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Nutritional Facts of *Mytella strigata* Collected from Cochin Backwater, Kerala, India

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Abstract

The present study investigates the nutritional facts of *Mytella strigata* collected from Cochin backwaters during the monsoon season. *M. strigata* is a non-native invasive mussel recently established in the estuaries and backwaters of Kerala. The samples of *M. strigata* were analyzed for the proximate composition, total carbohydrate, crude fibre, cholesterol content, fatty acid composition, amino acid profile, mineral and heavy metal content. The moisture, crude protein, ash, crude fat and carbohydrate contents were 84.13 ± 0.33, 10.40 ± 0.21, 1.7 ± 0.03, 1.7 ± 0.03, 4.48 ± 0.53 % respectively. The cholesterol content was high (117.35 ± 0.75 mg/100g) whereas crude fibre content was 20 ± 0.01mg/100g. The saturated fatty acid content (41.67 %) observed was higher followed by the polyunsaturated fatty acids and the monounsaturated fatty acids. Among the saturated fatty acids, palmitic acid (C16:0) constituted the highest percentage. The obtained n3/n6 ratio of 1.48 indicates better nutritional quality with respect to polyunsaturated fatty acids. Glutamic acid, lysine and aspartic acid were the predominant amino acids in the species studied. The mineral and heavy metal content analysis revealed that the black mussel, *M. strigata* is a good source of minerals such as P, K and the concentrations of all the heavy metals studied were well below the acceptable limit indicating the safety of *M. strigata* for human consumption. The present study aimed to give an insight into the nutritional components of *M. strigata,* which will make it suitable for its exploitation. The information obtained will strengthen the database as the exploration of the nutritional quality of any resource will form the basis for its judicious exploitation and management in the future.

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Introduction

Mytella strigata (Hanley, 1843), the American brackish water mussel has been recently established in the marine, backwater and estuarine ecosystems in Kerala. It is popularly known as black mussel or charru mussel. This invasive non-native species is considered as a potential biofouler considering its rapid growth, quick invasion potential, high fecundity and good dispersal ability (Jayachandran et al., 2019). It is found attached to the diverse substratum in the water bodies like seawall rocks, floating plastic bottles, wooden pilings, walls of fish cages, hulls of boats, pond beds, sluice shutters etc. and flourishes in high densities during summer months (Lim et al., 2018; Jayachandran et al., 2019; Manjulekshmi et al., 2021). Furthermore, they are present in freshwater habitats for shorter periods (Kumar et al., 2019).

Mussels are a popular food commodity due to their delicate flavour and nutritional importance. They are one of the most exploited bivalve resources in India. The flesh is rich in essential amino acids, essential minerals and vitamins and they are an excellent source of n-3 polyunsaturated fatty acids (España et al., 2007; Carboni et al., 2019). Understanding the nutritional composition of different species is of utmost importance and is inevitable to prepare a roadmap on the strategies for exploiting the resource rationally. There is a paucity of research on the nutritional quality of *M. strigata* available from different ecosystems. As the species is a non-native, invasive biofouler, which is at present considered as a threat to the aquatic ecosystems and indigenous mussel population, the utilization of the species is not well appreciated by the food technologists and the resource is seldom consumed. Further, farming activities are restricted for preventing its spread. However, its use can be explored for non-human or animal/feed products to overcome the threat of this invasive fauna. Understanding the nutritional information is essential for this. Hence, the present work was undertaken to assess the nutritional quality and safety in terms of heavy metals of *M. strigata*, which will be the first report of it from Indian waters.

Materials and Methods

The samples of *M. strigata* were collected from Cochin backwater, Kerala, India during the monsoon season. In the study, the size of the mussel in terms of shell length was measured using a digital vernier calliper. The meat yield (wet meat weight/ whole mussel weight) *100 as well as the proximate composition (moisture, crude fat, crude protein and ash) of the sample was analysed as described by AOAC (2019). Further, carbohydrate content was analysed by the method of Hedge & Hofreiter (1962), crude fibre and acid insoluble ash by the method of AOAC (2019) and estimation of total cholesterol by the method of Folch et al. (1957) with slight modifications.

The fatty acid composition of *M. strigata* was determined. Lipid was extracted from the sample by the method of Folch et al. (1957) and the extract was converted to fatty acid methyl ester (FAME) according to AOAC (2019). Fatty acid composition analysis was performed using gas chromatography (Varian, Guindy, Model no: CP-3800) with a CP-sil 88 FAME column (100 m length x 0.25 mm internal diameter; 0.20 μm film thickness) with flame ionization detector. The amino acid profile was determined using HPLC (high-performance liquid chromatography) pre-column derivatization method (Shimadzu Prominence, Japan) (Ishida et al., 1981). The mineral and heavy metal profile of *M. strigata* was studied using Inductively Coupled Plasma–Optical Emission Spectrometer (iCAP 6000 series, Thermo Fisher Scientific, Waltham, MA, USA) and iTEVA operational software was used for elemental analysis. The results were expressed as mean ± standard deviation to triplicate values.

Results and Discussion

The present study explored the nutritional quality of *M. strigata,* considering the presence of larger biomass of young and mature *M. strigata* throughout the year in the different ecological niches. In the past few years, the population of *M. strigata* has expanded exponentially in the ecosystem of Kerala. The probability of finding this tropical mussel in different ecosystems is high because of its excellent dispersal and colonisation capacity (Lim et al., 2018). This invasive mussel was first reported in the Cochin backwater, Kerala in 2019 (Jayachandran et al., 2019) and further reported from different estuaries and brackish water lakes of Kerala state, India (Kumar et al., 2019). The complete eradication of *M. strigata* from different ecosystems is very difficult, highlighting the importance of the exploration of diverse strategies to manage the resource.

In the study, biometric measurements such as the shell length and meat yield were studied. The biometric measurements and the meat yield are important parameters that determine the mussel market value. The external shell colour of *M. strigata* collected during the monsoon season was uniformly black. The mean shell length (N=10) obtained was 28.65 ± 3.10 mm, which is less than the average shell length reported for similar species of mussels such as *Perna viridis* (60.00 ± 0.01 mm) (Chakraborty et al., 2016). The smaller size helps them to multiply in limited space. Further, the average weight of individual meat observed for *M. strigata* was 0.70 ± 0.09 g. The low individual meat content (less than 1 g) compared to related mussel species like *P. viridis* (12 g) (Chakraborty et al., 2016) is one of the reasons for its low preference for edible purposes. However, the meat yield obtained for *M. strigata* (26 %) was similar to the *P. viridis* (24-28 %).

The nutritional composition of *M. strigata* is presented in Table 1. The moisture, crude protein, ash, crude fat and carbohydrate content observed were 84.13 ± 0.33, 10.40 ± 0.21, 1.7 ± 0.03, 1.7 ± 0.03 and 4.48 ± 0.53 %, respectively. The cholesterol content was high in *M. strigata* (117.35 ± 0.75 mg/100 g). A total cholesterol level of 96.6 ± 0.78 mg/100 g was

Table 1. Nutritional composition of *M. strigata*

Moisture (%)	84.13 ± 0.33
Crude Protein (%)	10.40 ± 0.21
Ash (%)	1.7 ± 0.03
Crude Fat (%)	1.7 ± 0.03
Carbohydrate (%)	4.48 ± 0.53
Crude fibre (mg/100 g)	20.00 ± 0.01
Cholesterol (mg/100 g)	117.35 ± 0.75
Acid insoluble ash (%)	0.002 ± 0.001

Data expressed as mean ± SD (n=3)

reported in *P. viridis* (wild) (Chakraborty et al., 2016). The crude fibre content obtained was 20 ± 0.01 mg/100 g. A similar level of crude fibre was reported by Haldar et al. (2014) in the sample of *Lamellidens marginalis* (10 ± 0.001 10mg/100 g). Low content of fibre was reported for wild (12 ± 0.002 mg/100 g) and cultured (14 ± 0.001 mg/100 g) *P. viridis* collected from Cochin (Chakraborty et al., 2016). The same author reported the acid insoluble ash content in *P. viridis* (wild) as 0.61 ± 0.01 % from Cochin, whereas in our study the average content of acid insoluble ash in *M. strigata* sample was 0.002 ± 0.001 % (Table 1).

The crude protein content *M. strigata* (10.40 ± 0.21 %) was more compared to wild-caught *P. viridis* (7.14 ± 0.07 %) but it was less than the cultured mussel (12.02 ± 0.05 %) collected from Cochin (Chakraborty et al., 2016). Moreover, the crude fat content (1.7 ± 0.03 %) in *M. strigata* was higher than

Table 2. Fatty acid profile (% of total fatty acids) of *M. strigata*

Notation	Fatty Acid	Percentage
C12:0	Lauric acid	2.00
C14:0	Myristic acid	6.84
C14:1, n5	Myristoleic acid	1.60
C15:0	Pentadecanoic acid	0.58
C16:0	Palmitic acid	23.95
C16:1, n7	Palmitoleic acid	8.04
C17:0	Heptadecanoic acid	1.71
C17:1, n8	cis-10-heptadecanoic acid	3.15
C18:0	Stearic acid	6.22
C18:1 trans 9, n9	Elaidic acid	0.15
C18:1 cis 9, n9	Oleic acid	10.88
C18:2, n6	Linoleic acid	10.40
C18:3 cis 6, 9, 12 gamma, n3	cis 6, 9, 12 gamma Linolenic acid	0.14
C18:3 cis 6, 9, 12, 15 alpha, n3	Linolenic acid	6.08
C20:0	Arachidic acid	0.15
C20:1 cis 11, n9	cis-11-Eicosenoic acid	2.01
C20:2, n6	cis-11, 14-Eicosadienoic acid	0.36
C20:3, n6	Eicosatrienoic acid	0.10
C20:3 cis 11, 14, 17, n3	Eicosatrienoic acid	0.24
C20:4, n6	Arachidonic acid	2.05
C20:5, n3	Eicosapentaenoic acid	6.46
C22:0	Behenic acid	0.15
C22:1 cis 13, n9	Erucic acid	0.08
C22:2 cis 13, 16, n6	Docosadienoic acid	0.17
C22:6, n3	Docosahexaenoic acid	6.43
C24:0	Lignoceric acid	0.07
SFA	Saturated fatty acid	41.67
MUFA	Monounsaturated fatty acids	25.91
PUFA	Polyunsaturated fatty acids	32.43
n3 PUFA		19.35
n6 PUFA		13.08
n3/n6		1.48
EPA/DHA		1.00

in wild-caught *P. viridis* (1.27 ± 0.04 %) but less than the cultured *P. viridis* (1.90 ± 0.02 %). A previous report on *M. strigata* from Ashtamudi Lake, Kerala, India reported mean moisture content of 77.46 ± 1.48 %, protein 8.30 ± 0.60 %, ash 7.79 ± 0.57 %, fat 0.10 ± 0.003 % and carbohydrate content of 1.15 ± 0.12 % during March to August 2019 (Vineetha et al., 2020). The crude protein (10.40 ± 0.21 %) and crude fat (1.7 ± 0.03 %) content of *M. strigata* obtained from the Cochin backwater were more than the sample from Ashtamudi Lake whereas the ash content was higher in the samples from the Ashtamudi Lake (7.79 ± 0.57 %). A higher percentage of moisture content was found in the sample of *M. strigata* in our study (84.13 %). Similarly, Fuentes et al. (2009) also reported that generally, a high percentage of moisture content is recorded in mussel samples where 79 % was the lowest moisture content recorded in samples collected from Galicia, Spain. A similar result was also reported by Vineetha et al. (2020) were high percentage of moisture (77.46 ± 1.48 %) was observed in mussel samples collected during the monsoon period owing to the decrease in salinity, which leads to loss of salt and gain of water to the tissue to compensate the osmotic pressure. Further, the black mussel is reported to have less palatability when compared with similar species like the green mussel (Laxmilatha et al., 2021).

The fatty acid composition of *M. strigata* is shown in Table 2. The saturated fatty acid content (41.67 %) was higher than the monounsaturated fatty acids (25.91 %) and polyunsaturated fatty acids (32.43 %). Fuentes et al. (2009) reported that the composition of saturated fatty acids in *Mytilus galloprovincialis* samples from Galicia, the Ebro Delta, and Valencia, Spain were 33.77, 28.47, and 39.28 % respectively and polyunsaturated fatty acids were 28.17, 25.46, and 31.53 % respectively. In contrast, several other authors have reported that polyunsaturated fatty acids predominate saturated and monounsaturated fatty acids in mussels (Freites et al., 2002; Orban et al., 2002; Dernekbasi et al., 2015). The result of the present study indicated that the content of EPA (6.46 %) and DHA (6.43 %) were comparatively less in *M. strigata* whereas other studies have reported a much higher percentage of EPA and DHA in *M. galloprovincialis* and *P. viridis* (Dernekbasi et al., 2015; Chakraborty et al., 2016; Akter et al., 2019). The variations in the composition of fatty acid were obvious in samples collected from different locations as it largely depends on the origin of the mussel and conditions of seed development (De Moreno et al., 1980). In the present study, among the individual fatty acids, palmitic acid (C16:0) constituted the highest percentage (23.95 %) to total fatty acids. Numerous other studies have also reported that palmitic acid is the major saturated fatty acid in the mussel samples (Karakoltsidis et al., 1995; De Moreno et al., 1980; Orban et al., 2002; Vernocchi et al., 2007). The n3/n6 ratio indicates the nutritional value of fatty acids and it is usually used as an index for fatty acid nutrition (Chen et al., 2007). In general, an n3/n6 ratio higher than 0.2 is considered more beneficial to human health (Wu et al., 2010). The n3/n6 ratio obtained was 1.48, which indicates that the samples of *M. strigata* collected from Cochin backwater possess polyunsaturated fatty acids with high nutritional value.

In the present study, a total of 17 amino acids were identified and the amino acid composition of *M. strigata* is presented in Table 3. The result indicated that essential amino acid constitutes 48.57 % and

Table 3. Amino acid profile of *M. strigata*

Amino acid composition	% of total aminoacids
Essential amino acids (EAA)	
Arginine	5.81
Histidine	2.74
Threonine	4.50
Lysine	11.95
Leucine	7.02
Methionine	1.53
Valine	4.82
Phenyl alanine	4.28
Isoleucine	5.92
Total	48.57
Non-essential amino acids (NEAA)	
Aspartic acid	10.42
Glutamic acid	14.69
Serine	5.70
Glycine	6.47
Alanine	5.81
Cysteine	0.77
Proline	2.96
Tyrosine	4.61
Total	51.43

non-essential amino acids constitute 51.43 % of the total. Among the individual amino acids, glutamic acid (14.69 %), lysine (11.95 %) and aspartic acid (10.42 %) were predominant whereas amino acids such as cysteine (0.77 %), methionine (1.53 %) and histidine (2.74 %) were found in lower amounts. Fuentes et al. (2009); Akter et al. (2019) have reported taurine and lysine as the major amino acids in mussels.

Table 4. Mineral and heavy metal profile of *M. strigata*

Elements	Concentration (ppm)
Phosphorus	2136 ± 28.45
Potassium	628.8 ± 12.17
Iron	471.3 ± 15.75
Sodium	470.4 ± 11.11
Magnesium	271.7 ± 1.86
Aluminium	267.3 ± 3.48
Calcium	182.7 ± 3.73
Zinc	14.56 ± 0.21
Manganese	13.88 ± 0.33
Copper	3.60 ± 0.03
Boron	1.22 ± 0.10
Barium	1.13 ± 0.02
Selenium	0.66 ± 0.02
Heavy metals	
Cadmium	0.40 ± 0.01
Lead	0.28 ± 0.01
Arsenic	0.26 ± 0.05
Mercury	0.01 ± 0.01

The levels of different minerals observed in the sample of *M. strigata* are shown in Table 4. The minerals such as phosphorus (2136 ± 28.45 ppm), potassium (628.8 ± 12.17 ppm), iron (471.3 ± 15.75 ppm), sodium (470.4 ± 11.11 ppm) and magnesium (271.7 ± 1.86 ppm) were found in higher quantity in the mussel. Studies have reported that mussels are a good source of calcium, zinc, magnesium, phosphorous and iron (Karakoltsidis et al., 1995). The amount of calcium and zinc were found to be comparatively lesser in quantity in the sample of *M. strigata.* Higher levels of calcium, magnesium, sodium, potassium, magnesium and iron were also reported from mussel samples reported from Valencia, Galicia, Spain (Fuentes et al., 2009). The variation in the mineral content in different samples is mainly attributed to the origin, size and maturity stage of the mussel (Szefer et al., 2006; España et al., 2007). Along with the minerals, the content of heavy metals such as cadmium (Cd), lead (Pb), arsenic (As) and mercury (Hg) were also studied (Table 4). It is imperative to screen the concentration of different metals in mussel samples as mussels accumulate diverse metals in their soft tissue, which can pose potential health risks to the consumers (Stankovic et al., 2012). The levels of Cd, Pb, As and Hg in mussles in the present study were 0.40 ± 0.01, 0.28 ± 0.01, 0.26 ± 0.05 and 0.01 ± 0.01 ppm respectively. Ozden (2008) reported that mussel samples collected in all seasons (June 2003 to May 2004) from Istanbul fish markets were having high levels of cadmium and arsenic. The same study reported the mean concentrations (mg/kg) of Hg, Pb, As, Cd and Sn in the mussel tissue were 0.01-0.16, 0.90-1.64, 2.68-3.87, 0.75-1.06 and 0.05-0.11 respectively. In the present study, the concentration of all the heavy metals analysed is less than the limit of heavy metals specified in Food Safety and Standards (contaminants, toxins and residues) regulation, 2011 for the bivalve molluscs (FSSAI, 2020).

Demand for protein-rich food of animal origin is ever-increasing especially in developing countries like India. The high demand stimulates the search for untapped and non-conventional fishery resources (Dilip Kumar & Ranjan, 2016). The resource of *M. strigata* is new to Indian aquatic environment and is not considered as a food as it is invasive and is considered to pose a great threat to the indigenous mussel species. It is not possible to completely eradicate the resource from our ecosystems but the propagation can be controlled. Since the species is edible, it is recommended that it can be heavily fished and consumed and also it can be utilized in fish or animal feed as an ingredient (Laxmilatha, 2021).

Hence, the information on the nutritional quality of *M. strigata* will help to explore the strategies for the management of this non-indigenous resource available in many coastal and estuarine areas in Kerala. The results of the present study indicated that the *M. strigata* collected from Cochin backwater possess all the essential nutrients in moderate quantities, comparable to similar species of mussel.

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