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RESEARCH ARTICLE

Condition Index, Meat Yield and Biochemical Composition of Mediterranean Mussel (*Mytilus Galloprovincialis* Lamarck, 1819) from Canakkale Strait, Turkey

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ABSTRACT

The present study was performed in Çanakkale Strait from September 2012 to August 2013. Biochemical composition (protein, total lipid, moisture, and ash), condition index, and meat yield of Mediterranean mussel, *Mytilus galloprovincialis* in the net systems hung out the open sea cage units monthly. The mean condition index and meat yield of *M. galloprovincialis* were found 8.12±0.48 and 16.07±0.70%, respectively. A positive correlation was found between condition index and protein, carbohydrate, and meat yield whereas a negative correlation was seen between condition index and weight, length, lipid, moisture, and ash. In terms of seasons, condition index and protein values were high in autumn, lipid values in summer, and carbohydrate values in spring.

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Introduction

Mediterranean mussel (*Mytilus galloprovincialis*) has a distribution in the Aegean, Marmara, and Black sea (Uysal, 1970). Bivalve aquaculture has limited to *M. galloprovincialis* in Turkey (907 tons aquaculture, 604 tons capture) (FAO, 2020). As a considerable source of nutrient, mussels are quite crucial in terms of marine ecology and human diet (Pogoda et al., 2013). Based on the increasing production of *M. galloprovincialis*, it is important to determine its nutritional characteristics for encouraging consumers to buy and enabling producers to be engaged in the aquaculture of the species.

Biochemical composition, condition index, and meat yield are indicators of commercial and nutritional quality of bivalve (Orban et al., 2002; Yıldız et al., 2011; Irisarri et al., 2015).

A variety of factors affect biochemical composition in shellfish such as spawning, fecundity (Litaay and De Silva 2003; Acarli et al., 2018), variations in the seston-natural diet of suspension feeders quality and quantity (Irisarri et al., 2015).

Where net cages are present, fish feeds are dissolved in water, creating significant amounts of nitrogen and phosphate input thus enabling phytoplankton to increase (Sanz-Lazaro and Marin, 2008). Fish feces and unutilized feed provide additional food sources for bivalve species (Troell et al., 2003). In bivalve-fish culture, bivalves feed on phytoplankton and other particles in water, and covert the nutrients in the environment into edible meat as well (Aquado- Gimenez et al., 2014). Some research reported that bivalve species to capture and assimilate organic wastes caused by fish farms (Mazzola and Sarà, 2001; Redmond et al., 2010;). Integrated bivalve-fish culture seem

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to have a with remarkable benefits of increasing bivalve growth performance and decreasing the amount of wastes in the fish farm. This study, it was aimed to examine the biochemical compositions, condition index, and meat yield of *M. galloprovincialis* on the open sea cage units.

Materials and Methods

Sampling Area

The study was carried out at the Open Sea Cage Unit (1100 m from the shore, 35-50 m depth) in which sea bass was reared in the Faculty of Marine Science and Technology of Çanakkale Onsekiz Mart University between September 2012 and August 2013 in Çanakkale Strait in the North-Western part of Turkey (40º03’42’’N-26º20’36’’E). One of 12 net packets each of which contained 30 individual *M. galloprovincialis* attached cage was taken out of the water every month to examine condition index, meat yield, and biochemical composition (Figure 1).

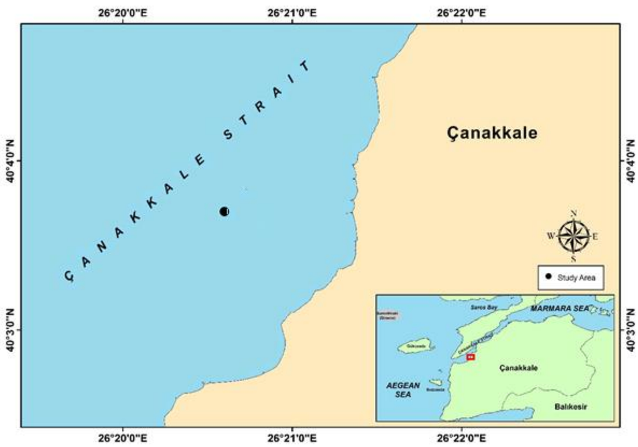

Figure 1. Sampling area

Condition index and Meat Yield

Taken out of the net packets monthly, *M. galloprovincialis* samples were brought in a cold chain to the laboratory, and fouling organisms were removed from the mussel shell. The length of the mussel from anterior (umbo) to posterior tip was measured using Vernier caliper with a precision of 0.05 mm. Mussels were weighed by a 0.1 g accuracy scale, meats remove from the shells and they were weighed separately. To determine the condition index (CI) and meat yield (MY); the shells were dried with an oven at 60 ºC until reach to constant weight (42-72 h), while the soft tissues were freeze-dried (Crosby and Gale, 1990, Freeman, 1974, respectively).

$$MY = \frac{Wet\ meat\ weight\ (g)}{Total\ weight\ (g)} \times 100$$

$$CI = \frac{Dry\ meat\ weight\ (g)}{Dry\ shell\ weight\ (g)} \times 100$$

Biochemical Composition

For biochemical composition analysis, the samples were freeze-dried, ground, and stored in a refrigerator until they were analyzed. Protein content (%) was determined, according to Kjeldahl method (N x 6.25), the lipid (%) was extracted with chloroform-methanol (Erickson, 1993), amount of ash was measured by incinerating the samples to ash in a muffle furnace (AOAC, 2000), carbohydrate content was determined by (Çelik et al., 2014), and moisture was calculated by AOAC (2000).

$$Carbohydrate(\%) = 100 - [Lipid(\%) + Protein(\%) + Ash(\%)]$$

Statistical Analysis

All data were presented as mean±standard deviation. Investigation of the normality of data was performed by the Kolmogorov-Smirnov test. Differences in corresponding values of $p<0.05$ were considered to be statistically significant. To investigate the relationship between CI, MY, and biochemical compositions (carbohydrate, protein, lipid, ash, moisture) of *M. galloprovincialis* was used by Pearson correlation. In the correlation analysis graphs, dark colors were indicated a very high relationship and red colors were indicated a negative relationship. As the darkness of the color was increased, the strength of the relationship increases (Figure 2). The results were also examined with principal component analysis (PCA) using R Version 3.6.1., to identify the biochemical composition, CI and meat yield, that most contribute to the monthly variations (Figure 3).

Results

Meat Yield and Condition Index

Table 1 exhibits monthly changes in meat yield and condition index of *M. galloprovincialis*. The mean condition index was recorded as 8.12±0.48. The highest condition index was found to be 10.56 in October, whereas the lowest value was 4.93 in August. Condition index was positively correlated with meat yield but negatively correlated with length, and weight ($p<0.05$) (Figure 2). Meat yield varied from 13.01% (May) to 17.79% (April) with a mean of 16.07±0.70%. Meat yield was positively correlated with condition index but negatively correlated with weight ($p<0.05$) (Figure 2).

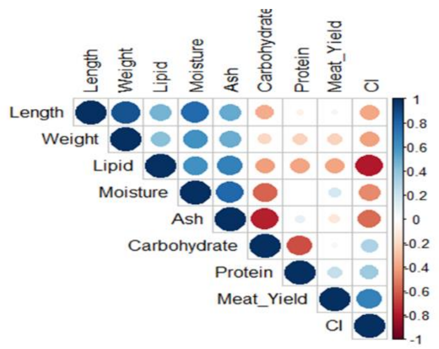

Figure 2. Pearson correlation of length, weight, meat yield, condition index (CI), moisture, protein, lipid, carbohydrate, ash.

Table 1. Monthly variation (Mean±S.D.) in length, weight, condition index and meat yield of *M. galloprovincialis*

	Length (mm)	Weight (g)	Meat Yield (%)	Condition index
September	68.97±5.46	32.98±7.76	15.70±2.64	9.61±2.33
October	77.60±6.73	42.29±14.30	17.54±3.09	10.56±2.14
November	78.05±7.45	40.37±12.75	17.89±2.99	8.75±2.25
December	82.16±5.99	46.00±11.13	16.67±2.53	8.85±1.18
January	80.22±7.64	42.88±11.86	13.43±3.86	7.26±1.90
February	83.04±6.35	45.17±12.13	17.52±4.83	8.42±1.21
March	84.24±5.39	45.86±10.54	17.64±2.86	8.60±1.60
April	83.69±5.64	45.30±9.60	17.79±2.87	9.33±1.77
May	80.13±5.24	50.35±10.02	13.01±2.92	6.97±1.53
June	85.84±5.74	53.77±10.33	15.65±2.26	7.84±1.36
July	79.36±4.44	42.52±9.59	15.66±2.59	6.32±1.32
August	84.67±6.56	47.34±12.95	14.35±2.58	4.93±0.78

Biochemical Composition

Mean moisture and ash contents were 75.52±0.39% and 11.96±1.76% respectively. The main component of meat was protein varying from 52.68% in May to 63.54% in January. The average amount of lipid during the study period was 15.43%. Ash changed from 9.27% in September to 15.15% in June. The average ash was found to be 11.96%. Carbohydrate changed from 8.44% in January to 21.47% in May (Table 2). Moisture was positively correlated with length, weight, meat yield, lipid, and ash while a negative correlation was observed between moisture, and carbohydrate, and condition index ($p < 0.05$) (Figure 2).

PCA biplot explained 71.4% of the variance (Dimension 1=48.7%, Dimension 2=22.7%) between biochemical composition and months. According to the PCA biplot graph, the contribution of ash, moisture, carbohydrate, and protein among other parameters were higher. There was proximity June, July, and August with lipid, weight, length, ash, and moisture. Furthermore, proximity was observed February, October, November, and December with condition index, meat yield, and protein (Figure 3).

Table 2. Monthly changes (mean±S.D.) in protein, lipid, carbohydrate, moisture and ash in *M. galloprovincialis*

	Protein (%)	Lipid (%)	Carbohydrate (%)	Moisture (%)	Ash (%)
September	57.75±0.17	12.45±0.88	20.52±0.90	68.12±2.34	9.27±0.15
October	61.75±0.14	14.27±0.52	12.89±0.27	74.56±1.98	11.09±0.11
November	60.86±0.11	15.27±0.34	10.76±0.15	77.32±1.48	13.11±0.08
December	63.25±0.53	13.69±0.34	10.65±0.14	77.06±1.70	12.42±0.05
January	63.54±0.42	16.24±0.11	8.44±0.32	73.21±2.32	11.77±0.00
February	61.56±0.06	12.74±1.81	14.16±4.34	76.57±1.10	11.55±2.47
March	54.69±0.12	16.61±0.39	17.53±0.09	76.55±1.19	11.17±0.42
April	56.88±0.25	14.43±1.19	18.88±3.51	74.57±1.66	9.81±2.57
May	52.68±0.25	15.30±2.47	21.47±2.06	73.83±1.73	10.55±0.16
June	58.19±0.12	16.74±0.53	9.93±0.00	77.46±1.91	15.15±0.40
July	54.69±0.62	18.30±1.21	13.38±0.63	77.64±1.86	13.63±0.04
August	57.38±0.53	19.18±0.04	9.40±0.49	79.35±2.00	14.05±0.07

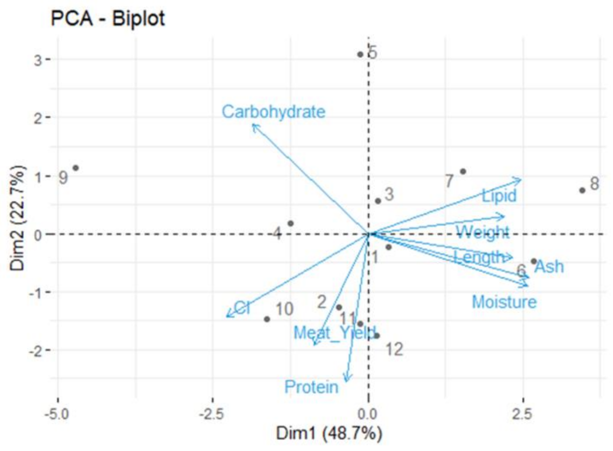

Figure 3. Principal component analysis (PCA)- Biplot of the composition of meat yield, condition index, moisture, protein, lipid, carbohydrate and ash (1: January, 2: February, 3: March, 4: April, 5: May, 6: June, 7: July, 8: August, 9: September, 10: October, 11: November, 12: December)

Discussion

Condition index and meat yield, especially with ecophysiological and economic importance for industrial processing (Yıldız et al., 2011). Meat yield and condition index are important in quality and marketing, that is, the higher the meat ratio of bivalves, the higher the quality value. Environmental parameters; such as temperature, salinity, quality, and quantity of food (Yıldız and Lök., 2005; Vural et al., 2015); remaining outside water, body size, and reproduction cycle (Gosling, 1992; Acarlı et al., 2015) have impacts on the condition index, meat yield, and biochemical compositions of bivalves (Azpeitia et al., 2017). Seasonal changes of environmental factors lead to complex interactions between temperature, food, and salinity that affect somatic growth and reproduction and indirectly the condition index. In this study, meat yield and condition index of *M. galloprovincialis* were found respectively 13.01%-17.89% and 4.93-10.56. Meat yield and condition index of *M. galloprovincialis* were calculated as 13-32% and 8-17 in Çanakkale- Dardanelles (on suspended ropes) (Yıldız et al., 2006), 16.23-23.93% in Sinop (in raft culture) (Karayücel et al., 2010), 23-31% and 7.33-25.20 in İzmir-

Mersin Bay (collected from natural beds) (Kırtık, 2014), respectively. These parameters of *M. galloprovincialis* in this current study was found lower than the studies with mussels capture from natural beds and cultured. Yıldız et al. (2013) were performed a simultaneous study with the present research. These authors were reported that chlorophyll-a values were determined from 0.08 to 2.59 µg/l and. particulate organic matter and particulate inorganic matter were measured as 7.01±5.64 mg/l and 8.54±2.56 mg/l, respectively. According to these authors, chlorophyll-a values of the study area were lower than other studies, while the amount of particulate organic matter and particulate inorganic matter were higher than other studies. Abundance and quality of nutrient in environment is very effective on these parameters. Some authors indicated that metabolic waste, feces and some uneaten feed pellets which included high amount of nitrogen in put made by the fish farm might reason the raised phytoplankton biomass (i.e. concentration of chlorophyll-a) and particulate organic matter in the sea water (Kaspar et al., 1988; Wang, et al., 2020). Cheshuk et al. (2003) observed that there was no difference in the growth and condition index of bivalves at a distance of 70, 100, 500, 1200 m from the fish cage. Although particulate wastes from fish farms could be important, subsequent dilution and dispersion from open-water cages might not improve available food concentrations for integrated bivalves. It has not been as expected in the present study and chlorophyll-a value was not reached to high concentrations. Consequently *M. galloprovincialis* may not have gained sufficient condition due to their low chlorophyll-a value of the environment. Besides feces and unutilized feed did not contribute to the meat yield and condition index of the *M. galloprovincialis*. The high current of the Çanakkale Strait (Meriç et al., 2009) and the study area being 1 km away from the shore may also have effect on this situation. Organic waste may be too diluted to by high current velocity that's why quantity or quality of food available have been not importantly increase at the study area.

In this study, when protein, lipid, carbohydrate and ash values of *M. galloprovincialis* were compared with the studies conducted in Turkish seas, the amount of lipid and ash was found to be higher than other studies (Karayücel et al., 2003; Yıldız et al., 2006; Lök et al., 2011; Çelik et al., 2012) (Table 3). The high amount of ash in this study may have resulted from the high amount of particulate inorganic matter (Yildiz et al., 2013) in the environment. It is known that biochemical composition of bivalve depends on food quality and abundant. Generally, when food was abundant in the form of lipid, glycogen and protein substrates, energy was stored before gametogenesis, then was metabolized and was used in gamete production when metabolic demand was high (Dridi et al., 2007; Acarli et al., 2015). In this study, the high level of storage of lipid amount may depend on the nutrient profile in the environment and the use strategy of energy.

Table 3. Biochemical composition of *M. galloprovincialis* in Turkey (minimum and maximum value)

Study area	Protein (%)	Total lipid (%)	Carbohydrate (%)	Ash (%)	Literature
Çanakkale	58.47-67.51	5.50-6.74	17.7-25.22	10.22-14.55	Yildiz et al. (2005)
Sinop	54.93-75.23	6.03-18.03	-	5.53-10.83	Çelik et. al. (2012)
Sinop	52.30-71.60	6.00-13.42	12.78-34.82	5.54-8.26	Karayücel et al. (2003)
Sinop	40.70-58.66	6.18-10.38	-	-	Lök et al (2011)
Balıkesir-Bandırma	38.31-47.22	5.53-11.91	-	-	Lök et al (2011)
İzmir	40.57-73.98	4.11-7.81	-	-	Lök et al (2011)
Çanakkale	52.68-63.54	12.45-19.18	8.44-21.47	9.27-15.15	This study

This study was showed that there was a strong relationship between condition index and carbohydrate. A negative correlation attracted attention between condition index and lipid. The condition index, which is at the lowest level in the periods when the gonads are drained, increases during the development phase and reaches the maximum value in the maturity phase (Kırtık, 2014). It is reported that spawning of mussels occurs in Galicia of Spain during spring (Villalba, 1995), and in Tokyo bay in Japan between October and May (Okaniwa et al., 2010). The spawning of *M. galloprovincialis* in Turkey, Sinop all the year round except in June and July, the highest increase was observed in January of the year in Edincikaltı (Balıkesir) (Lök et al., 2011). The study showed that participation of protein, lipid, and carbohydrate in the structures of reproductive cells enables them to be used as an energy source as well. In other words, reproduction activity has an influence on condition index and meat yield based on biochemical composition.

Proteins are the most abundant component of mussel meat, followed by carbohydrates (Orban et al., 2002). Protein is used to meet the demand for energy in case of insufficient amounts of lipid and carbohydrate (Aksoy, 2014). Protein values (8.03-12.71% wet weight, ww, and 57.38-63.54% dw) of this study were similar to those of the other studies (Yıldız et. al., 2006; Özden and Erkan, 2011; Bongiorno et al., 2015; Cherifi et al., 2018). Low protein values in the period of spring spawning were reported for *M. galloprovincialis* (Çelik et al., 2012), suggesting an important role of proteins in gonad maturation. Lipids are crucial energy reserves in respect of their high calory values. The amount of lipid in bivalve species is influenced by numerous factors such as temperature, food and, the composition of plankton (Prato et al., 2010; Çelik et al., 2012). Seafood is generally classified into high fat, medium fat, and lean (Tzikas et al., 2007). Considering that the lipid content in *M. galloprovincialis* meat in the present study was in the range between 2.59-3.03% ww and (13.99- 15.44% dw), it can be considered as medium fat. Moreover, the amount of lipid was higher than those of Özden and Erkan. (2011), Cherifi et al. (2018), Bongiorno et al. (2015) and Dernekbaşı et al. (2015) but lower than those of Vernocchi et al. (2007). The level of lipid in bivalve species is reported to be higher at the beginning of spawning but lower following it (Surh et al., 2003). In the present study observed the highest values in spring-summer period similar to those by Cherifi et al (2018), Prato et al. (2010) and Azpeitia et al. (2017).

Carbohydrates have a structural function and are used in the long-term storage of energy (Çelik et al., 2014). Bivalves use their carbohydrate stocks in the spawning period (Çelik et al., 2012). Cherifi et al. (2018) found the carbohydrate amount in *M. galloprovincialis* in the spring-summer months to be 1.41-5.81% in ww. In the present study, the amount of carbohydrate was in the range of 1.79-3.80% ww (10.90-23.81% dw) and with the highest value in the spring-autumn period unlike Cherifi et al. (2018).

Conclusion

From the results of the study, it is clear that consumption of *M. galloprovincialis* would be of great use in terms of its meat yield, condition index, and biochemical composition. The areas where bivalve species feeding by filtering water abound are of great importance considering public health. A bivalve culture system to be constructed near fish farms could help decrease potential negative impacts of fish farm wastes (undigested feed waste and fish feces) on the environment moreover bivalves in this area could be marketed safely as they have not been exposed to any contaminants.

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