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Research article

Yield Performance, Proximate Composition, Fatty Acid Profile and Economic Viability of Farmed Oyster (*Crassostrea* spp.) in Bangladesh

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A B S T R A C T

Oyster meat is consumed for its high nutritional value. Marine oysters (several species under the genus *Crassostrea*) have been commercially cultured long since around the world to satisfy the increased demand of oyster. Bangladesh has taken approaches to initiate oyster mariculture. Three pilot commercial oyster (*Crassostrea* spp.) farms were constructed by District Fisheries Office, Cox's Bazar at Nunia Chara (NC – 21°28ˈ19.5" N, 91°57ˈ42.7" E), Chowfoldandy (CD – 21°30ˈ44.1" N, 92°01ˈ00.1" E) and Sonadia Island (SI – 21°30ˈ18.7" N, 91°53ˈ43.3" E) in Cox's Bazar, Bangladesh. Live oysters were collected from the farm and taken to the laboratory maintaining cold chain to analyse proximate and fatty acids. Data on yield as well as cost-benefit were collected from the District Fisheries Office, Cox's Bazar to analyse yield performance and economic viability. Biological yield was observed 19.9 ± 5.7 kg/m^2 and economic yield was observed 11.3 ± 2.5 kg/m^2. Moisture, protein, lipid, carbohydrate, ash and fiber was found 79.2 ± 0.2%, 58.1 ± 2.1%, 10.2 ± 0.7%, 13.5 ± 1.4%, 12.3 ± 0.7% and 0.4 ± 0.0%, respectively, while moisture was determined in wet weight basis and rests were determined in dry weight basis. Saturated fatty acid, monounsaturated fatty acid, omega-3 fatty acid, omega-6 fatty acid and polyunsaturated fatty acid were observed 35.22 ± 10.91%, 13.77 ± 4.36%, 7.39 ± 4.00%, 43.62 ± 19.21, 51.01 ± 15.23% of total fatty acid, respectively. Annual net profit of the farms was found 34557 ± 5636 BDT and payback period was found 2.6 ± 0.4 years. Thus, oyster farming was found to be potential for high food value as well as an economically viable oyster farm enterprise.

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1. INTRODUCTION

Across the planet, the blue economy is an emergi ng challenge that may support the rising needs of the world's population. The Bay of Bengal, large marine ecosystem is an ecological gift from nature to Bangladesh that made her richest in diversity of marine productivity. A great percentage of foreign earning from frozen food products comes from marine aquatic resources (DoF, 2018). Marine fish and shellfishes are not only satisfying hunger of people but also significantly providing nutraceutical value to the consumers containing comparatively higher amount of fatty acids (Aziz et al., 2013).Out of several edible species of oyster, *Crassostrea gryphoides* (Schlotheim), *C. belcheri* (Sowerby), *C. madrasensis* (Preston) are observed under the genus *Crassostrea* with different abundance in coastal waters of Bangladesh (Pagcatipunan 1984). Highest concentration of protein and glycogen is found in oysters rather than other animal species (Sizaret and Jardin, 1985). Though being a seafood item oyster contains good quality protein but their standard quality depends on high level of n-3 (EPA, DHA, n-3 HUFA) fatty acids (Sargent and Tacon 1999). Evidences prove that n-3 HUFA ($C \geq 20$), EPA, and DHA have remarkable significance in human disease prevention. Moreover, imbalance in n6/n3 fatty acids ratio may contribute to coronary heart disease with increased risk (Simopoulos, 1990). It is also proved that regular EPA and DHA intake with diet significantly prevents inflammatory, cardiovascular and neural disorders (Casula et al., 2013). Immune diseases, hypertensions, depression, inflammatory disorders and neurological disorders can also be caused by the lack of these fatty acids in the diet. However, certain functions in retina and in brain cannot be performed by n-6 series which can successfully be carried out by DHA (Neuringer et al., 1988).

Japan, China, European countries and USA started oyster farming several decades ago. Even India also started oyster farming few decades ago. FAO executed a pilot project in 1983-1984 to initiate oyster farming in Bangladesh (Pagcatipunan 1984). However, investors didn’t come forward due to several reasons. Firstly, due to information gap in economic viability of the enterprise. Secondly, as people don’t know the nutritional value of oyster local market demand of oyster wasn’t established and initiating fully export oriented oyster farming is not an easy task at all. Finally, government approaches wasn’t sound enough to initiate commercial oyster farming. According to Cheremisinoff (1995), economic viability can be figured out by using payback period method or by net present value method or even by using internal rate of return method. But this refers to businesses on a medium to large scale. For short-duration small scale businesses or farming, the payback period approach can theoretically be good enough. In the last few years, different institution have developed several budgeting tools to assist bivalve producers in budgeting (Adams et al., 2001; Hudson et al., 2012a). Most of the tools are used for cultchless method but there is no specific tools for shellstring method.

World oyster farming nations are harnessing oyster production as well as oyster farm-oriented tourism economies. Thus this single group of species is assisting a lot to earn blue economy. As Bangladesh is also planning for harnessing blue economy, oyster farming can be an appropriate option for this. Department of Fisheries (DoF), Bangladesh has already constructed pilot oyster farms at Cox’s Bazar coast. This study was aimed to estimate the yield performance, proximate as well as fatty acids of farmed oyster and also the economic viability of oyster farm enterprise. The results of this study will help raising awareness of the nutritional value of oyster and inspire investors to demonstrate the viable condition of the oyster farm.

2. MATERIALS AND METHODS

Oyster farms

Three oyster farms were identified at Nunia Chara (NC – 21°28ˈ19.5" N, 91°57ˈ42.7" E), Chowfoldandy (CD – 21°30ˈ44.1" N, 92°01ˈ00.1" E) and Sonadia Island (SI – 21°30ˈ18.7" N, 91°53ˈ43.3" E) in Cox’s Bazar, Bangladesh. These three farms were constructed by District Fisheries Office, Cox’s Bazar as pilot oyster farm.

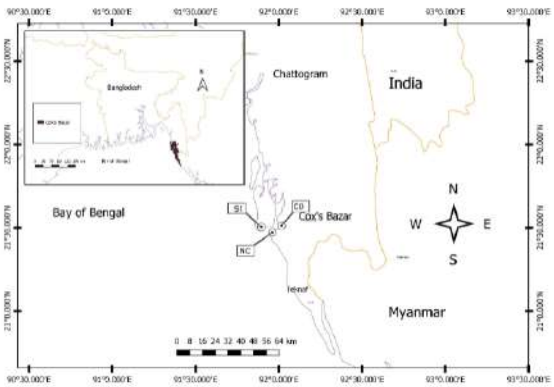

Figure 1. Location of the three oyster farms. NC, CD and SI represents Nunia Chara, Chowfoldandy and Sonadia Island oyster farms, respectively.

All the three farms were situated in estuarine dynamic water environment. All of them were made of floating bamboo raft. The raft area was 50 m^2 at NC, 16 m^2 at CD and 40 m^2 at SI oyster farm. Shell-string arrays were deployed from bamboo that contained 5-7 shells in each string.

Substrates of NC farm became dry during low tide while substrates of CD and SI farms remained submerged under water. Salinity ranges were 7–35 g/L at NC, 1–32 g/L at CD and 5–34 g/L at SI farm round the year. *Crassostrea* spp. settle on substrates from natural sources. After resettlement to the substratum, non-target species were manually discarded.

Oyster collection

A total of 50 live oysters were collected randomly from each oyster farm on January 2020. The collected oysters were 36.5 ± 2.4 mm in shell length, 30.3 ± 1.9 mm in shell width and 20.0 ± 1.9 mm in shell thickness at NC farm; 37.1 ± 0.9 mm in shell length, 36.1 ± 1.2 mm in shell width and 18.7 ± 0.7 mm in shell thickness at CD farm; 34.3 ± 1.2 mm in shell length, 28.6 ± 1.9 mm in shell width and 18.6 ± 1.1 mm in shell thickness at SI farm. Oysters were stored in ice after collection. Within 12 hours of collection, oysters were taken to the laboratory and fresh meat (whole body) was collected. Oyster meat was then dried using hot air oven.

Proximate composition

Moisture, protein, lipid, ash and crude fiber were determined according to the standard methods of AOAC (2000). Wet oyster meat were dried at 105 ^{0}C temperature in hot air oven until reaching to a constant weight. Dried oyster meat samples were blended into fine powder. Oyster from three different sources were used as the three replications. Protein content of dry oyster samples were determined by Kjeldahl method (N x 6.25) using Kjeldahl apparatus and manual titration. Soxhlet apparatus was used to determine lipid at 100 ^{0}C and using diethyl ether as solvent. Ash content was determined by using muffle furnace at 550 ^{0}C temperature for 6 hours. Crude fiber was determined by using fiber extraction apparatus and muffle furnace. Samples were first acid boiled and then alkali boiled at 100 ^{0}C and then filtered with acetone. Then the residue was ignited at 600 ^{0}C for 3 hours in muffle furnace. Carbohydrate analysis was conducted based on the method (Dubios et al., 1956). Samples were homogenously mixed with distilled water using tissue homogenizer. Samples were analyzed by adding 1 ml of 5 % phenolic solution and 5 mL of concentrated sulphuric acid. Glucose was used to prepare standard. The optical density was measured at 488 nm using a spectrophotometer (UV-VIS Double beam, Model-T80, HANNA).

Fatty acid profile

Fatty acids were determined according to Prato et al. (2017). At first, lipid was extracted from the sample using Soxhlet apparatus. Diethyl ether was used as solvent during lipid extraction. At the final stage of lipid extraction 60 °C temperature was maintained. This lipid sample was used to analyze fatty acid methyl esters. Analysis of Fatty acids methyl esters (FAMEs) were conducted by gas chromatography mass spectrophotometry using a GCMS-QP2020 (Shimadzu, Japan), equipped with flame ionization detector. FAMEs were separated with a capillary column (Length 30 m, internal diameter 0.25 mm, film thickness 0.15 µm, phase ratio 250). Helium was used as carrier gas at a flow rate of 1.42 ml/min. The column temperature program was as follows: 180 to 280 °C at 5 °C /min and then held at 280 °C. FAMEs were identified by comparing retention times with a standard (FAME mix C8-C24; Sigma-Aldrich, Germany). Quantities were expressed in ppm. Then it was converted into % of total fatty acids. Oysters from the three oyster sources were used as three replications.

Yield performance

Data on yield of oyster was collected from District Fisheries Office, Cox's Bazar. Following calculations were used to estimate yield performance:

Biological yield = Total weight of oyster produced in a season (on-shell) / total area (m^2)

Economic yield = Total weight of oyster produced in a season (grade A and B) / total area (m^2)

Where, grade A was the oysters that were 100 – 200g in body weight (on-shell) and grade B was the fresh oyster meat (off-shell) collected from oysters of >200g in body weight.

Economic viability

Cost–benefit data (see Table 1, 2) of three oyster farms were collected from District Fisheries Office, Cox's Bazar.

Economic viability was estimated from the net profitability and payback period of the farms.

Following calculations were used to estimate net profit and payback period:

Net profit = Annual income - (Depreciation cost + recurring cost)

Where, Depreciation cost is the 33.33% of fixed cost.

Payback period (years) = Initial investment / net profit

Where, initial investment = Fixed cost + recurring cost

Table 1. Expenditures of the three oyster farms

Farm	Categories	Item	Unit Price (BDT)	Units	Amount (BDT)
NC	Fixed	Anchor	2500	4	10000
		Floats	1200	12	14400
		Drums	500	8	4000
		Rope	500	10	5000
			Sub total		33400
	Recurring cost	Bamboo	400	20	8000
		Rope	370	25	9250
		Cultch	25	100	2500
		Labor	500	20	10000
		Security	4000	8	32000
		Oyster cleaning	10	400	4000
		Transport	2000	1	2000
		Trade license	500	1	500
			Sub total		68250
				Total	**101650**
CD	Fixed	Anchor	2500	4	10000
		Floats	1200	4	4800
		Drums	600	4	2400
		Rope	500	10	5000
			Sub total		22200
	Recurring cost	Bamboo	400	10	4000
		Rope	370	10	3700
		Cultch	25	60	1500
		Labor	500	10	5000
		Security	3000	8	24000
		Oyster cleaning	10	200	2000
		Transport	1000	1	1000
		Trade license	500	1	500
			Sub total		41700
				Total	**63900**
SI	Fixed	Anchor	2500	4	10000
		Floats	1200	10	12000
		Drums	600	8	4800
		Rope	500	10	5000
			Sub total		31800
	Recurring cost	Bamboo	400	20	8000
		Rope	370	25	9250
		Cultch	25	100	2500
		Labor	500	24	12000
		Security	3000	8	24000
		Oyster cleaning	10	300	3000
		Transport	3000	1	3000
		Trade license	500	1	500
			Sub total		62250
				Total	**94050**

Table 2. Income of the three oyster farms

Farm	Grade	Yield (Kg)	Unit Price (BDT)	Total Price
NC	A	400	250	100000
	B (off-shell)	50	500	25000
	B (on-shell)	300	–	–
CD	A	200	250	50000
	B (off-shell)	60	500	30000
	B (on-shell)	300	–	–
SI	A	300	250	75000
	B (off-shell)	50	500	25000
	B (on-shell)	280	–	–

Statistical analysis

Mean and standard error of mean (SE = σ/√n) were calculated in Microsoft excel.

3. RESULTS AND DISCUSSION

Yield performance

Mean yield performance is shown in Figure 2. In case of oysters of grade B (>200g, on-shell), only oyster meat is bought by consumers. Thus, biological yield is higher than economic yield.

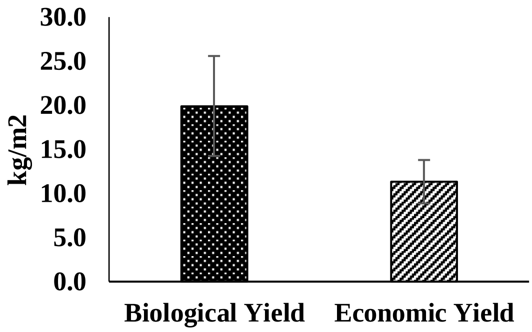

Figure 2. Yield performance of oyster, farmed along Cox's Bazar coast (*n* = 3).

Proximate

Mean proximate composition of farmed oysters are shown in the Figure 3. The protein, lipid and carbohydrate contents are similar to a previous study on *Crassostrea rhizophorae* (Martino and Cruz, 2004). The quality and texture of seafood mainly depends on the quality of protein. Withal, during cooking process meat textural degradation occurs due to loosing water from low protein seafood (Økland et al. 2005). However, proximate composition varies with the findings of Prato et al. (2019) in *Ostrea edulis.* However, value of proximate composition of *Crassostrea* spp. is nutritionally good for human health according to Martino and Cruz (2004).

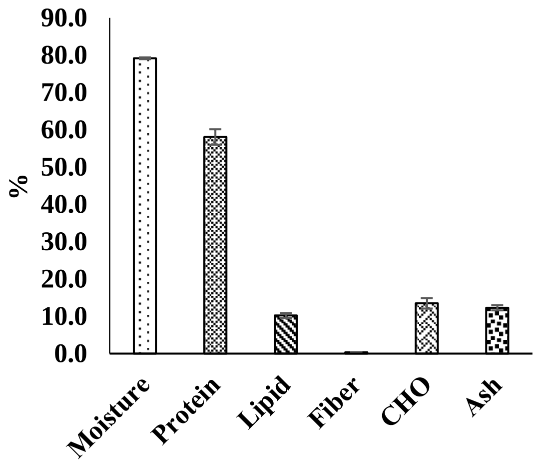

Figure 3. Proximate composition of oyster, farmed along Cox's Bazar coast (*n* = 3).

Fatty acids

Individual fatty acids (% of total fatty acids) are shown in Table 3; saturated fatty acid, monounsaturated fatty acid, omega-3 fatty acid, omega-6 fatty acid and polyunsaturated fatty acid (% of total fatty acids) are shown in Figure 4; different fatty acid ratios are shown in Figure 5.

Table 3. Fatty acids in oyster expressed in % of total fatty acids (*n* = 3).

Carbon	Fatty Acids	% of total fatty acids
C8:0	Octanoic acid	1.17 ± 0.06
C10:0	Decanoic acid	1.07 ± 0.05
C12:0	Lauric acid	4.45 ± 0.72
C13:0	Tridecanoic acid	0.96 ± 0.17
C14:0	Myristic acid	12.30 ± 4.30
C16:0	Palmitic acid	7.60 ± 2.84
C18:0	Stearic acid	1.42 ± 0.78
C20:0	Arachidic acid	1.65 ± 0.17
C17:0	Heptadecanoic acid	1.22 ± 1.21

C21:0	Heneicosanoic acid	0.04 ± 0.01
C22:0	Behenic acid	1.50 ± 0.56
C23:0	Tricosanoic acid	0.42 ± 0.03
C24:0	Lignoceric acid	1.42 ± 0.34
C16:1	Palmitoleic acid	8.03 ± 4.32
C18:1	Oleic acid	0.61 ± 0.11
C20:1	cis-11-Eicosenoic acid	3.35 ± 0.85
C22:1	Erucic acid	1.43 ± 0.02
C24:1	Nervonic acid	0.34 ± 0.18
C18:2n-6	Linoleic acid	40.27 ± 20.03
C20:3n-6	Eicosatrienoic acid	0.95 ± 0.30
C20:4n-6	Arachidonic acid	2.39 ± 0.53
C18:3n-3	Linolenic acid	1.17 ± 0.75
C20:5n-3	Eicosapentanoic acid	5.15 ± 2.95
C22:5n-3	Docosapentaenoic acid	0.54 ± 0.26
C22:6n-3	Docosahexaenoic acid	0.52 ± 0.08

High palmitic acid was observed in farmed oyster from this study. According to Ackman and Eaton (1966) palmitic acid plays key role in many metabolic processes in a lot of fish and other aquatic animals. Martino and Cruz (2004) and Prato et al. (2019)found higher EPA and DHA in other oysters than the findings of this study. Long-chain n-3 PUFAs must be taken through diet by human as they cannot synthesize those fatty acids (Alasalvar et al., 2002). Omega-3 fatty acids are much lower than omega-6 fatty acids. While, Martino and Cruz (2004) and Prato et al. (2019) found higher omega-3 fatty acids than omega-6 fatty acids. However, saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids are similar to their findings. High SE was observed for n-3/n-6 fatty acids ratio. This was happened due to the high variation among the oysters of different farms. Oysters from CD farm had very poor n-3 fatty acid. Moreover, n-3/n-6 ratio varied from Martino and Cruz (2004) and Prato et al. (2019). With the increased concentration of phytoplankton in water, Bachok et al. (2003) observed energetically important fatty acids at higher levels. Furthermore, phytoplankton availability varies seasonally and spatially in coastal areas which are preferably consumed by oysters (Mehedi et al., 2017). In the tissue of marine primary producers, Dalsgaard et al. (2003) discovered unique fatty acid patterns that can be unchangeably passed to species with a higher trophic level.

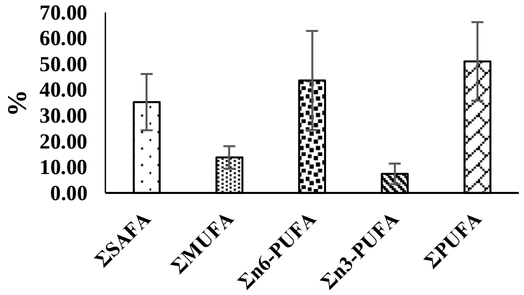

Figure 4. Different groups of fatty acids in farmed oyster. SAFA– Saturated Fatty Acid, MUFA– Monounsaturated Fatty Acid, n6-PUFA– omega-6 Polyunsaturated Fatty Acid, n3-PUFA– omega-3 Polyunsaturated Fatty Acid, PUFA– Polyunsaturated Fatty Acid (*n* = 3).

Availability of 20:1 And 18:2n6c in marine bivalves indicates the presence of herbivore zooplankton, algae, and fungi as a dietary source in their habitat (Auel et al., 2002; Erwin, 1973; Kayama et al., 1989). Withal, dinoflagellates as a major food source is reflected by higher level of 22:6n3 in tissues (Joseph, 1975; Sargent et al., 1977). On the other hand, presence of 20:5n3 and 16:1 intimate the dominance of diatoms (Graeve et al., 1997), whereas the presence of 22:6n3, 20:1, and 14:0 reflect the abundance of dinoflagellates, herbivorous zooplankton and diatoms(Auel et al., 2002; Graeve et al., 1997; Joseph, 1975; Sargent et al., 1977). Abundance of bacteria, algae, fungi, and diatoms are reflected in the concentration of 20:4n6, 18:2n6c, and 17:0 in marine bivalves (Ackman, 1989; Erwin, 1973; Kayama et al., 1989; Kharlamenko et al. 2001).

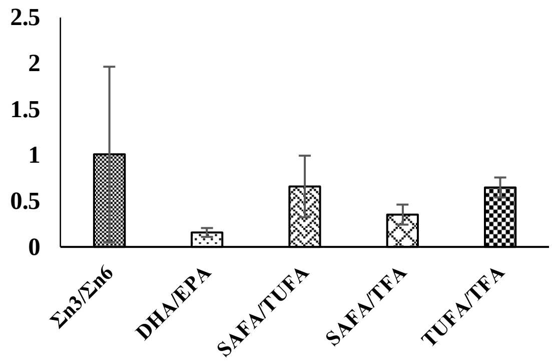

Figure 5. Ratios of fatty acids in farmed oyster. SAFA– Saturated Fatty Acids, TUFA– Total Unsaturated Fatty Acids, TFA– Total Fatty Acids, n3– omega-3 Polyunsaturated Fatty Acids, n6– omega-6 Polyunsaturated Fatty Acids, DHA– Docosahexaenoic Acid, EPA– Eicosapentanoic Acid(*n* = 3).

Fatty acids compositions also varies with different intrinsic factors (age, sex, size and way of life) as well as extrinsic factors (diet, temperature, and salinity). Among these factors, temperature has remarkable influence on fatty acids composition such as decreased level of temperature stimulates unsaturation of fatty acids thus to ensure body flexibility and membrane fluidity through maintaining freezing point below the temperature of surrounding water (Eastman, 1990; Martino et al., 2002). However, increased temperature also triggers raising phospholipids thus to counteract excessive membrane fluidity (Martino et al., 2002).

Being a bivalve oyster is filter-feeding animal which accumulate elements from water, inorganic particulate and food that may also result in bioaccumulation of toxic substances (Amiard et al., 2008; Liao and Ling, 2003). But it can only be potentially hazardous if the concentration level of these substances exceed the permitted level (Amiard et al., 2008; Liao and Ling, 2003). Though this farmed oyster have good nutritional value but still it can't be declared as health safe before heavy metals and other persistent organic pollutants analysis.

Economic viability

Annual net profit of the farms was observed 34557 ± 5636 BDT and payback period was observed 2.6 ± 0.4 years. According to Cheremisinoff (1995), any enterprise can be marked as economically viable if the revenue exceeds the production cost. It is expected that in near future the consumer demand of bivalves will increase greatly and the worldwide production has consistently increased from 7.1 million to 16.1 million over the years 1995 to 2014 (FAO 2016) which may help to sustain oyster farming. However, billions of dollars can be wasted in freshwater and infrastructures including aquaculture due to biofouling (Abbott et al., 2000; Champ, 2000). This is difficult to estimate in budgeting.

4. CONCLUSION

It can be concluded that oyster farming would be an economically viable business in Bangladesh, taking the results of this study into account. Besides, this farmed oyster has high nutritional value with high protein, carbohydrate and lipid content consisting good quantity of fatty acids. Burgeoning awareness among local consumers about the food value of this seafood would make it more sustainable. However, availability of oyster spat must be ensured prior to the start of the enterprise. Until selling goods for consumption, persistent organic contaminants and heavy metals must be checked.

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