward, assuming that the density of body tissues is 1 g/cm[ref. 6], by subtracting the shell wet weight from the whole weight, the capacity of the inner cavity of the shell was obtained (g) equivalent to the volume of the cavity (cm^3). The body tissues removed from the shell were placed at 30 °C for 18 h to obtain the dry weight of the tissue.

After collecting the above data, the condition index (CI) is obtained as follows[7,8]:

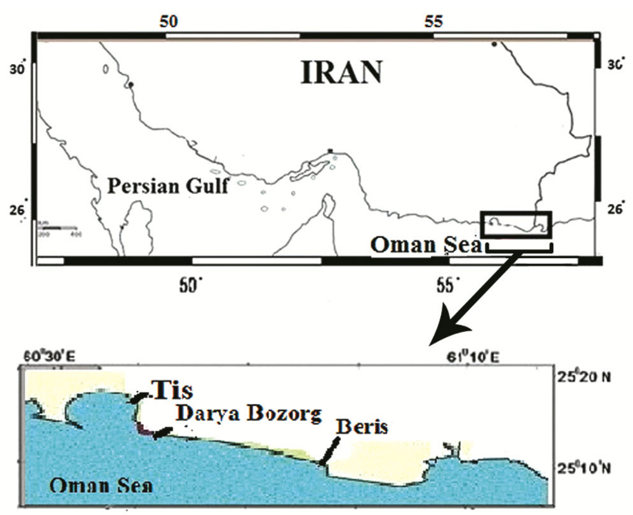

Fig. 1 — Geographical location of sampling stations in the Northern coasts of Gulf of Oman

Table 1 — Geographical coordinates of sampling stations on the Northern coasts of Gulf of Oman

Station	Latitude (N)	Longitude (E)
Station 1 (Tis)	25°21'22"	60°16'07"
Station 2 (Beris)	25°19'55"	60°15'13"
Station 3 (Darya-Bozorg)	25°18'34"	60°17'40"

CI = (TDW ×100) / (WWW-SWW)

Where, WWW = whole wet weight, SWW = shell wet weight, and TDW = tissue dry weight.

Total lipids measurement

The Soxhlet method[9] was used with the solvent to measure the total lipids (TF) using the following formula:

TF (%) = (flask weight before fat extraction + weight of boiling chips/weight of sample)×100

The one-way ANOVA was used to determine the statistical differences in length and weight, total lipids and physico-chemical parameters within different stations and seasons. The Duncan test was employed for the pair-wise comparison between different stations and seasons. Also, the Pearson correlation coefficient was utilized to analyze the relationship between the environmental factors, total lipids and length and weight using the SPSS 19 software.

Results

Physico-chemical parameters

The highest temperature was recorded in Tis station (28.23±0.27 °C) in October and the lowest temperature in Darya-Bozorg station (23.1±0.18 °C) in March. The highest salinity recorded was 37.61±0.11 ppt in October at Tis station and the lowest salinity was 35.45±0.43 ppt recorded in March at same station. Similarly, the highest value of acidity (pH) was observed in Tis station (8.39±0.19) in January and the lowest (8.15±0.01) in Darya-Bozorg station in March.

According to Figure 2, there was a significant difference in salinity, pH and temperature at Tis, Beris and Darya-Bozorg stations as 37.23±0.45 > 36.95±0.45 > 36.16±0.5; 8.27±0.06 > 8.26±0.06 > 8.19±0.02; 26.29±0.15 > 26.15±0.14 > 25.11±0.17 ($p < 0.05$), respectively.

Biometry

According to the results of length data (Table 2), the highest mean length (62±7.19 mm) was recorded at Tis in October, while the lowest mean length (36.2±3.59 mm) was observed in February at Darya Bozorg station. In total, the highest length with significant difference ($p < 0.05$) was recorded in December (45.6±4.93 mm) and the lowest in February (38.5±4.66 mm; $p < 0.05$). Similarly, the highest total weight was recorded in October (29.03±11.78 g) with significant difference (compared to February and March; $p < 0.05$), and the lowest weight in January (19.2±12.14 g) with significant difference ($p < 0.05$) (compared to October; Table 2).

The highest and lowest meat dry weight was obtained in October (0.33±0.16 g) and January (0.26±0.15 g), respectively; but there was no statistically significant difference between the different months in terms of meat dry weight index ($p > 0.05$). Likewise, the highest meat wet weight was recorded in October (2.38±1 g) with significant difference compared to January ($p < 0.05$) and the lowest in January (1.68±0.15 g) with significant difference compared to other months ($p < 0.05$) (Table 2).

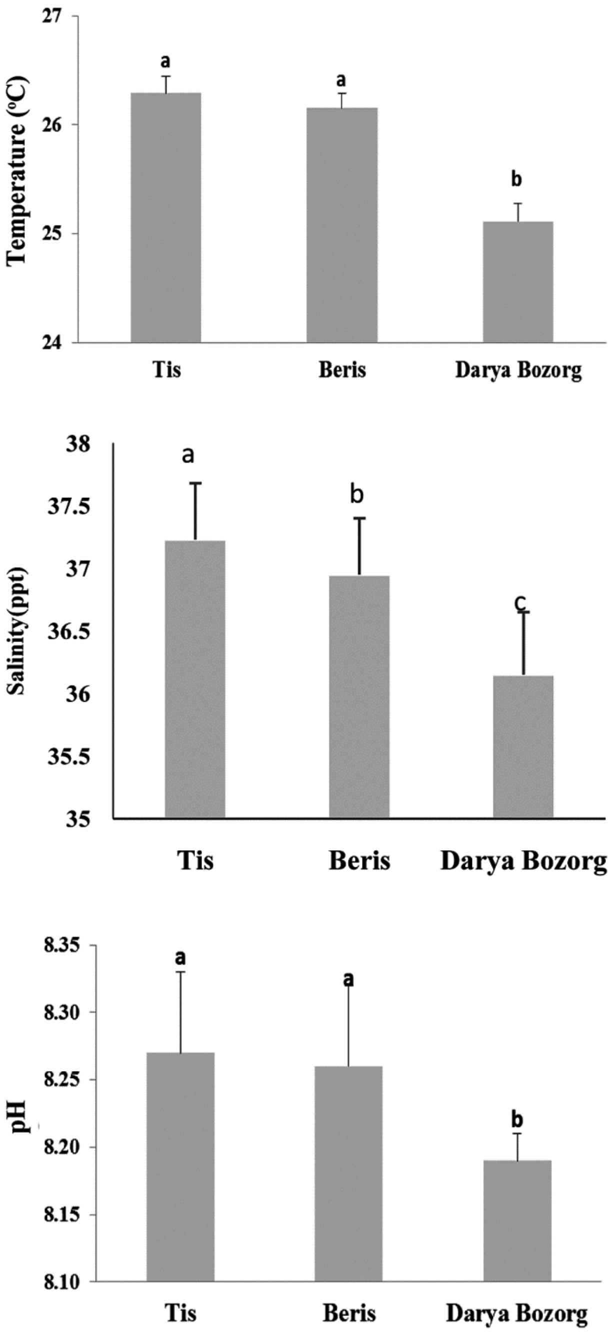

Fig. 2 — Comparison of temperature, salinity and pH (Means±SD) at different stations of Northern coasts of Gulf of Oman (2018). Similar marks in each row indicate that there is no significant difference

The highest condition index was recorded at Tis station with mean of 17.8±1.09 in October and the lowest one with mean of 11.5±4.82 in January at Beris station. In total, the highest and lowest condition index was observed in October (16.91±1.46) and January (11.68±0.15), respectively ($p < 0.05$) (Table 2). The comparison of total length, total weight, meat dry weight, meat wet weight and condition index at different stations is shown in Table 2. According to the table, there was a significant difference ($p < 0.05$) in total length, total weight, meat dry weight and meat wet weight at Tis, Beris and Darya-Bozorg stations. However, there was no significant difference in the condition index at all the stations (14.35±2.1 > 14.1±1.83 > 13.57±1.41; $p > 0.05$; Table 2).

Total lipids

The highest amount of total lipids was recorded at Tis station with mean of 4.12±1.29 % in December and the lowest (1.15±1.05 %) in November at Beris station. In total, the highest amount of total lipids was recorded in March (3.1±1.84 %) with a significant difference compared to October and November and the lowest in October (2.15±1.6 %; Table 3). The mean (±SD) of total lipids (%) at Tis, Beris and Darya-Bozorg stations was 2.82±1.44, 2.45±1.48 and 2.77±1.59 %, respectively, but no significant difference was found between the stations for total lipids ($p > 0.05$).

Pearson correlation

The Pearson correlation was used to evaluate the relationship between length and weight of the oysters. The results revealed a positive relationship between the total weight and the total length, wet weight and dry weight of meat (Table 4).

A significant relationship was observed between the total lipids and the temperature and wet weight factors considering the p-value ($p < 0.05$), but no significant difference was observed between the total lipids and other factors ($p > 0.05$; Table 5).

Table 2 — Total length (TL), total wet weight (TWW), meat dry weight (MDW); meat wet weight (MWW); and condition index (CI) of *Saccostrea cucullata*, North of Gulf of Oman (2018). Values are represented in Mean ± SD. (St1 = Tis; St2 = Beris; St3 = Draya Bozorg)

	St/ Month	Oct	Nov	Dec	Jan	Feb	Mar	Mean
TL (mm)	St1	62±7.19^{a}	53.5±7.67^{ab}	53±7.48^{ab}	41.2±6.87^{c}	39±4.56^{c}	38.3±5.78^{c}	47.67±6.61^{A}
	St2	39.3±4.56^{b}	39.2±4.1^{b}	43.3±4.94^{a}	42.4±3.81^{a}	37.5±5.73^{b}	39.9±6.94^{b}	40.36±5.01^{B}
	St3	44.2±4.96^{a}	41.2±4.1^{a}	41±4.87^{a}	41±4.56^{a}	36.2±3.59^{b}	39±6.31^{ab}	40.43±4.73^{B}
	Mean	44.4±5.73^{ab}	44.3±4.13^{ab}	45.6±4.93^{a}	44.2±4.85^{ab}	38.5±4.66^{c}	39.1±6.71^{bc}	
TWW (g)	St1	32.42±12.3^{a}	24.33±7.98^{b}	21.62±7.88^{b}	18.8±4.04^{c}	24.3±6.84^{b}	34.1±7.86^{a}	25.92±7.75^{AB}
	St2	29.9±13.17^{a}	26.7±14.29^{a}	26.9±13.46^{a}	27.2±14.42^{a}	26.5±13.68^{a}	20.8±6.52^{a}	26.33±12.62^{A}
	St3	24.8±9.84^{ab}	27.11±6.39^{a}	18±7.41^{bc}	22.3±6.14^{ab}	15.1±4.67^{c}	21.4±11.31^{ab}	21.45±7.62^{B}
	Mean	29.03±11.78^{a}	25.9±9.46^{ab}	21.96±10.72^{ab}	19.2±12.14^{b}	22±8.5^{ab}	19.83±5.38^{b}	
MDW (g)	St1	0.24±0.09^{bc}	0.24±0.13^{bc}	0.19±0.06^{c}	0.32±0.16^{ab}	0.33±0.17^{ab}	0.41±0.13^{a}	0.29±0.12^{A}
	St2	0.38±0.17^{a}	0.33±0.22^{a}	0.44±0.24^{a}	0.37±0.12^{a}	0.41±0.24^{a}	0.27±0.21^{a}	0.37±0.18^{B}
	St3	0.27±0.13^{a}	0.24±0.11^{a}	0.19±0.1^{ab}	0.21±0.08^{ab}	0.13±0.06^{b}	0.29±0.12^{a}	0.24±0.1^{A}
	Mean	0.33±0.14^{a}	0.27±0.16^{a}	0.27±0.19^{a}	0.26±0.15^{a}	0.29±0.2^{a}	0.30±0.16^{a}	
MWW (g)	St1	2.62±1.09^{ab}	2±1.13^{bc}	1.71±1.06^{c}	0.79±1.16^{d}	2.3±1.17^{bc}	3±1.13^{a}	2.07±1.12^{AB}
	St2	2.43±1^{ab}	2.09±1.35^{ab}	3.09±1.31^{a}	2.5±0.82^{ab}	2.5±1.15^{ab}	1.86±1.08^{b}	2.41±1.11^{A}
	St3	2.07±0.85^{a}	2.3±1.24^{a}	1.53±0.81^{ab}	1.77±0.64^{ab}	1.23±0.7^{b}	1.7±0.5^{ab}	1.76±0.78^{B}
	Mean	2.38±1^{a}	2.13±1.11^{ab}	2.11±1.14^{ab}	1.68±0.95^{c}	2±0.1^{ab}	2.2±0.98^{ab}	
CI	St1	17.8±1.09^{ab}	15.2±1.13^{bc}	13.9±3.06^{c}	12±5.16^{d}	13±1.17^{bc}	14.2±1.13^{a}	14.35±2.12^{A}
	St2	16.8±1^{ab}	15.5±1.2^{ab}	13.7±2.31^{a}	11.5±4.82^{ab}	13.5±1.15^{ab}	13.6±1.19^{b}	14.1±1.9^{A}
	St3	15.8±1.85^{a}	14±1.24^{a}	13.8±4.81^{ab}	11.9±4.99^{ab}	12.2±2.7^{b}	13.7±1.5^{ab}	13.56±2.85^{A}
	Mean	16.91±1.46^{a}	14.9±1.26^{ab}	13.94±3.03^{b}	11.68±4.64^{c}	12.83±1.44^{bc}	13.76±1.16^{b}	

Similar marks indicate that there is no significant difference

Table 3 — Mean (±SD) of *Saccostrea cucullata* total lipids in sampling months at different stations North of Gulf of Oman (2018)

Station/Month	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Tis	2.46±1.55^{a}	2.44±1.41^{a}	4.12±1.29^{a}	2.17±1.2^{a}	2.83±1.33^{a}	2.94±1.86^{a}	2.82±1.44^{A}
Beris	1.73±1.43^{b}	1.15±1.35^{b}	2.68±1.62^{a}	3±1.38^{a}	3±2.31^{a}	2.98±0.8^{a}	2.45±1.48^{A}
Darya-Bozorg	2.25±1.4^{b}	2.17±1.2^{b}	2.78±1.56^{a}	2.87±1.66^{a}	2.99±1.39^{a}	3.56±2.37^{a}	2.77±1.59^{A}
Mean	2.15±1.6^{b}	2.17±1.61^{b}	2.99±1.62^{a}	2.46±1.45^{a}	2.62±1.74^{a}	3.1±1.84^{a}	

Similar marks in each row indicate that there is no significant difference

Table 4 — Pearson correlation between total wet weight and total length, dry weight and wet weight of meat at North of Gulf of Oman (2018)

		Length	Meat dry weight	Meat wet weight
Total wet weight	p	0.000	0.02	0.02
	r	0.359	0. 893	0.653

Discussion

Among bivalves, the oysters have extensively been used in biomonitoring programmes[10]. Condition index, length and weight are essential biological parameters in aquatics that are used to determine the growth and status of stocks, assess the availability of food resources, and show the possible differences between individual stocks of identical species[11,12].

In the present study, the highest and lowest length was recorded in December (45.6±4.93) and February (38.5±4.66), respectively with significant difference ($p < 0.05$). From October to January, the presence of adults (with higher mean weight and length) is higher than that in February and March (young individuals with lower mean weight and length). The mean length calculated in the study of Zare *et al.*[13] was 55.42 mm. Ashja Ardalan[14] reported the highest estimated length of the *Saccostrea cucullata* rock oyster in the waters of Sistan and Baluchestan province as 90 mm. Further, Dye[15] reported the maximum calculated length of 90 mm for *S. cucullata* on the coast of South Africa.

The reproduction time may lead to changes in species length during different seasons[16,17]. Ashja Ardalan[14] reported that the spawning for *S. cucullata* occurs in the spring season *i.e.* from April to May along the coast of Sistan and Baluchistan province. According to Ashja Ardalan[14], smaller individuals are added in the fall to the stock after the spawning in the spring. Hong & Lee[18] and Mackie *et al.*[19] reported that during the reproduction season, the bodyweight is decreased as the gametes leave the body.. However, given that the number of young individuals (with low length and weight groups) reached its maximum value in February and March, this indicates the onset of reproduction in this species during these months.

Table 5 — Pearson correlation of biological indicators and environmental factors with total lipids of oysters at North of Gulf of Oman (2018)

		Total length	Total wet weight	Meat wet weight	Meat dry weight	Temperature	Salinity	pH
Total lipids	P	0.302	0.03	0.871	0.679	0.02	0.504	0.886
	r	0.177	0.116	-0.121	-0.124	0.314	0.215	0.211

The nutrition factor can also contribute to the length and weight for bivalves in different seasons. This is reported by Behzadi[20] and Hosseinzadeh[16] that increase in the phytoplankton biomass and bloom in autumn increases the mean weight and length (growth) of bivalves. Many studies have also considered the nutrition restrictions in hot and cold seasons as one of the causes for the decrease in the growth of bivalves[21,22]. Another factor affecting the length and weight changes of bivalves in different seasons is the environmental factors. Temperature and salinity in autumn months are higher than those in the colder months of the year. In contrast, pH was higher in the cold months than that in autumn months. However, there was a positive correlation between the temperature and salinity and the length and weight, and a negative correlation was observed between pH and weight of bivalves. This has been confirmed by a large number of previous studies. In the study of Zare *et al*.[3] a positive correlation was found between the temperature and salinity and the weight. Further, Rodgers *et al*.[23] viewed environmental constraints (including reduced temperature, inadequate nutrition, and pollution) as the factors influencing the decrease in the length and weight growth of *Pincta daradiata* oysters. Moreover, Kimani & Mavuti[24] stated that the temperature changes affect the length, weight and even abundance of oyster population. The environmental parameters, salinity in the study of Beisel *et al*.[25] and the temperature and salinity in the study of Davenport & Wong[26] had found to exhibit a significant effect on the length and weight of the bivalve *Saccostrea cucullata* mollusks.

The mean (±SD) value of total length at Tis, Beris and Darya-Bozorg stations were 47.67±6.61, 40.36±5.01 and 40.43±4.73 mm, respectively. As a result, it can be stated that the oysters at the Tis station have a larger size than those at Beris and Darya-Bozorg stations. Pauly *et al*.[27] stated that the predominance of older individuals in the population indicates the lack of exploitation of the community or, in other words, the desirable dynamic cycle in the community. Dye[15] also suggested that the absence of older individuals in the oyster population can be due to the disruption to one of the reproduction stages, larval settlement stage, larval survival and mortality rate in the population. Further, Zare *et al*.[3] reported that the oysters in the two regions of Hormoz Island and the rocky shores of the Gulf of Oman in Chabahar have larger sizes, despite the lower abundance, due to the lack of social activity and pollution. Additionally, Gerami[28] stated that the habitats and coasts undergone social changes exhibit the lowest amount of length, weight and width. The rationales for the spatial-temporal variations of the communities are explained as the changes in the habitat homogeneity[29], and the changes include salinity[30], changes in organic matter content, bed material, oxygen content and most importantly, the pollution[31,32].

The growth rate of aquatics varies in different seasons, and the aquatics cannot usually maintain their body weight-to-length ratio during different periods of life[27]. The condition index is employed to compare the quality of aquatics in terms of obesity or fitness and, generally, population health status. The aquatics with high condition index or obesity factor are more substantial compared to their lengths, and conversely, the aquatics with low condition index or obesity factor are lighter compared to their lengths[33,34].

According to the results from the study of oyster samples, Tis station had the highest condition index among the studied stations. Also, the monthly condition index was October (16.91±1.46), November (14.90±1.62), December (13.94±3.03), January (11.68± 4.64), February (12.83±1.44), and March (13.76±1.16), respectively. Overall, the condition index of autumn months showed more value than that of winter months. Zare *et al.*[13] investigated the condition index of the *Saccostrea cucullata* rock oyster on the coast of the Persian Gulf. The condition index for autumn, winter, spring and summer seasons was calculated as 14.36, 16.87, 20.85, and 20.76, respectively which were contrasting to the present study. Further, Zeynalipour[35] studied some aspects of population dynamics and bivalve distribution of *Barbatia decussata* in the intertidal zone of the Bandar Lengeh coast in the northern Persian Gulf and stated that the condition index showed an increasing trend from October 2011 (13.8) to August 2012

(20.26). In total, the condition index of autumn months in the present study showed more value than the winter months. It seems that in the autumn months, the environmental and ecological conditions are appropriate and the fish properly feeds using proper nutritional conditions in the environment and this indicator has an increasing trend. In the late winter, the condition index is decreased when the spawning and nutritional restrictions begin in the winter. The study of Ashja Ardalan[14] on *S. cucullata* bivalves of the Sistan and Baluchistan coast was consistent with the present study.

According to the present study, the highest dry weight of meat was recorded in October (0.33±0.16) and the lowest one in December (0.26±0.15). Similar results were recorded for the meat wet weight as 2.38±10 in October with significant difference compared to January ($p < 0.05$) and the lowest in January (1.68±0.15), significantly different from other months ($p < 0.05$). Brown & Hartwick[36] stated that temperature and salinity had a positive correlation with dry and wet weight of meat. According to the above, because of the higher temperature and salinity in the autumn months compared to the winter months, the two factors can be viewed as one of the reasons for the increase of wet and dry weight of meat in these organisms. Mainly, in the case of Beris and Tis stations, as the increase of temperature and salinity was more significant than the Darya-Bozorg station, the wet and dry weights were significantly increased. There was also a positive correlation between the total weight and the meat wet weight ($r = 0.653$) and dry weight ($r = 0.389$). As a result, all the factors contributing to the weight increase of oysters during the fall, including the favorable nutritional conditions, resting and environmental factors such as temperature and salinity, can also play a role in the increased wet and dry weight of meat of bivalves in the fall/autumn season.

In the present study, the highest total lipids were recorded in March (3.1±1.84) with a significant difference compared to October and November and the lowest in October (2.15±1.6). In fact, the winter months showed a higher total lipids content than the autumn months. There was also a positive relationship between the total lipids and the temperature. Su examined the amounts of total lipids and polyunsaturated total lipids (PUFAs) in the oysters of Phillip Bay in Victoria and found that the summer samples had the highest levels of fat and the autumn samples had the lowest levels of fat[37]. In contrast, in the study of Sajjadi & Mooraki[6], no significant difference was observed in the amount of total lipids during the hot and cold seasons of the year ($p < 0.05$). Yildiz[38] studied the seasonal variations in the condition index, meat production and biochemical composition of oysters from the Dardanelles Strait of Turkey. He stated that a negative correlation was found between the temperature rise and the protein, total lipids and chlorophyll-*a*, and the maximum amounts of condition index and fat content were observed in the winter. Besides, Dagorn[39] investigated the lipids and fatty acids in the *Crassostrea gigas* oyster on the Atlantic coast of France. The results showed that the total lipids content varied from 7.1 % in winter to 6.6 % in autumn. Additionally, Sajjadi & Eghtesadi[2] studied the fatty acids of predominant mollusks in Persian Gulf and reported that the highest amount of fatty acid in mollusks was found in winter and the lowest one in autumn. Further, the results of other studies in different tissues of *Crassostrea virginica* oyster indicated an inverse relationship between the temperature and the amount of unsaturated fatty acids[40].

Conclusion

In total, in the winter months, as the bivalves (oysters) begin to reproduce, the body weight is reduced and the fatty acid content is increased. The reason for the increase in fatty acids in the winter months is the adaptation of the melting point of the lipid of cell membrane of the bivalve so that with the decreasing temperature, the cell membrane permeability should remain constant[6]. The study of some bivalves by Remacha & Anadon[41] and the study of Saeedi & Ashja Ardalan[42] on the bivalves of the Persian Gulf indicate that autumn is the resting period for the bivalve gonad follicles (the follicles are full of yolk oocytes and organic matter), which may be the reason for the low contents of fatty acids in autumn compared to winter in the present study.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Author Contributions

NJ designed experiments and analyzed data; ML designed experiments, analyzed and interpreted the data and wrote, edited and reviewed the article; and GAF performed the experiments.

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