Eco. Env. & Cons. 29 (July Issue) pp. S68-S77
Copyright@ EM International
ISSN 0971–765X

Special Issue on "Int. Conf. on Impact of Clim. Change on Aq. Life and Mtgn. Measures for a Sust. Blue Economy", 23-25 Nov, 2022, PG & Res. Dept. of Zoology, FMNC, Kollam, Kerala, India.

DOI No.: http://doi.org/10.53550/EEC.2023.v29isp2.011

Proximate composition with dimensional relationships in *Meretrix casta* and *Villorita cyprinoides* from Neendakara part of Ashtamudi lake, Kerala, India

N. Parvathy*[1], B.T. Sulekha[2] and S. Sheeba[3]

[1]Post Graduate & Research Department of Zoology, Sree Narayana College, Kollam 691 001, Kerala, India

ABSTRACT

Besides the augmentation of palatable value, relationship between shell characteristics and proximate composition of bivalves are significant to understand the ecological productivity of a system. Dimensional studies have great significance in fishery researches, for the improvement of current production and management. During the study period (July 2021 to May 2022), a total of 300 individuals from each clams, *M. casta* and *V.cyprinoides* were collected bimonthly from Neendakara region of Ashtamudi Lake, a Ramsar site from Kerala. The allometrical relation and the biochemical composition of bivalves were determined. The negative allometric growth showed by the length to width and thickness relationship implies that the increase in the width and thickness of the bivalves were inferior to the growth in length. Linear regression results showed that there is significant variation ($p<0.05$) in the allometrical relationship in the two bivalves. Various biochemical constituents such as, ash, moisture, carbohydrate, protein and fat have been also estimated. Single Factor ANOVA studies of bimonthly data reveals that, there was no significant differences ($p>0.05$) in the proximate compositions of the two clams. Condition Index (CI) and Edibility Percentage or Percentage Edibility (EP) were also estimated. Condition Index was recorded to be <1 during the entire study period. The results showed that the studied bivalve species could be considered as a good dietary resource, due to its high protein content as well as remarkable composition of carbohydrate and fat contents. Therefore, the present study will be helpful for implementing various sustainable management practices to increase the culturing potential of the bivalve in the estuarine beds.

Key words: *Proximate analyses, Allometry, Percentage Edibility, Condition Index, Meretrix casta, Villorita cyprinoides.*

Introduction

Marine food comprises various forms of aquatic biota. Among them, bivalves are known for a highly demanding proteinaceous food. India bangs second, position in capture fisheries among the Asian countries. The country has an annual production of 84,483 tonnes of bivalves and the major share is contributed from Kerala (75.8%) among the south-west coast of India. Ashtamudi Lake, a Ramsar wetland (no.1204) contributed a significant portion of these resources.

Estimation of shell dimensions for growth, biomass and total meat production are considered as a simple and non-destructive methods (Bailey and Green, 1988; Rodhouse *et al*., 1984). Allometric studies reflects the relationship between the body parts of an organism (Reiss, 1989). It deals with the study about size and shape. Allometrical relationship act as a taxonomic aid, helps to recruit and estimation of

([1]Ph.D Scholar, [2,3]Associate Professor)

stock (Spiers, 1952). It provide information for managing resources and understanding the surrounding variations (Palmer, 1990). The variation in the allometric parameters reveals the physiological status in bivalves. The physiological condition and the variation in environmental parameters can alter the meat composition of bivalves (Wilbur and Owen 1964). Various proximate factors can influenced by the allometric values. In India allometric studies on clams have been studied in several works (Algarswami and Chellam(1977); Rao (1988) and Appukuttan (1993).

As clams are one of the versatile dietary for humans, it is often a delicacy to humans. Many ecophysiological and aquaculture studies have depended on the proximate biochemical analysis (Giese, 1969; Ansell *et al*., 1980; Davis and Wilson, 1983). Biochemical constituents of bivalves shows variations depending on factors viz. water temperature, nutrient availability, reproductive cycle etc. (Okumus and Stirling, 1998; Orban, Di Lena *et al*., 2002). Shellfishes are good source of rich proteins, dietary essential aminoacids, low fat diet, and lower proportions of saturated fat, the presence of good lipids, significant amounts of omega-3-fatty acids, dietary essential amino acids, vitamin B12 and several important minerals such as iron, zinc and copper which helps to maintain the growth of the human body (Krzynowek *et al*., 1989; Dong, 2001; Trung tamTin hoc- Bo Thuy San, 2007; George and Gopakumar, 1995; Dincer, 2006; King *et al*., 1990). Various factors affecting the proximate composition of shellfishes such as spawning season (Durve, 1964), fecundity (Durve, 1964; Litaay andDe Silva, 2003), depth of culture area (Ngo *et al*., 2006) have also been investigated (Rivonker and Parulekar, 1995).

The biological and chemical aspects, shell and meat contents, typical taste and flavor reflects the nature and quality of clams. Bivalves have nutritional, commercial, health attributes and ecological significance (Orban *et al*., 2002; 2006). Besides the edibility, bivalves are highly worthfull biotic component of an ecosystem due to its high conversion efficiency and rich biochemical constituents. And also, comparitively, very limited works have been done in the allometrical studies on bivalves, especially in Ashtamudi Lake. This work provide information about the nutritional qualities of the two commercially valuable bivalve species (*M.casta* and *V.cyprinoides*) of Neendakara region of Ashtamudi. Therefore, the present work has a significant practical application on human health perspective based on the shell fish consumption as well as a marketing food on bivalves cultures.

Materials and Methods

Study area

For the present study, Neendakara barmouth (Fig. 1) (8–56'09''N & 76– 32' 45''E) of the Ashtamudi lake was selected as the sampling station. This area is characterized by inorganic pollution, Fishing Harbour, large scale mechanized boats/ trawler traffic, oil spillage, mining in far areas etc

Sample collection and preparation

A total of 100 specimens of *Meretrix casta* and 198 specimens of *Villorita cyprinoides* were collected bi-

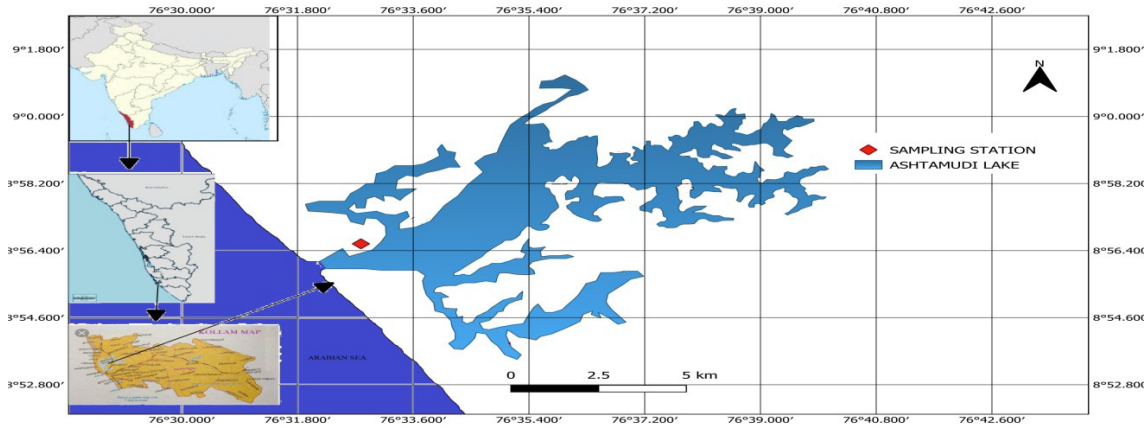


Fig. 1. Ashtamudi Lake

monthly from the sampling station, Neendakara of the Ashtamudi Lake (Fig. 1) during the study period from July 2021 to May 2022. The study site was surveyed and bivalves were collected during low tides by random free hand collection. The live samples were brought to the laboratory, cleaned to remove attached particles and kept alive for depuration. in aerated water for a day. Thereafter, the specimens were sorted out for allometrical and biochemical analyses.

Allometric analysis

Individual bivalve specimens were measured for its whole weight (mg), shell length (mm), shell width (mm) and shell thickness (mm). Length, width and thickness were measured with the Vernier Caliper (mm) and whole body weight was measured with an electric balance (accuracy 0.01g). The allometrical parameters were used to compare the body measurements of the two populations of the stations as well as used to determine the relation with the proximate composition of the clams. Allometrical relationships were studied by testing each pair of variables potential allometric equation;

Y= a+ Xb, where Y is the dependent variable (mm); X is the independent variable(mm); a is the intercept of the regression line and b is the slope regression co-efficient.

Percentage Edibilty or Edibility percentage and Condition Indices were determined as per Mohite *et al.*, 2008; Okumus and Stirling (1998) respectively:

$$\text{Percentage Edibilty(EP)} = \frac{\text{wet weight}}{\text{Total weight}} \times 100$$

$$\text{Condition Index (CI)} = \frac{\text{wet weight}}{\text{Shell weight}} \times 100$$

Proximate Analyses

Proximate composition analyzes of the samples were done in triplicate for Ash, moisture, carbohydrate, protein and total fat lipid contents. Moisture was determined by oven drying at 105ºC (3hrs.) to constant weight (AOAC, 2005). Samples were dried in an oven until constant weight obtained. Then cooled in dessicator and weighed to get the differential moisture content between fresh and dry weights. Ash content was estimated by heating the dried samples (550 ºC overnight) in a muffle furnace and the percentage of ash was estimated by deducting the weight of the ash from the initial weight. Carbohydrate was analysed by the method of DuBois (1956). The crude protein was determined by the Kjeldahl method (AOAC, 2005). Total fat was extracted in Soxhlet apparatus using petroleum ether (AOAC, 2005).

Results

Allometry

Minimum, maximum, mean and standard deviation of shell measurements such as shell length (SL), shell width (SW), shell thickness (ST), Condition Index (CI) and Percentage Edibility (EP) were calculated (Table 1). The results showed linear models for length-width and length- thickness relationships (Graph1a to d). Linear regression analysis showed that there is a significant variation ($p<0.05$) observed in the allometrical relationship in the two bivalves. Table 2 showed the linear regression results for the relationships between the morphometric parameters.

Percentage edibility (%) showed an increasing trend during monsoon season and highest values were recorded in July and September for *M. casta* (26.37) and *V. cyprinoides* (24.02) respectively. Lowest values were recorded in May and it was 11.85 in *M.casta* and 9.54 in *V. cyprinoides*. Maximum value of Condition Index % (CI) were recorded during November (81.52) for *M. casta* and during October (74.23) for *V. cyprinoides*. Lowest condition index

Table 1. Mean, standard deviation (S.D), minimum, maximum, Percentage edibility and Condition Index values of *M. casta* and *V. cyprinoides* of Neendakara during the study period from July 2021 to May 2022.

Measurement parameters	*M. casta*	Minimum (mm)	Maximum (mm)	*V. cyprinoides*	Minimum (mm)	Maximum (mm)
Shell length (mm)	27.47±3.51	*21.64*	*43.91*	24.34±3.16	*20.89*	*42.49*
Shell width (mm)	37.96±2.94	*19.65*	*41.16*	27.77±3.33	*16.15*	*36.03*
Shell thickness (mm)	17.47±3.25	13.98	23.15	18.49±2.43	*12.31*	*34.17*
Percentage edibility (%)	21.067±5.01	11.85	26.37	20.07±4.03	*9.54*	*24.02*
Condition Index	78.5±7.1	19.42	81.52	58±6.92	*16.93*	*74.23*

were observed during May in *M. casta* (19.42) and in *V. cyprinoides* (16.93) (Table 1).

Proximate Analysis

Bimonthly analysis reveals that ash content ranged from 5.00-8.30 in *M. casta* and 5.80-8.05 in *V. cyprinoides*. Amount of Ash content indicates the presence of inorganic compounds in the tissues. Ash content was found to be lowest during the month of July and highest during March (*M. casta*) and during November (*V. cyprinoides*). *M. casta* and *V. cyprinoides* showed a bimonthly mean of 7.05±1.297 and 6.9±1.670 respectively (Graph 2 and 3).

The bivalves reveals high amount of moisture followed by protein, ash, carbohydrate and fat. The main constituents of the two bivalve species was the moisture, which indicates its freshness. Moisture content was ranged from 77.4%-90% in *M. casta* and 73%-92% in *V. cyprinoides*. Moisture content was found to be lowest in the month of May and highest during September (*M.casta*) and during July (*V. cyprinoides*). *M. casta* and *V. cyprinoides* showed a bimonthly mean of 84±0.058 and 84±0.072 respectively (Graph 2 and 3).

Carbohydrate content was ranged from 3.8-6.8 in *M. casta* and 3.3-6.9 in *V. cyprinoides*. Carbohydrate content was found to be lowest in the month of March (*M. casta*) and September (*V. cyprinoides*) and highest during May. *M. casta* and *V. cyprinoides* showed a bimonthly mean of 5.05±1.420 and 5.01±1.499 respectively (Graph 2 and 3).

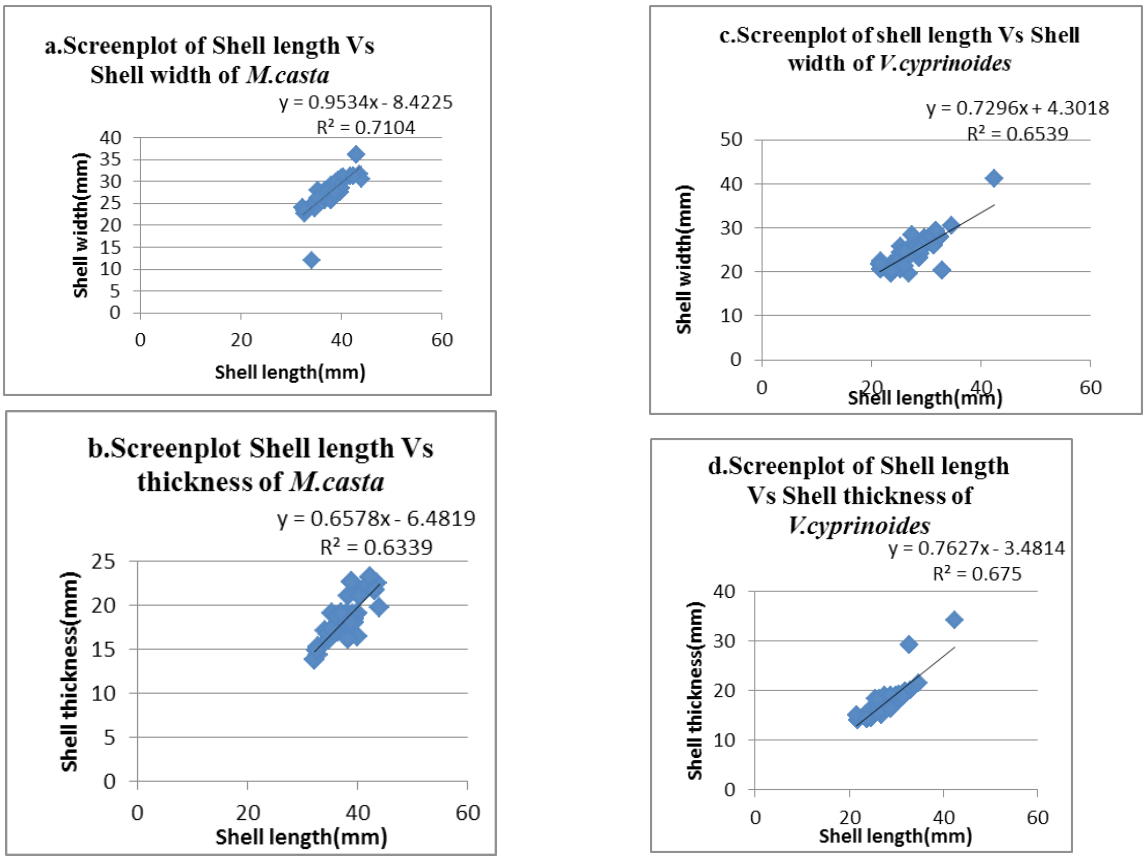
Protein content was ranged from 9.7-10.6 in *M. casta* and 8.9-10.4 in *V. cyprinoides*. Protein content was found to be lowest in the month of March and highest during January (*M.casta*) and during September (*V. cyprinoides*). *M. casta* and *V. cyprinoides* showed a bimonthly mean of 10.033±0.372 and 9.80±0.521 respectively (Graph 2 and 3).

Total fat content was ranged from 0.98-1.9 in *M. casta* and 0.98-1.7 in *V. cyprinoides*. *M. casta* and *V. cyprinoides* showed a bimonthly mean of 1.496±0.456 and 1.43±0.402 respectively (Graph 2 and 3).

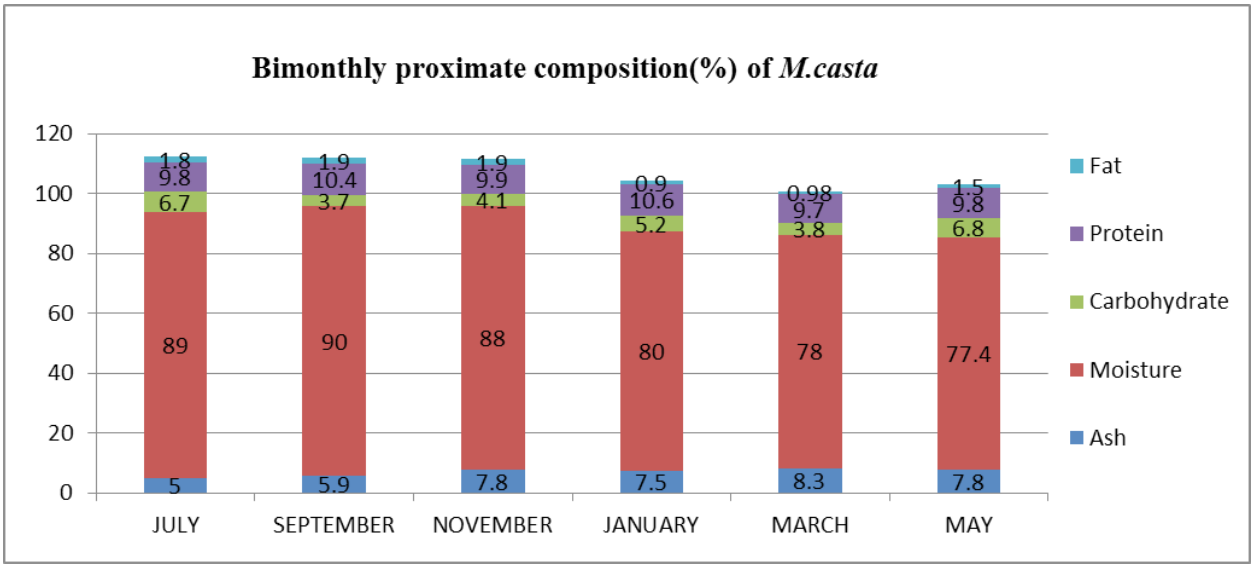
The biochemical constituents of the studied bivalves exhibited seasonal variations in Moisture, Ash, Protein, Carbohydrate and Lipid. Sesaonal analysis revealed that ash content in both *M. casta* and *V. cyprinoides* was found to be lowest during monsoon and highest during pre-monsoon. *M. casta* and *V. cyprinoides* showed a seasonal mean variation of 7.05±0.769 and 6.9±1.125 respectively. Moisture content in both *M. casta* and *V.cyprinoides* was found to be lowest during pre-monsoon and highest during post-monsoon. *M. casta* and *V. cyprinoides* showed a seasonal mean variation of 84±5.02 and 84±4.00 respectively. Carbohydrate content in both *M. casta* and *V. cyprinoides* was found to be lowest during post-monsoon and highest during monsoon. *M. casta* and *V. cyprinoides* showed a seasonal

Table 2. Linear regression results for the relationships between the morphometric parameters such as, Shell length (SL), shell width (SW), shell thickness (ST) collected from Neendakara, Ashtamudi lake during the study period from July 2021 to May 2022.

	Meretrix casta	*Villorita cyprinoides*
Shell length- Shell width	a=4.301	a=8.422
	b=0.729	b=0.953
	R^2=0.653	R^2=0.710
	SE=1.047	SE=0.0614
	P<0.05	P<0.05
	t=4.10	t=4.04
	95% confidence	95% confidence
	Lower=0.0174	Lower=0.2649
	Upper=0.0718	Upper=0.2894
Shell length- Shell thickness	a=3.481	a= -6481
	b=0.762	b=0.657
	R^2=0.675	R^2=0.633
	SE=1.044	SE=0.0504
	P<0.05	P<0.05
	t=20.22	t=4.04
	95% confidence	95% confidence
	Lower= -0.4092	Lower=0.1868
	Upper= -0.2751	Upper=0.2158



Graph 1. (a-d). Regression analysis of various allometrical parameters of the bivalves, *M. casta* and *V. cyprinoides*.

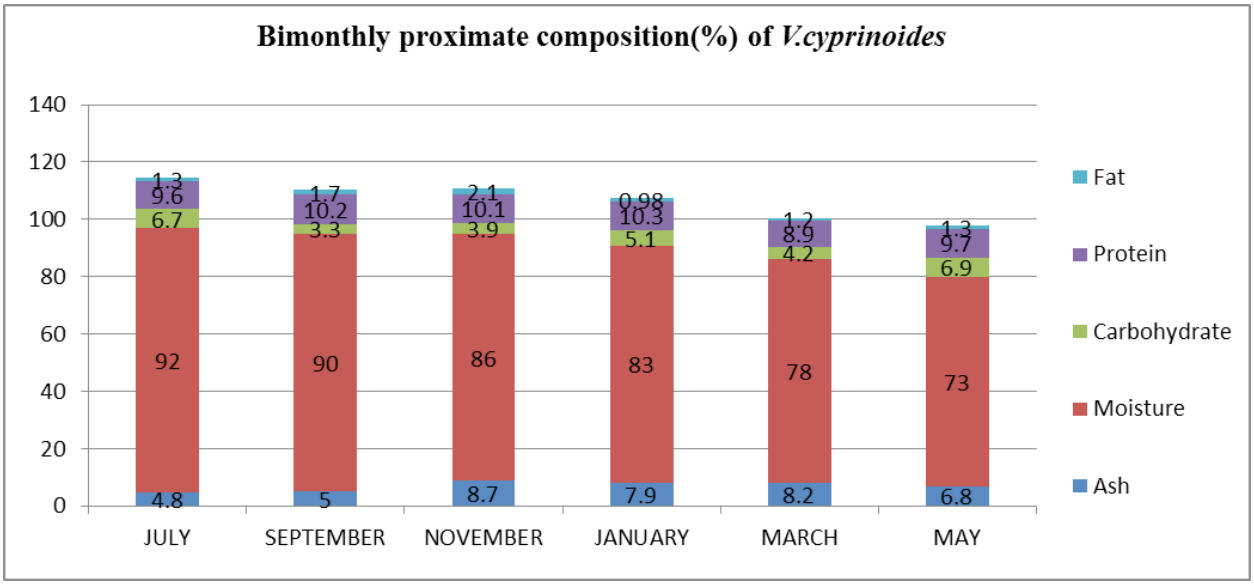


Graph 2. Bimonthly analysis of proximate composition (%) of *M.casta* during the study period from July 2021 to May 2022.

mean variation of 5.05±1.502 and 5.01±1.63 respectively. Protein content in both *M. casta* and *V.cyprinoides* was found to be lowest during monsoon (*M. casta*) and pre-monsoon (*V. cyprinoides*) and highest during pre-monsoon and post-monsoon in *M. casta* and during post-monsoon in *V. cyprinoides*. *M. casta* and *V. cyprinoides* showed a seasonal mean variation of 10.033±0.372 and 9.75±0.217 respectively. Total fat content in both *M. casta* and *V. cyprinoides* was found to be lowest during pre-monsoon and highest during post- monsoon. *M. casta* and *V. cyprinoides* showed a seasonal mean variation of 1.49±0.49 and 1.43±0.420 respectively (Table 3 and 4). Analysis of variance (ANOVA) was used to evaluate the proximal composition (ash, moisture, carbohydrate, protein and fat) data and there is no significant differences ($p > 0.5$) were observed among the two bivalve species.

Discussion

M. casta (Chemnitz) a Venerid edible clam, act as a part of sustenance level fishery in both east and west coast of India. This species contributes to a large part of livelihood along the Ashtamudi estuary (Laxmilatha *et al.*, 2006 a, b). The abundance of



Graph 3. Bimonthly analysis of proximate composition (%) of *V.cyprinoides* during the study period from July 2021 to May 2022.

Table 3. Seasonal analysis of proximate composition (%) of *M.casta* during the study period from July 2021 to May 2022.

	M. casta				
	Ash	Moisture	Carbohydrate	Protein	Fat
Pre-monsoon	7.9	79	4.5	10.15	0.94
Monsoon	6.4	83.20	6.75	9.8	1.65
Post-monsoon	6.85	89	3.9	10.15	1.9

Table 4. Seasonal analysis of proximate composition (%) of *V.cyprinoides* during the study period from July 2021 to May 2022.

	V. cyprinoides				
	Ash	Moisture	Carbohydrate	Protein	Fat
Pre-monsoon	8.05	81	4.65	9.6	1.09
Monsoon	5.8	83	6.8	9.65	1.3
Post-monsoon	6.85	88	3.6	10	1.9

M.casta is influenced by several environmental factors (Tanyaros and Tongnunui (2011). It has been listed as Vulnerable (A 1c, 1d) of International Union for Conservation of Nature (IUCN), due to the population decline in the estuarine beds, habitat quality and number of mature individuals (Ananda-Rao *et al.,* 1998). *Villorira cyprinoides* (Gray, 1825), the black clam found in the fine sand, clay and silt regions of backwaters. It contributes 45,000 t to the annual landings of clams of the Kerala State (Narasimhan *et al.,* 1993). Hydrological conditions and productivity of the estuary have an important role on the growth of the clams (Abraham, 1963; Seshappa, 1971).Various ecological factors are identified for their effect on bivalve shell shape: wave impact, trophic conditions, water depth, density etc.

The demand for proteinaceous food has been increasing globally and expected to rise in the near future. The molluscan meat, especially the meat of bivalves has been regarded as a promising source to meet this need. The meat of the bivalves are good sources for the provision of high quality protein with all the essential amino acids for the growth and maintenance of human body.

Studies about the cyclical changes in biochemical composition of tissue help to assess the nutritive status of an organisms. Accumulation of protien, carbohydrate and lipid will be high during the proliferation phase of gonads (George, 1980). Proximate analysis showed that bivalves are rich in protein, carbohydrate and moisture levels. Many research works have already reveals about the protein, carbohydrate and lipid contents of the bivalves (Asha *et al.,* 2014; Dupcic *et al.,* 2014, Jagadis, 2005; Babu *et al.,* 2012; Salaskar and Nayak, 2011 and Laxmilatha, 2009) and its relation with various environmental as well as gametogenic activities (Orban *et al.,* 2002; Smolders *et al.,* 2005).

The present study exhibited seasonal variation in the proximate composition. Moisture content of the bivalves reflects the onset of spawning period (Singh *et al.,* 2012) and showed a negative correlation with salinity conditions (Maqbool, 1993). In the present study also, moisture content showed its highest content during monsoon period. Moisture content is an indication of flesh value (Ojea *et al.,* 2004; Dridi *et al.,* 2007; Ovissipour *et al.,* 2013). As an indication of the amount of inorganic nutrients, ash content of the tissue has a determining role in the biochemical quality of the tissues. Ash content in both the tissue samples were highest during post-monsoon and lowest during pre-monsoon period.

During the present study, a remarkable protein levels were observed in *M. casta* and *V. cyprinoides*, reached to a mean value of 10.15 and 10.1 respectively. A gradual increase in the protein content of the bivalves were observed during post monsoon season (maturity period) and then a slight decreasing trend during monsoon (spawning period). Similar results were observed in various studies (Jayabal and Kalyani, 1986; Berthelin *et al.,* 2000). Many studies showed a positive correlation of protein content with reproductive state (Eble, 1969). In contrast, part wise protein content in some clams remains without any remarkable variation in relation with reproductive cycle (Easterson and Kandasamy, 1988).

Amount of protein and carbohydrate is an important aspect to assess the quality and texture of seafoods (Loje *et al.,* 2007). Elevation in the level of protein and carbohydrate were in the gametogenesis period and a decrease in spawning phase. While carbohydrate shows a decline trend during reproductive phase (Ojea *et al.,* 2004; Dridi *et al.,* 2006). In bivalves, carbohydrate contents shows a reduction during monsoon periods. This may be due to the exploitation of carbohydrate stores during conditions such as stress, low salinity, gametogenesis stage etc. (Eble, 1969). Gradual increase in the carbohydrate content could be happen and may be due to the development of gonads (Shettigar and Seetharamaiah, 2013)

Fat contents have various important biological functions such as energy reserves, structural constituent of membranes, bio-signalling. Lipid utilization starts when all carbohydrate resources are exhausted. Temperature is an important factor which augment the fat consumption by the clams for energy and shows a negative correlation with temperature. Several research reports reveals the same results (Dridi and Romdhana, 2017).

Several studies have demonstrated that the Edibility Percentage (EP) and Condition Index (CI) as the main tools for the commercialization of bivalves depending various endogeneous and exogeneous conditions (Gabott, 1975; Lagade *et al.,* 2015). Condition Index (CI) serve as an indication of physiological status. During the present study, CI and EP have peak values during July to November and then showed a rapid decline. It indicates the best time for consumption on nutritional aspects. The Percentage Edibility denotes the quality of meat and it undergoes seasonal variations. It may be due to the energy

utilization for the meat production and gametogenesis during the unfavourable seasons (Biandolino *et al.*, 2008). During spawning period percentage edibility declined (Mohite, 2009; Venkataraman and Chari, 1951). Besides economically very cheap, bivalves remains always a nutritional source, which are highly significant to humans a balanced diet. Therefore, a seasonal exploration and a sustainable use of the bivalves are recommended for the demand of a nutritional food as well as exploitation of bivalves at juvenile state (low nutritional stage).

Conclusion and Recommendation

Since the bivalves have remarkable concentrations of the essential biochemical constituents such as ash, moisture, carbohydrate, protein and fat, these are highly recommended for a rich nutritional diet. Allometric parameters have greater influence on its biochemical constituents. A scientific and continuous monitoring system is needed for enhancing the potential of bivalve cultures to overcome the problem of unscientific exploitation on clam beds. Therefore, this study suggested for an immediate implementation of strict scientific guidelines for culturing and conservation against overexploitation of these bivalves.

Acknowledgement

The author[a] is thankful to the CSIR HRDG for providing JRF Fellowship to fulfill the research activities in this topic and also to the University of Kerala for granting Ph.D affiliation. All the authors are also grateful to the Sree Narayana College, Kollam, the respective Institution from which the facility for the research work is provided.

Conflict of Interest

All the authors hereby declare, there is no conflict of interest on this matter.

References

Abraham, K.C. 1963. Observations on the biology of *Meretrix casta* (Chemnitz). *J. Zool. Soc. India*. 5(2) : 163-190.

Alagarswami, K. and Chellam. 1977. Changes of form and dimensional relationship in the pearl oyster *Pinctada fucata* from Gulf of Mannar. *Indian J. Fish.* 24 (1&2): 1-14.

Ananda Rao, T., Molur, S. and Walker, S. (Eds.) 1998. Report of the workshop on 'Conservation assessment and Management plan for mangroves of India' Zoo outreach organization, Coimbatore, India, P. 106.

Ansell, A.D., Frenkiel, L. and Moueza, M. 1980. Seasonal changes in tissue weight and biochemical composition for the bivalve *Donax trunculus* L. on the Algerian coast. *J. Exp. Mar. Biol. Ecol.* 45: 105–116.

AOAC, 2005. *Official Methods of Analysis of AOAC International,* 725 18th edition, in: W. Horwitz, W. George, J.R. Latimer (Eds.), 726 AOAC International, Gaithersburg, MD, USA Official methods, 727 2005, 08 p.

Appukuttan, K.K. 1993. *Studies on the ecobiology and fishery of Paphia malabarica Chemnitz (Veneridae: Bivalvia) from Ashtamudi estuary, southwest coast of India.* Ph.D thesis, University of Kerala.185 pp. (Unpublished).

Asha, K. K., Anandan, R., Mathew, S. and Lakshmanan, P. T. 2014. Biochemical profi le of oyster *Crassostrea madrasensis* and its nutritional attributes. *Egyptian Journal of Aquatic Research.* 40(1): 35–41.

Bailey, R.C. and Green, R.H. 1988. Within-basin variation in the shell morphology and growth rate of fresh water mussel. *Can. J. Zool.* 66 : 1704-1708.

Baker, D.H. and Han, Y. 1994. Ideal amino acid profile for chicks during the first three weeks posthatching. *Poult Sci.* 73 : 1441-1447.

Berthelin, C., Kellner, K. and Mathieu, M. 2000. Storage metabolism in the Pacific oyster (*Crassostrea gigas*) in relation to summer mortalities and reproductive cycle (West Coast of France). Comparative biochemistry and physiology Part B: *Biochemistry and Molecular Biology.* 125 : 359-369.

Biandolino, F., Prato, E. and Caroppo, C. 2008. Preliminary investigation on the phytoplankton contribution to the mussel diet on the basis of fatty acids analysis. *Journal of the Marine Biological Association UK* 88: 10091017 DOI 10.1017/S0025315408001598.

Davis, J.P. and Wilson, J.G. 1983. Seasonal changes in tissue weight and biochemical composition of the bivalve *Nucula turgida* in Dublin Bay with reference to gametogenesis. *Neth. J. Sea Res.* 17: 84–95.

Dincer, T. 2006. Differences of Turkish clam (*Ruditapes decussates*) and *Manila clam* (*R. philippinarum*) according to their proximate composition and heavy metal contents. *J. Shellfish Res.* 25 (2): 455-459.

Dong, M. Fayne. 2001. The nutritional value of shellfish. www.wsg.washington.edu., p. 1-8.

Dridi, S. and Romdhane, M.S. 2017. Nutritional quality in terms of lipid content and fatty acid composition of neutral and polar lipids in the adductor muscle of the oyster *Crassostrea gigas* (Thunberg) farmed in the Bizert lagoon (Tunisia) in relation with sexual cycle and environmental settings. *The Egyptian Journal of Aquatic Research*. 43: 329-336.

Dridi, S., Romdhane, M. and Elcafsi, M. 2006. Seasonal variation in weight and biochemical composition of

the Pacific oyster, *Crassostrea gigas* in relation to the gametogenic cycle and environmental conditions of the Bizert lagoon (Tunisia). *J. Aquaculture.* 263: 238–248.

Dridi, S., Romdhane, M.S. and Elcafsi, M. 2007. Seasonal variation in weight and biochemical composition of the Pacific oyster, *Crassostrea gigas* in relation to the gametogenic cycle and environmental conditions of the Bizerte lagoon, Tunisia. *Aquaculture.* 263 : 238–248. https://doi.org/10.1016/j.aquaculture.2006.10.028.

Dupèiæ-Radiæ I., Cariæ M., Najdek M., Jasprica N., Bolotin J., Peharda, M. and Cetiniæ, B. 2014. Biochemical and fatty acid composition of Arcanoae (Bivalvia: Arcidae) from the Mali Ston Bay, Adriatic Sea Mediterranean. Mar. https://doi.org/10.12681/mms.436.

Durve, V. S. 1964. Preliminary observation on the seasonal gonadal changes and spawning in the clam *Meretrix casta* (Chemnitz) from the marine fish farm. *J. Mar. Biol. Ass. India.* 6(2): 241- 248.

Durve, V.S. 1964. On the percentage edibility and the index of condition of the oyster, *Crassostrea gryphoides* (Schlotheim). *J. Mar. Biol. Ass. India.* 5 : 221-231.

Easterson, D.C.V. and Kandasamy, D. 1988. Biochemical changes in the oyster *Crassostrea madrasensis* (Preston) with maturation. *CMFRI Bulletin.* 42: 203-205.

Eble, A.F. 1969. A histochemical demonstration of glycogen, glycogen phosphorylase and branching enzyme in the American oyster. *Proceedings of the National Shellfish Association.* 59: 27-34.

Gabbott, P.A. 1975. Storage cycles in marine bivalve molluscs: a hypothesis concerning the relationship between glycogen metabolism and gametogenesis. In: H. Barnes (ed), *Proc. 9th Eur Mar BiolSymp Oban.* Aberdeen University Press, Aberdeen, pp. 191-211.

George, C. and Gopakumar, K. 1995. Biochemical and microbiological studies on Clam *Villorita cyprinoides*. *J. Mar. Biol. Ass. India.* 37(1&2): 27-30.

Giese, A.C. 1969. A new approach to the biochemical composition of the mollusc body. Ocean. *Mar Biol Ann Rev.* 7: 175–229.

Jagadis, I. 2005. *Biology of An Intertidal Clam Gafrarium tumidum (Roding) from South East Coast of India*. Ph.D., Thesis, Tamilnadu, India: Annamalai University, p.155.

Jayabal, R. and Kalyani, M. 1986. Biochemical Studies in the hard clam, *Meretrix meretrix* (L.) from Vellar estuary, East Coast of India. *Indian J. Mar. Sci.* 15 : 63-64.

King, I., Childs, M.T., Dorsett, C., Ostrander, J.G. and Monsen, E.R. 1990. Shellfish: proximate composition, minerals, fatty acids and sterols. *Journal of the American Dietetic Association.* 90: 677-685.

Krzynowek, J., Daniel L. D'entremont and Murphy, J. 1989. Proximate composition and fatty acid and cholesterol content of squid *Loligo pealei* and *Illex illecebrosus*. *J. Food Sci.* 54(1): 45-48.

Lagade, V.M., Shital, S., Deepak, T. and Muley, V. 2015. Seasonal Variation in the Biochemical Constituents, Percentage Edibility and Condition Index of the Estuarine Clam, *Soletellina diphos* (Linnaeus, 1771) (Mollusca: Bivalvia: Veneroida: Psammobiidae). *International Journal of Zoological Research*. 11: 127-139. https://doi.org/10.3923/ijzr.2015.127.139

Laxmilatha, P. 2009. Proximate composition of the surf clam *Mactra violacea* (Gmelin 1791). *Indian Journal of Fisheries.* 56: 147-150.

Laxmilatha, P., Velayudhan, T.S., Mohamed, K.S., Kripa V., Radhakrishnan, P. and Jenny Sharma, C. 2006a. The fishery and biology of *Meretrix casta* (Chemnitz) in the Moorad estuary. *Kerala. Indian J. Fish.* 53(1) : 109-113.

Litaay, M. and Sena S. De Silva 2003. Spawning season,fecundity and proximate composition of the gonads of wild-caught blacklip abalone (*Haliotis rubra*) from Port Fairy waters, south-eastern Australia. *Aquat. Living, Resour.* 16 : 53-361.

Løje H., Jensen K.N., Hyldig G., Nielsen H.H., Nielsen J., 2007. Changes in liquidholding capacity, water distribution and microstructure during chill storage of smoked salmon. *Journal of the Science of Food and Agriculture*. 87 (14): 2684-2691 https://doi.org/10.1002/jsfa.3031.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurement with the folin phenol reagent. *J. Biol. Chem.* 193 : 265-273.

Maqbool, T.K. 1993. Studies on the biology of the clam *Marcia opima* Gmelin from Kayamkulam Lake.

Mohite, S., Mohite, A. and Singh, H. 2008. On condition index and percentage edibility of the shortneck clam *Paphia malabarica* (Chemnitz) from estuarine regions of Ratnagiri, West coast of India. *Aquaculture Research.* 40(1) : 69–73. DOI: 10.1111/j.1365-2109.2008.02064.x.

Narasimhan, K.A., V.Kripa, and Balan, K. 1993. Molluscan Shell fish resources of India- An overview. *Indian J. Fish.* 40(1-2) : 112-124.

Ngo, T. T. T., Sang-Gyun Kang, Do-Hyung Kang, Patrick Sorgeloos and Kwang-Sik Choi 2006. Effect of culture depth on the proximate composition and reproduction of the Pacific oyster, *Crassostrea gigas* from Gosung Bay, Korea. *Aquaculture.* 253: 712-720.

Ojea, J., Pazos, A.J., Martinez, D., Novoa, S., Sanchez, J.L. and Abad, M. 2004. Seasonal variation in weight and biochemical composition of the tissues of *Ruditapes decussatus* in relation to the gametogenic cycle. *Aqu.* 238: 451-468. https:// doi.org/ 10.1016/j. aquaculture. 2004.05.022.

Okumus, I. and Stirling, H.P. 1998. Seasonal variations in the meat weight, condition index and biochemical

composition of mussels (*Mytilus edulis* L.) I suspended culture in 2 Scottish Sea lochs. *Aquaculture.* 159-261-294.

Orban, E., Di Lena, G., Nevigato, T., Casini, I., Caproni, R., Santaroni, G. and Giulini, G. 2006. Nutritional and commercial quality of the striped venus clam, *Chamelea gallina*, from the Adriatic sea. *Food Chemistry* 101 : 10631070 DOI 10.1016/ j.foodchem.2006.03.005.

Orban, E., Di Lena, G., Nevigato, T., Casini, I., Marzetti, A. and Caproni, R. 2002. Seasonal changes in meat content, condition index and chemical composition of mussels (*Mytilus galloprovincialis*) cultured in two different Italian sites. *Food Chemistry.* 77: 5765 DOI 10.1016/S0308-8146(01)00322-3.

Orban, E., Nevigato, T., Di., Lena, G., Masci, M., Casini, I., Gambelli, L. and Capron, R. 2008. New trends in the seafood market.Sutchi catfish (*Pangasius hypophthalmus*) fillets from Vietnam. Nutritional quality and safety aspects. *Food Chemistry.* 110 (2): 383-389https://doi.org/10.1016/j. foodchem. 2008.02.014.

Orban, E., Di, Lena, G., Nevigato , T., Casini, I., Marzetti, A. and Caproni, R. 2002. Condition index and chemical composition of mussels (*Mytilus galloprovincialis*) cultured in two different Italian sites. *Food Chemistry.* 77: 57-65.

Ovissipour, M., Rasco, B., Tang, J. and Sablani, S.S. 2013. Kinetics of quality changes in whole blue mussel (*Mytilus edulis*) during pasteurization. *Food. Res. Int*. 53 : 141–148. https://doi.org/10.1016/j.foodres. 2013.04.029.

Palmer, A.R. 1990. Effect of crab effluent and scent of damaged conspecifics on feeding, growth and shell morphology of the Atlantic dogwhelk *Nucella lapillus* (L). *Hydrobiologia.* 193: 155-182.

Rao, G.S. 1988. Biology, of *Meretrix casta* (Chemnitz) and *Paphia malabarica* (Chemnitz) from Mulky estuary, Dakshina Karnataka. In National seminar on shell fish resources and farming - Tuticorin. 19-21 January 1987. *Bull. Cent. Mar. Fish. Res. Inst.* 42(1): 148-153.

Reiss, M.J.1989. *The Allometry of Growth and Reproduction,* Cambridge University press, New York. 279 pp.

Rivonker, C. U and Parulekar, A. H. 1995. Proximate biochemical composition and calorific potential in the raft grown green mussel *Perna viridis*. *J. Mar. Biol. Ass. India.* 37(1&2): 231-236.

Rodhouse, P. G., C.M. Roden, G.M. Burnell, M.P. Hensey, T. Mcmahon, B. Ottway and T.H. Ryan. 1984. Food source, gametogenesis and growth of *Mytilus edulis* on the shore and in suspended culture: Killary Harbour, Ireland. *J. Mar. Biol. Ass. U.K.* 64: 513-529.

Salaskar, G.M., and Nayak., V.N., 2011. Nutritional quality of bivalves, *Crassostrea madrasensis* and *Perna viridis* in the Kali estuary, Karnatakan, India. *Rec. Res. Sci. Technol.* 3(4): 6-11. www.recent-science.com.

Seshappa, G. 1971. Some observations on the backwater clam *Meretrix casta* (Chemnitz) in the Beypore and Korapuzha estuaries. *Indian J. Fish.* 14 (1&2) : 298-305.

Shettigar Malathi and Seetharamaiah Thippeswamy, 2013. Fatty acid composition in Freshwater mussel *Parreysia corrugata* (Muller, 1774) from Tunga River in the Western Ghats, India.*Advanced Biotech.* 11.

Singh, Y.T., Krishnamoorthy, M. and Thippeswamy, S. 2012. Seasonal variations of Cu, Pb, Fe, Ni and Cr in the edible wedge clam, *Donax faba* (Mollusca, Bivalvia) from the Padukere beach, Karnataka. *J Theo Exp Biol*. 8: 95-100.

Spiers, J. M. 1952. Nomenclature of the channel cat fish and the turbot in North America. Copeia. 2: 99-103.

Tamayo, D., Ibarrola, I. and Navarro, E. 2013. Thermal dependence of clearance and metabolic rates in slow- and fast-growing spats of manila clam *Ruditapes philippinarum*. *J. Comp. Physiol. B* 183: 893–904.

Tanyaros, S. and Tongnunui, P. 2011. Influence of environmental variables o the abundance of estuarine clam *Meretrix casta* (Chemnitz, 1782) in Trang Province, Southern Thailand. *Songklanakarin J. Sci. Technol.* 33(1): 107-115.

Trung tam Tin hoc- Bo Thuy San 2007, http:// www.fishnet.gov.vn/DMSP/index-e. asp.

Venkataraman, R. and Chari, S. T. 1951. Studies on oysters and clams: Biochemical variations. *Ind. Jour. Med. Res.* 39(4): 533-541.

Wilbur, K.M. and Owen, 1964. Growth. In: *Physiology of Mollusca,* (ed. K.M. Wilbur and C.M. Yonge). Vol. 1: pp. 211-242. Academic Press, New York.

Zhukova, N. V. 2014. Lipids and fatty acids of Nudibranch Mollusks: Potential sources of bioactive compounds. *Marine Drugs.* 12(8): 4578–4592.