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Fatty Acid Profiles of Venus Clam (*Marcia opima*) and Blood Cockles (*Anadara granosa*) Harvested at Different Geographical Locations in the Northwest Coast of Sri Lanka

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ABSTRACT

The present study elucidated the effects of species and geographical location on the fatty acid profile and lipid indices of bivalves. Lipid profiles of venus clam (*Marcia opima*) and blood cockles (*Anadara granosa*) harvested from Naruvilikulam and Achchankulam situated on the northwest coast of Sri Lanka were determined, and lipid indices were calculated. The dominant fatty acid group found in bivalves was saturated fatty acids. Total n-3 and n-6 fatty acid contents were similar between the two species. Both bivalve species were identified as potential sources of docosahexaenoic acid. Bivalves from Naruvilikulam site had significantly abundant levels of linolenic and eicosapentaenoic acids (0.83% and 5.69%, respectively). Thrombogenicity index was not influenced by species and geographical location of bivalves. M. opima and bivalves from Naruvilikulam site were detected with lower atherogenicity indices and higher hypocholesterolemic/hypercholesterole-mic ratios than their counterparts and, therefore, can be recommended for consumers interested in healthy food selection.

KEYWORDS

Polyunsaturated fatty acids; bivalves; atherogenicity index; thrombogenicity index; hypercholesterolemic

Introduction

Marine bivalves are among the most traded seafood worldwide (Ricardo et al. 2021). The consumption of bivalves has increased over the years, mainly due to their great nutritional value and high market availability (Tabakaeva et al. 2018; Zhukova 2019). Bivalve molluscs are consumed as a traditional food item (Tabakaeva et al. 2018) and have become prominent seafood in South East Asian countries. Marine mollusc species have an excellent commercial value, and cultivation of such species is more applicable in coastal areas (Periyasamy et al. 2014). Sri Lanka is a well-known Island augmented with plenty of economically important bivalve species, such as oysters (*Crassostrea madrasensis* and *Saccostrea cucullata*), mussels (*Perna viridis* and *P. perna*), clams (*Marcia opima, M. hiantina* and *Meretrix casta*), cockles (*Gafrarium tumidum* and *Anadara granosa*), and pearl oysters (*Pinctada vulgaris* and *P. margaritifera*), along the coastal areas of the country including Mannar, Chilaw, Negombo, Kalpitiya, and Jaffna (Wanninayake 2017).

Edible marine bivalves are cultured worldwide, as they are well-known sources of *n*-3 polyunsaturated fatty acids (PUFA), in particular eicosapentaenoic acid (EPA, C20:5 *n*-3) and docosahexaenoic acid (DHA, C22:6 *n*-3; Chu and Greaves 1991; Cruz-Romero et al. 2008). However, the ideal bivalves for human consumption are determined by the nutritional quality of lipids present in their tissues (Tan et al. 2020). Accordingly, the abundance of *n*-3 and *n*-6 fatty acids, *n*-3/*n*-6 ratio, and PUFA/saturated fatty acids (SFA) ratio (Stratev et al. 2017),

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atherogenicity index (AI), thrombogenicity index (TI), and hypocholesterolemic/hypercholesterolemic ratio (h/H) are extensively used to assess the nutritional quality of lipids in foods (Prato et al. 2018; Tan et al. 2020). Hence, bivalves containing lipids with high nutritional quality in their tissues are considered as ideal, healthy, and well-balanced PUFA sources (Simopoulos 2002, 2003). Fatty acid profile of bivalves is, however, primarily influenced by factors, such as species and feeding mode (Tan et al. 2020; Zhukova 2019), type and amount of feed ingested (Simopoulos 2004), composition of the diet, reproductive cycle (Orban et al. 2002; Zhukova 2019), and seasonal and geographical variations (Orban et al. 2007).

Venus clam (*M. opima*) and blood cockle (*A. granosa*) are found abundantly along the northwest coast of Sri Lanka (Kumar et al. 2018). Clam meat has been recommended by dieticians due to its high protein content, low calorific value, low fat/cholesterol profile (Jagadis et al. 2015; Salaskar and Nayak 2011), lower levels of SFA, abundant levels of *n*-3 PUFA, and other trace elements (Dong 2001; Krzynowek et al. 1989). In addition, *A. granosa* is popular as a highly utilized food species with high protein content (Awang-Hazmi et al. 2007). Although *A. granosa* has a low lipid content, it has been identified with the presence of both SFA and unsaturated fatty acids (Martínez-Pita et al. 2012). However, literature available on the fatty acid profile and, in particular, lipid indices of *M. opima* and *A. granosa* from different geographical locations is scant. The aim of this study was to evaluate the fatty acid profiles and lipid indices of *M. opima* and *A. granosa* harvested from different geographical locations, Naruvilikulam and Achchankulam, situated on the northwest coast of Sri Lanka.

Materials and methods

Study area and samples

The samples of venus clam (*M. opima*) and blood cockles (*A. granosa*;) were collected as three batches weighing 6 kg each, separately from two geographical locations–Naruvilikulam (8° 86066′ N and 79° 92844′ E) and Achchankulam (8° 82373′ N, 79° 92497′ E)–situated on the northwest coast of Sri Lanka (Figure 1). The total length, total weight, and individual muscle weight of *M. opima* was reported as 47.30–49.08 cm, 34.70–49.16 g, and 4.32–5.41 g, respectively, whereas the same parameters of *A. granosa* were 56.47–61.56 cm, 78.25–117.53 g, and 11.70–16.22 g, respectively. The collected samples were transported in ice (3 ± 1°C) to the Meat Processing and Research Laboratory, Uva Wellassa University, Sri Lanka. After thoroughly cleaning the bivalves, edible meat was removed from the shells and two pooled samples containing meat of 20 bivalves each were prepared from each batch for analysis of fatty acid profiles (total of six replicates each from species and geographical locations).

Fatty acid analysis

Lipids in the bivalve samples were extracted by Folch extraction procedure using chloroform:methanol (2:1, v/v; Folch et al. 1957). Fatty acid methyl esters were prepared from the extracted lipids using boron trifluoride (BF3)-methanol (Sigma-Aldrich), followed by separation in a gas chromatograph (GC-2014 Shimadzu, Kyoto, Japan). A split inlet (split ratio, 100:1) was used to inject the samples into a fused silica DB wax capillary column (30 m × 0.32 mm; 0.25 µm; Omegawax 320, Supelco, Bellefonte, PA), and the sample components were separated using a ramped oven temperature (150°C for 5 min, temperature increased to 170°C at 5°C/min and maintained for 8 min, then increased to 190°C at 5°C/min and maintained for 15 min, and finally increased to 220°C at 5°C/min and maintained for 30 min). The inlet and detector temperatures were 210°C and 230°C, respectively. N_2 gas served as the carrier at a constant flow rate of 0.7 mL/min. Relative quantities were expressed as weight percent of total fatty acids identified via comparison of retention times to known standards (17 fatty acid methyl esters mix, Sigma–Aldrich).

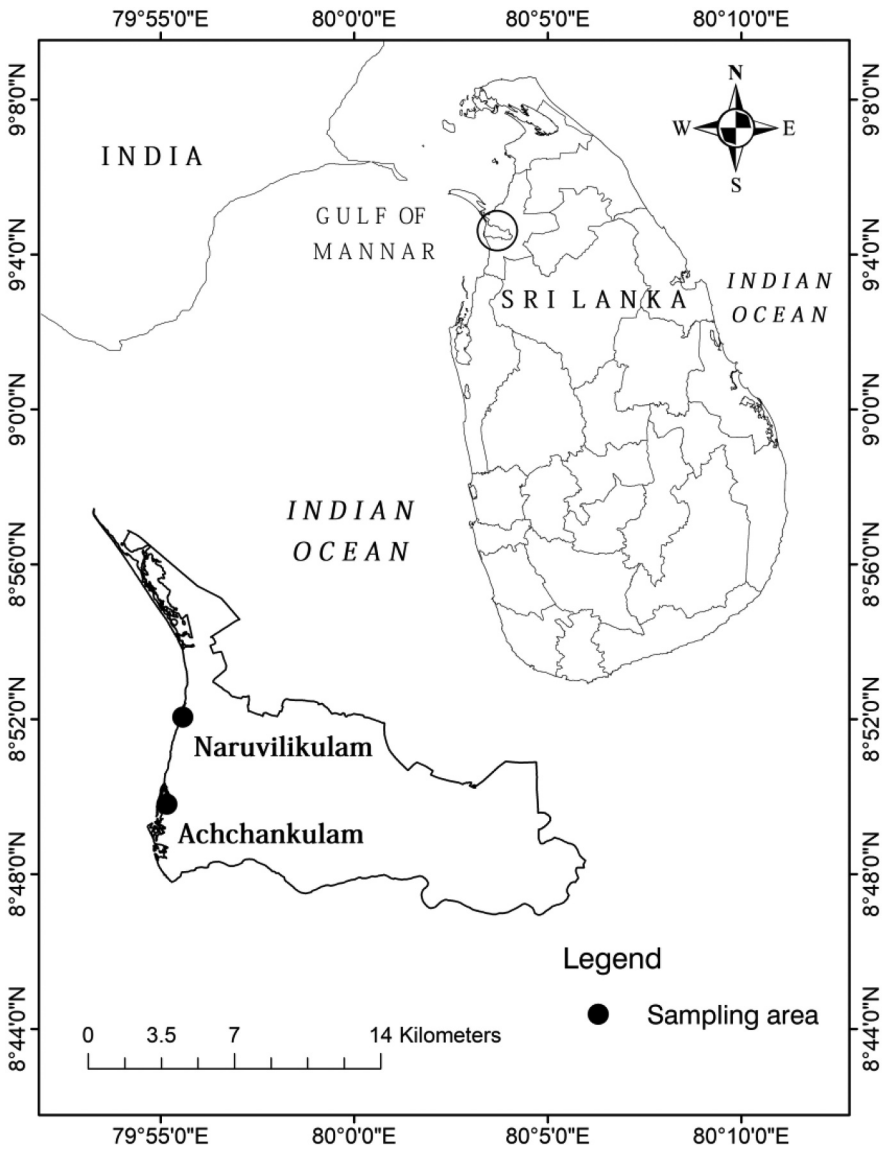

Figure 1. Sample collection sites of *M. opima* and *A. granosa* from the northwest coast of Sri Lanka.

Lipid indices

The following equations suggested by Ulbricht and Southgate (1991) were used to calculate AI and TI.

$$AI = [C12:0 + 4 \times C14:0 + C16:0] / [\Sigma MUFA + \Sigma n-6 + \Sigma n-3]$$

$$TI = [C14:0 + C16:0 + C18:0] / [0.5 \times \Sigma MUFA + 0.5 \times \Sigma n-6 + 3 \times \Sigma n-3 + (\Sigma n-3 / \Sigma n-6)]$$

The hypocholesterolemic/hypercholesterolemic ratio was calculated as proposed by Santos-Silva et al. (2002).

$$h/H = [C18:1 + C18:2n-6 + C20:4n-6 + C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3]/[C14:0 + C16:0]$$

Statistical analysis

The effects of species and geographical location on fatty acid profile and lipid indices were estimated using a two-way analysis of variance (ANOVA) model and the general linear model (GLM) procedure in SAS 9.3 (SAS Institute Inc., Cary, NC, USA). Mean separation was conducted using Tukey's multiple range test ($p < .05$). All tables indicate the mean values of six samples and standard errors of the mean (SEMs).

Results and discussion

The effects of species (*M. opima* and *A. granosa*) and geographical location (Naruvilikulam and Achchankulam) on the fatty acid profile and lipid indices of bivalves were studied during the present experiment. A total number of 17 fatty acids were detected in both species. The species of bivalves had a significant effect on the myristic (C14:0), pentadecanoic (C15:0), palmitic (C16:0), vaccenic (C18:1 *n*-7), oleic (C18:1 *n*-9), linoleic (C18:2 *n*-6), and docosapentaenoic acid (C22:5 *n*-3) contents, and ΣSFA content (Table 1). Regarding the fatty acid indices, only *n*-3/*n*-6 ratio, AI, and h/H ratio of bivalve lipids were affected by the species ($p < .05$; Table 2).

Table 1. Fatty acids profile (% total fatty acids) of two bivalve species from two different geographical locations in Sri Lanka.

	Species		Geographical location		SEM[#]
Fatty acids	*M. opima*	*A. granosa*	Achchankulam	Naruvilikulam	
Saturated fatty acids					
Myristic acid (C14:0)	3.30[b]	4.72[a]	5.60[a]	2.41[b]	0.21
Pentadecanoic acid (C15:0)	1.74[a]	1.37[b]	1.79[a]	1.32[b]	0.06
Palmitic acid (C16:0)	32.23[b]	40.11[a]	39.95[a]	32.40[b]	1.05
Stearic acid (C18:0)	18.55	12.38	11.99	18.94	2.34
ΣSFA*	55.82[b]	58.58[a]	59.33[a]	55.07[b]	0.06
Monounsaturated fatty acids					
Palmitoleic acid (C16:1 *n*-7)	0.90	1.63	0.60	1.93	0.50
Vaccenic acid (C18:1 *n*-7)	3.14[b]	5.40[a]	5.64[a]	2.90[b]	0.20
Oleic acid (C18:1 *n*-9)	9.61[a]	4.37[b]	5.73[b]	8.25[a]	0.35
11-eicosenoic acid (C20:1 *n*-9)	3.53	4.41	5.33[a]	2.61[b]	0.48
Erucic acid (C22:1 *n*-9)	0.41	0.38	0.62[a]	0.17[b]	0.12
ΣMUFA**	17.59	16.19	17.92[a]	15.86[b]	0.50
Polyunsaturated fatty acids					
Linoleic acid (C18:2 *n*-6)	2.78[a]	1.96[b]	2.01	2.73	0.24
Linolenic acid (C18:3 *n*-3)	0.49	0.71	0.37[b]	0.83[a]	0.14
Octadecatetraenoic acid (C18:4 *n*-3)	0.34	0.52	0.64	0.22	0.33
Arachidonic acid (C20:4 *n*-6)	1.36	1.58	2.50[a]	0.44[b]	0.10
Eicosapentaenoic acid (C20:5 *n*-3)	1.90	3.97	0.18[b]	5.69[a]	1.25
Docosatetraenoic acid (C22:4 *n*-6)	3.38	2.69	0.57[b]	5.50[a]	0.59
Docosapentaenoic acid (C22:5 *n*-3)	3.72[a]	1.14[b]	2.37	2.48	0.24
Docosahexaenoic acid (C22:6 *n*-3)	12.62	12.66	14.11[a]	11.18[b]	0.48
ΣPUFA***	26.59	25.23	22.75[b]	29.07[a]	1.19
Σ*n*-3	19.07	19.00	17.67	20.40	1.37
Σ*n*-6	7.52	6.23	5.08[b]	8.67[a]	0.54
ΣEPA+DHA	14.52	16.63	14.29[b]	16.87[a]	0.29

[#]Standard error of mean; *total saturated fatty acids; **total monounsaturated fatty acids; ***total polyunsaturated fatty acids. Data were presented as mean values of six samples. Different superscripts in the same row within each effect indicate significant difference ($p < 0.05$).

Table 2. Lipid indices of bivalves as affected by species and geographical location.

	Species		Geographical location		SEM[#]
Index	*M. opima*	*A. granosa*	Achchankulam	Naruvilikulam	
PUFA/SFA	0.48	0.43	0.38[b]	0.53[a]	0.03
n-3/*n*-6	2.59[b]	3.76[a]	3.87[a]	2.47[b]	0.33
Atherogenicity index (AI)	1.03[b]	1.42[a]	1.53[a]	0.94[b]	0.04
Thrombogenicity index (TI)	0.75	0.80	0.85	0.71	0.07
h/H ratio	0.91[b]	0.59[a]	0.60[b]	0.91[a]	0.03

[#]Standard error of mean. Data were presented as mean values of six samples. Different superscripts in the same row within each effect indicate significant difference ($p < 0.05$).

The geographical location of bivalves significantly affected the abundance of all 17 fatty acids found in this study, except palmitoleic (C16:1 *n*-7), stearic (C18:0), linoleic, octadecatetraenoic (C18:4 *n*-3), and docosapentaenoic acids (Table 1). In addition, geographical location influenced the contents of all fatty acid categories (ΣSFA, ΣMUFA, ΣPUFA), and Σ*n*-6 and ΣEPA+DHA contents ($p < .05$). Furthermore, geographical location of the bivalves had a significant impact on all lipid indices in the present study, except TI (Table 2). Regarding the interaction effect on fatty acid profiles and lipid indices of bivalves, the interaction between species and geographical location influenced the abundance of oleic and linoleic acids, Σn-6, ΣEPA+DHA, *n*-3/*n*-6 ratio, and AI ($p < .05$; Data not shown).

Effect of species

The most abundant type of fatty acids present in both bivalve species was SFA (55.82–58.58%), followed by PUFA (25.23–26.59%) and monounsaturated fatty acid (MUFA) (16.19–17.59%, Table 1). A similar pattern of results was reported for a few other edible marine bivalves from Taranto, Southern Italy (Prato et al. 2019) and in *Cerastoderma edule* and *Scrobicularia plana* from Portugal (Goncalves et al. 2016). In contrast, several other researchers observed PUFA as the predominant type of fatty acid in the majority of the edible marine bivalves tested in their works (Hikihara et al. 2020; Ricardo et al. 2017; Stratev et al. 2017). The aggregate SFA content was significantly greater in *A. granosa* compared to *M. opima* ($p < .05$). Palmitic acid was the predominant SFA detected in both bivalve species, with a higher content in *A. granosa* ($p < .05$). Palmitic acid – a key metabolite in the synthesis of other fatty acids – is relatively constant over the life cycle of seafood species (Nunes et al. 2003). Similar findings were previously reported for some other bivalve species (Joy and Chakraborty 2017; Prato et al. 2019; Stratev et al. 2017). Moreover, *A. granosa* had greater myristic acid and lower pentadecanoic acid content compared to *M. opima* (Table 1; $p < .05$). Myristic and palmitic acids are considered hypercholesterolemic (Fernandez and West 2005); the former has five to six-times greater potential to increase the cholesterol levels than the latter (Yu et al. 1995). Nonetheless, no significant differences in the stearic acid content were apparent between the two species ($p > .05$), which was in agreement with the findings of Joy and Chakraborty (2017).

The aggregate MUFA content was comparable between the two species ($p > .05$; Table 1). However, *M. opima* contained 2-fold higher oleic acid contents than *A. granosa*, whereas the latter had a greater content of vaccenic acid ($p < .05$). The content of MUFA reported in the present study was in line with those previously described for other bivalves (Azpeitia et al. 2016; Prato et al. 2019). Furthermore, *F. glaber* and *Mytilus galloprovincialis* recorded similar oleic acid contents (9.97% and 9.93%, respectively) to that of *M. opima* reported in the present study (Prato et al. 2019). Recently, Hikihara et al. (2020) reported comparable oleic acid (4.6%) and vaccenic acid (5.46%) levels for *Crassostrea nippona* to those observed in *A. granosa* in the current study.

The total PUFA contents of *M. opima* and *A. granosa* were similar ($p > .05$; Table 1), and the values are in agreement with those reported by Prato et al. (2019) for *F. glaber* (27.44%) and *Venus verrucosa* (27.39%). However, a significant difference in linoleic acid content was noted between the species with

higher levels in *M. opima* ($p < .05$). Interestingly, *M. opima* and *A. granosa* had similar contents of all *n*-3 PUFA ($p > .05$), except docosapentaenoic acid, which was three times higher in *M. opima* ($p < .05$). Similarly, Hikikara et al. (2020) demonstrated comparable EPA (C20:5 *n*-3) and DHA (C22:6 *n*-3) contents among bivalve species. In contrast, considerably higher EPA (C20:5 *n*-3) levels were found in *Modiolus barbatus* (10.6%), *M. galloprovincialis* (13.2%), and *O. edulis* (8.97%) compared to those reported for bivalves used in the present study (Prato et al. 2019).

In general, the sum of EPA (C20:5 *n*-3) and DHA (ΣEPA+DHA) is used to determine the nutritive value of seafood (Hibbeln 2002; Pietrowski et al. 2011; Sioen et al. 2007). EPA (C20:5 *n*-3) and DHA (C22:6 *n*-3) are agglomerated in bivalves via the ingestion of phytoplankton – their primary food source (Manthey-Karl et al. 2015; Pernet et al. 2012; Ricardo et al. 2017; Ruano et al. 2012). However, ΣEPA+DHA is comparable between *M. opima* and *A. granosa* (Table 1). Interestingly, DHA (C22:6 *n*-3) content as a proportion of *n*-3 PUFA content ranged from 69% to 80% in the bivalve species studied. Thus, both *M. opima* and *A. granosa* can be recommended as potential sources of DHA (C22:6 *n*-3).

In general, ideal bivalves for human consumption are determined by the nutritional quality of lipids in their tissues based on *n*-3/*n*-6 and PUFA/SFA ratios (Prato et al. 2018; Tan 2020). AI is a marker of risk for cardiovascular maladies, while TI is an indicator of the potential for blood platelets conglomeration (Joy and Chakraborty 2017). Hence, higher AI and TI values (>1.0) may cause harmful effect on human health (Bobe et al. 2004), whereas higher values of h/H ratio are recommended for human diets (Joy and Chakraborty 2017; Ramos-Filho et al. 2008). Table 2 shows the effect of species and geographical location on different lipid indices of bivalves. *M. opima* recorded a lower AI and *n*-3/*n*-6 ratio and a higher h/H ratio as opposed to *A. granosa* ($p < .05$), which can be attributed to the lower levels of myristic and palmitic acids and higher Σ*n*-6 levels in the former species. Both species used in this study, however, recorded comparable TI values ($p > .05$), which lie within the recommended limit. Similar AI values to that of *M. opima* have been reported recently for *M. galloprovincialis* (1.00) and *Arca noae* (1.06; Biandolino et al. 2019). In contrast, lower AI and TI values compared to those reported in the current study were detected in *Mytilus edulis* (0.61–0.65, 0.26) and *Paphia malabarica* (0.66, 0.31), respectively (Colombo et al. 2016; Joy and Chakraborty 2017). Furthermore, *P. malabarica* recorded a higher h/H ratio (1.71), whereas *Villorita cyprinoides* had a lower h/H ratio (0.52; Joy and Chakraborty 2017) as opposed to bivalve species tested in this study.

Foods with relatively high ratio of *n*-3/*n*-6 are labeled as healthy and well-balanced PUFA sources (Simopoulos 2002, 2003). It is generally recommended to have a ratio of *n*-3/*n*-6 greater than 1.0 (Bhardwaj et al. 2016). The same indices reported for *M. opima* and *A. granosa* in the present experiment were 2.59 and 3.76, respectively (Table 2). Tan et al. (2020) summarized *n*-3/*n*-6 ratios for commercially important bivalves including mussels (1.76–10.48), clams (2.86–9.53), scallops (2.54–18.2), oysters (2.40–11.67), and cockles (3.80–17.39). In addition, Joy and Chakraborty (2017) demonstrated a similar *n*-3/*n*-6 ratio in *P. malabarica* (2.31) to that of *M. opima*. In contrast, Karnjanapratum et al. (2013) reported a lower *n*-3/*n*-6 ratio (1.36) for Asian hard clam compared to those of bivalves tested in the present study.

As seen in Table 2, PUFA/SFA ratios were comparable between the two species. As per the recommendation, ratio of PUFA/SFA should be greater than 0.4 (Stratev et al. 2017). Prato et al. (2019) and Chow (2007) have reported that a PUFA/SFA ratio lower than the recommended level may elevate blood cholesterol concentrations. In this study, both *M. opima* and *A. granosa* reported PUFA/SFA ratios above the recommended level, 0.48 and 0.43, respectively (Table 2). According to Tan et al. (2020), PUFA/SFA ratios for commercially important bivalves including mussels (0.75–2.53), clams (0.68–2.04), scallops (0.31–1.69), oysters (0.60–2.13), and cockles (1.00–1.62) were typically above the recommended level. Considering the findings of the present study on individual fatty acids and lipid indices and recommended levels for different lipid indices, *M. opima* can be recommended for consumers interested in low fat food selection due to high nutritional quality of lipids present in their tissues compared with *A. granosa*.

Effect of geographical location

Environmental factors including salinity, water temperature, sediment type, availability of food, and trophic history have significant impacts on fatty acid profiles of bivalves (Caers et al. 2000; Calado and Leal 2015; Dalsgaard et al. 2003; Prato et al. 2018; Ricardo et al. 2017). The effect of two different geographical locations (Achchankulam and Naruvilikulam) on fatty acid profiles of bivalves is shown in Table 1. The percentage of SFA, PUFA, and MUFA ranged from 55.07% to 59.33%, 22.75–29.07%, and 15.86–17.92% of total fatty acids, respectively, at the two geographical locations. Bivalves from Naruvilikulam site had significantly lower total SFA and total MUFA contents than did those from Achchankulam site. In addition, bivalves from the former site reported a higher total PUFA content as opposed to those from the latter ($p < .05$). In terms of SFA, bivalves from Naruvilikulam site had lower levels of hypercholesterolemic fatty acids – myristic and palmitic acids – compared to those from Achchankulam site. The prevalence of high palmitic acid contents in bivalve tissues is associated with a diet rich in diatoms (Ricardo et al. 2021). Furthermore, Dalsgaard et al. (2003) noted that the fluidity and structure of cell membranes in bivalves is affected by high salinity fluctuations and low water temperatures as a consequence of their fatty acid composition, with membrane fluidity being secured by a replacement of SFA by PUFA (Fokina et al. 2015; Nemova et al. 2013).

Oleic acid was detected as the predominant MUFA in bivalves from both geographical locations, with higher levels from the Naruvilikulam site ($p < .05$). In contrast, contents of vaccenic, 11-eicosenoic (C20:1 *n*-9), and erucic (C22:1 *n*-9) acids were 2–3 folds higher in bivalves from the Achchankulam site compared to the Naruvilikulam site ($p < .05$). It is noteworthy that the elevation of oleic acid levels may be strongly correlated with the consumption of zooplankton (Maloy et al. 2009). The higher contents of vaccenic acid in bivalves from the Achchankulam site might result from the consumption of detritus and/or bacteria (Bergé and Barnathan 2005; Ricardo et al. 2021). Furthermore, 11-eicosenoic acid has been used as one of the trophic biomarkers to indicate the plenteous availability of zooplankton (Maloy et al. 2009; Ricardo et al. 2017).

The present study further revealed that bivalves from the Naruvilikulam site had significantly higher PUFA, Σ*n*-6, and ΣEPA+DHA contents as opposed to those from the Achchankulam site. In this regard, bivalves from the former site had significantly greater docosatetraenoic acid, EPA (C20:5 *n*-3), and linolenic acid levels as opposed to those from the latter site, which recorded higher contents of arachidonic acid and DHA (C22:6 *n*-3) ($p < .05$). Similarly, Fernandez-Reiriz et al. (1996) reported DHA (C22:6 *n*-3) and EPA (C20:5 *n*-3) as the most prominent PUFA found in *M. galloprovincialis* collected from two different zones in Spain. The geographical location, however, had no impact on Σ*n*-3 content in bivalve tissues. Ricardo et al. (2021) reported that the prevalence of linoleic and linolenic acids is linked with the ingestion of green microalgae. In addition, the abundance of EPA (C20:5 *n*-3) and DHA (C22:6 *n*-3) in bivalves reveals a diet rich in phytoplankton like diatoms and dinoflagellates (Dalsgaard et al. 2003; Parrish et al. 2000).

Bivalves gathered from the Naruvilikulam site had significantly higher PUFA/SFA and h/H ratios compared to those from Achchankulam, which had greater *n*-3/*n*-6 ratio and AI (Table 2). However, TI was not influenced by the geographical location of bivalves in this work. All lipid indices of bivalves from the Naruvilikulam site were within the recommended levels reported in the previous section compared to their counterparts. However, PUFA/SFA ratio of bivalves from the Achchankulam site (0.38) was below the recommended level (>0.4; Stratev et al. 2017). In addition, AI reported for bivalves from the same geographical location (1.53) was much higher than the recommended level (<1.0), which may increase the risk for cardiovascular maladies and thereby adversely affect human health (Bobe et al. 2004; Joy and Chakraborty 2017). Comparable *n*-3/*n*-6 ratios were observed in common cockles collected from eight different Portuguese ecosystems (2.68–3.75; Ricardo et al. 2017), while much higher values were recorded in mussels obtained from two geographical locations in Spain (3.4–15.6; Orban et al. 2002). In addition, blue mussel (*M. edulis*) from rocky shores and long line cultures in San

Jorge Gulf, Argentina recorded lower AI values (0.61–0.65; Colombo et al. 2016) compared with findings of the present work. Hence, bivalves from the Naruvilikkulam site are nutritionally superior due to higher quality of lipids in their tissues compared to those from the Achchankulam site.

Conclusion

The species and geographical location of bivalves had a significant impact on the fatty acid profiles and lipid indices of their tissues. Based on the findings of the present study and recommended levels reported for lipid indices, *M. opima* as the species and Naruvilikulam as the geographical location can be recommended for consumers interested in low fat food selection due to high nutritional quality of lipids present in their tissues.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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