University of Muhammadiyah Malang, Indonesia
e-ISSN 2622-4836, p-ISSN 2721-1657, Vol. 4 No.1, February 2021. pp. 14–23
Indonesian Journal of Tropical Aquatic
Journal homepage: http://ejournal.umm.ac.id/index.php/ijota

Implication of total replacement of fish oil with vegetable oils on nutritional and lipid profiles of fish

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ARTICLE INFO

Keywords:
Atherogenic
Nutritional quality
Polyene
Thrombogenic

ABSTRACT

In this study, the effects of using vegetable oils solely in fin fish feed on nutritional status as well as lipid damage was evaluated. Polyene index (PI), atherogenic index (AI) as well as hypocholesterolemic and hypercholesterolemic fatty acids were assessed. Also, n-3/n-6 and n-6/n-3 ratios were assessed. In all, 32 articles were used for this study after carefully assessing them. Eighteen (18) articles had studied Freshwater species (FWF) whiles fourteen (14) had studied Marine species (MF).
TI, n-3/n-6 and n-6/n-3 were significantly higher in fish fed saturated fatty acids (SFA), n-3 and n-6 dominant vegetables. We document that using vegetable oils without supplementing fish diets with fish oil does not compromise the nutritional status as well as lipid damage. This work provides important information about the effect of using 100 % vegetable oils in fish with respect to nutritional composition of the final product.

How to cite: Ayisi, C. L. (2021). Implication of total replacement of fish oil with vegetable oils on Nutritional and lipid profiles of fish. *IJOTA.* 4(1): 14–23.
DOI: https://doi.org/10.22219/ijota.v4i1.12378

1. Introduction

Fish is a nutritionally significant component in the diet because it is one of the few sources and main contributors to long-chain n-3 fatty acid intake (Hooper et al., 2009). This is because fish is not only a source of high nutritional quality protein, but also a significant reserve of polyunsaturated fatty acids, especially (EPA-C20:5n-3) and docosahexaenoic (DHA-C22: 6n-3) acids.

These two fatty acids are known to present health benefits to humans because they reduce the risk factors associated with cardiovascular diseases, hypertension, general inflammation, asthma, arthritis, psoriasis, and various types of cancer. The n-3 and n-6 fatty acids are primarily supplied in the diets because they cannot be synthesized by human body (Hosseini & Kenari, 2010; Blasbalg et al., 2011).

Due to the higher demand for fish and other sea foods, there is excessive pressure on aquaculture to produce enough for human consumption. On major problem that hinders aquaculture production is the cost of feed which accounts for approximately 50-60% of production cost. Lipids are important in the production of fish feed since it serves as the major source of essential fatty acids and provide energy to cultured fish. Traditionally, fish oil has been used as the major source of lipids since it is a major source of essential polyunsaturated fatty acids (PUFA), especially high unsaturated fatty acids (HUFA) (Ayisi & Zhao, 2017).

Despite the usefulness of FO in fish feeds, there are calls for suitable alternatives as a result of high cost, increase in demand and reduction in supply. Vegetable oils are suitable alternatives due to their low cost and higher production. Over the few decades, researchers have carried out studies to assess the possibilities of replacing FO with vegetable oils (Calder & Yagoob 2009; Morais et al., 2012; Aminikhoei et al. 2013; Fukada et al., 2017).

Vegetable oils are characterized with higher levels of C18 monounsaturated FA (MUFA) and C18 PUFA such as linoleic acid (LA, 18:2n6) and a-linolenic acid (ALA, 18:3n3), but deficient in eicosapentaenoic acid (EPA, 20:5n3), docosahexaenoic acid (DHA, 22:6n3) and arachidonic acid (ARA). Replacing FO with VO in fish diets could alter the dietary fatty acid composition, thereby resulting in a compromise of some biological functions.

Studies on the use of dietary vegetable oils in fish culture have predominantly focused on their effects on growth, feed utilization, health and recently how the genetic makeup of the fish is affected. To our best of knowledge, the effects dietary vegetable oils have on the final product (fish) has not been studied extensively. The purpose of this study is to evaluate how dietary vegetable oils influence nutritional status of fish using thrombogenic index, polyene index, atherogenic index and hypocholesterolemic/hypercholesterolemic ratios.

2. Material and Methods

2.1 Article collection (Selection)

To evaluate the effects of total replacement of fish oil with vegetable oils on the nutritional value of various fish species, English databases such as Springer, Wiley, and Elsevier etc, were browsed from 1 January 2007 to 10 August 2017. For the purpose of this study, the present search was done using aquaculture nutrition subject headings, terms and a combination of several keywords including: "Total Replacement"; "Vegetable oil"; "Palm oil"; "Coconut oil"; "Tilapia"; "Fish oil"; "Canola oil"; "Cat fish"; "Sea bream"; and "Rainbow trout". All articles downloaded from the above data base were manually screened. Initially all relevant papers were selected based on title and reviewed carefully to assess the eligibility for inclusion. After some articles had being excluded, the remaining articles were carefully analyzed if they really qualified to be part of this study. Finally, the required data were calculated using a data extraction sheet. The flowchart showing design process of this study is shown in Fig 1. Also, dynamics of all articles used in this study are listed in Table 1.

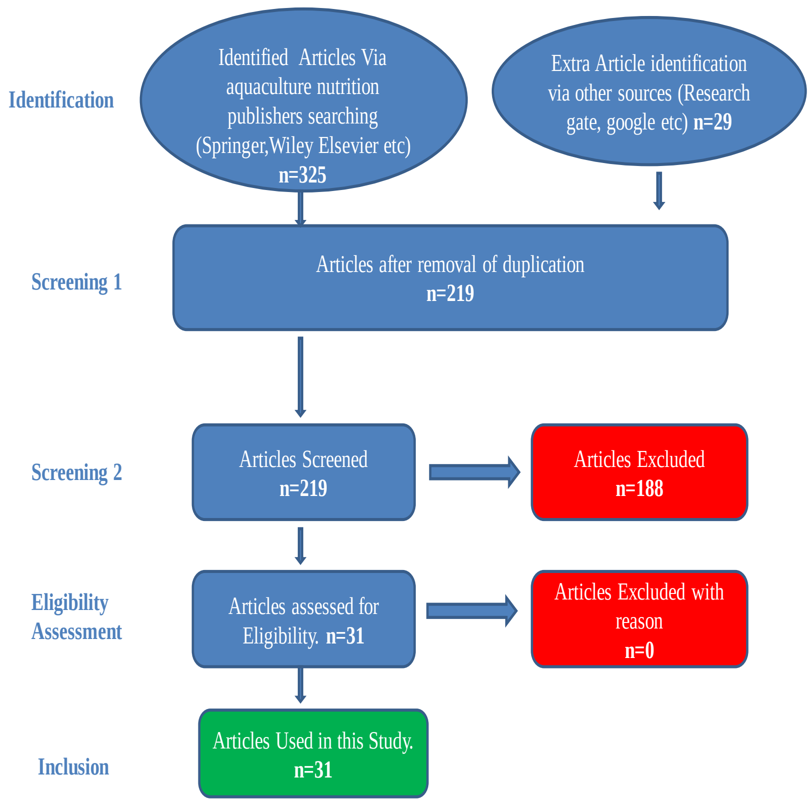


Figure 1. Flowchart showing selection process of articles used for study.

Table 1. List of articles used in study

Species	Marine (MF) or Fresh water (FWF)	Vegetable Oil	Vegetable Oil Class	References
Puntius gonionotus	FWF	Linseed oil	N-3 PUFA	18
Sparidentex hasta	MF	Canola oil	MUFA	19
		Sunflower oil	N-6 PUFA	
Maccullochella peelii	FWF	Linseed oil	N-3 PUFA	20
		Palm oil	SFA	
		Sunflower oil	N-6 PUFA	
Oreochromis niloticus	FWF	Linseed oil	N-3 PUFA	21
Acipenser baeri Brandt x A. schrenckii Brandt	FWF	Linseed oil	N-3 PUFA	22
		Soybean oil	N-6 PUFA	
Oncorhnchus mykiss	FWF	Unrefined peanut oil	N-3 PUFA	23
Ranchycentron canadum	MF	Soybean oil	N-6 PUFA	24
Pangasius hypophthalmus (Sauvage 1878)	FWF	Soybean oil	N-6 PUFA	25
		Palm oil	SFA	
		Linseed oil	N-3 PUFA	
Pangasius nastus (Bleeker 1863)	FWF	Soybean oil	N-6 PUFA	26
		Palm oil	SFA	
		Linseed oil	N-3 PUFA	
Gadus morhua	MF	Camelina oil	N-3 PUFA	5
Oreochromis sp	FWF	Perila oil	N-3 PUFA	27
		Canola oil	MUFA	
		Sunflower oil	N-6 PUFA	

Species	Marine (MF) or Fresh water (FWF)	Vegetable Oil	Vegetable Oil Class	References
Seriola lalandi	MF	Canola	MUFA	28
Mylopharyngodon piceus	FWF	Rapeseed oil	MUFA	29
		Sunflower oil	N-6 PUFA	30
Tor tambroides	FWF	Linseed oil	N-3 PUFA	
		Palm oil	SFA	
Nibea coibor	MF	Palm oil	SFA	31
Huso huso	FWF	Soybean oil	N-6 PUFA	4
		Canola oil	MUFA	
Sebastes schlegeli	MF	Soybean oil	N-6 PUFA	6
		Linseed oil	N-3 PUFA	
	FWF	Sesame oil	N-6 PUFA	32
Oncorhynchus mykiss		Sunflower oil	N-6 PUFA	
		Linseed oil	N-3 PUFA	
Yellowtail Seriolaa quinqueradiata (Temmich & Schlegel, 1845)	MF	Canola oil	MUFA	7
Argyrosomus regius	MF	Soybean oil	N-6 PUFA	33
Oreochromis niloticus	FWF	Palm oil	SFA	34
		Linseed oil	N-3 PUFA	
Oreochromis niloticus	FWF	Coconut oil	SFA	35
Oreochromis niloticus x O. aureus	FWF	Soybean oil	N-6 PUFA	36
Oreochromis niloticus	FWF	Sunflower oil	N-6 PUFA	37
		Cottonseed oil	N-6 PUFA	
Psetta maxima	MF	Safflower	MUFA	38
Cromileptes altivelis (V.)	MF	Palm oil	SFA	39
		Soybean oil	N-6 PUFA	
		Canola oil	MUFA	
Pseudosciaena crocea R.	MF	Soybean oil	N-6 PUFA	40
Oreochromis niloticus	FWF	Palm oil	SFA	41
Diplodus puntazzo	MF	Soybean oil	N-6 PUFA	42
		Linseed oil	N-3 PUFA	
Takifugu rubripes	MF	Soybean oil	N-6 PUFA	43
		Linseed oil	N-3 PUFA	
	MF	Soybean oil	N-6 PUFA	44
Larmichthys crocea		Linseed oil	N-3 PUFA	
		Rapeseed oil	MUFA	
		Peanut oil	N-3 PUFA	
Pelteobagrus vachelli	FWF	Soybean oil	N-6 PUFA	45

2.2 Nutritional quality of lipids, PUFAs damage and health lipid indices

The Polyene index (PI) was used as a measure of PUFA damage (Lubis & Buckle, 1990) while the Thrombogenic index (TI) and Atherogenic Index (IA) were used to assess the nutritional quality of the fish (Ulbricht & Southgate, 1991). Also the hypocholesterolemic and hypercholesterolemic fatty acid ratio (HH) was calculated according to (Santos-Silva, et al., 2002). These were calculated as follows:

1. PI: ((C20:5 + C22:6)/C16:0)
2. Atherogenic Index (IA) = (4 *C14: 0 + C16: 0)/ (Sum MUFAs + Sum n-3PUFAs+ sum n-6 PUFAs)
3. Thrombogenic Index (TI) = [(C14:0 + C16:0 + C18:0)/(0.5 * Sum MUFAs + 0.5 Sum n6 PUFAs + 3 *Sum n-3 PUFAs + (n-3/n-6))]

4. HH =C18 : 1n9 +C 18 : 2n6 +C20 : 4n6 + C18 : 3n3 + C20 : 5n3 + C22 : 5n3 + C22 : 6n3/(C14 : 0 + C16 : 0)

Where MUFA are monounsaturated acids, PUFA are polyunsaturated fatty acids

In order to have a clear understanding of the effects total replacement of fish oil has on nutritional composition of fish. The articles used for this study were grouped into different categories. The species under consideration (fresh water or marine water), effects on the tissue under consideration and the class of vegetable oil based on fatty acid composition. With respect to the tissue under consideration, the muscle, fillet and whole body were considered as one tissue. Vegetable oils were grouped into four categories based on fatty acid composition as follows; the first category are those abundant in saturated fatty acids (SFA) and they include palm and coconut oil. The second category are known to be abundant in monounsaturated fatty acids (MUFA) of which vegetable oils such rapeseed/canola and olive oil are included. The third category are abundant in polyunsaturated fatty acids (PUFA) of the omega-6 series (n-6 PUFA) and include soybean and sunflower oil whiles the fourth category are those rich in PUFA of the omega-3 series (n-3 PUFA) and include linseed/flaxseed and camelina oil (Turchini et al. 2010).

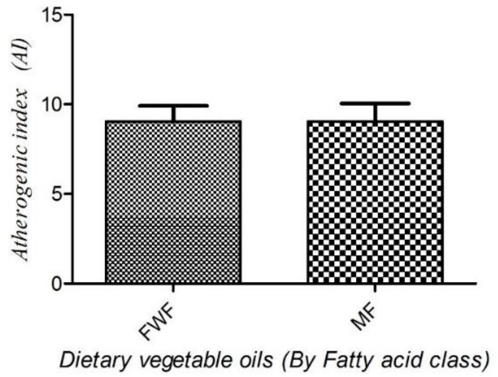
Statistical analysis

All results are presented as mean ± standard error of the mean (SEM). Data were analyzed by One-Way Analysis of Variances (ANOVA) to test the effects of different classes of vegetable oils on the evaluated parameters. Where significant differences were found ($P < 0.05$), a Tukey's test was used to compare all parts of a column and to rank the groups. Statistical analyses were made using GraphPad Prism 5.

3. Results

3.1. Fresh water versus marine water species

The results of how 100% vegetable oils affect freshwater fish (FWF) and marine water fish (MF) species with respect to the parameters evaluated in this study are shown in fig 2 (A-F). AI values for both FWF and MF were 9.04±0.85 and 9.05±0.99 respectively whiles PI for FWF and MF were 1.45±0.23 and 4.45±0.58 respectively. H:H for FWF and MF were 51.03±2.60 and 61.76±2.03 respectively. FWF and MF recorded mean TI values of 0.54±0.05 and 0.31±0.04 respectively. Also, n-3/n-6 values of 1.76±0.48 and 1.16±0.19 were recorded for FWF and MF respectively whiles n-6/n-3 values of 2.11±0.24 and 1.36±0.18 were recorded for FWF and MF respectively.



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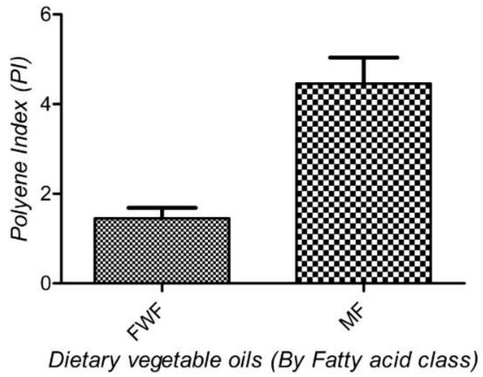

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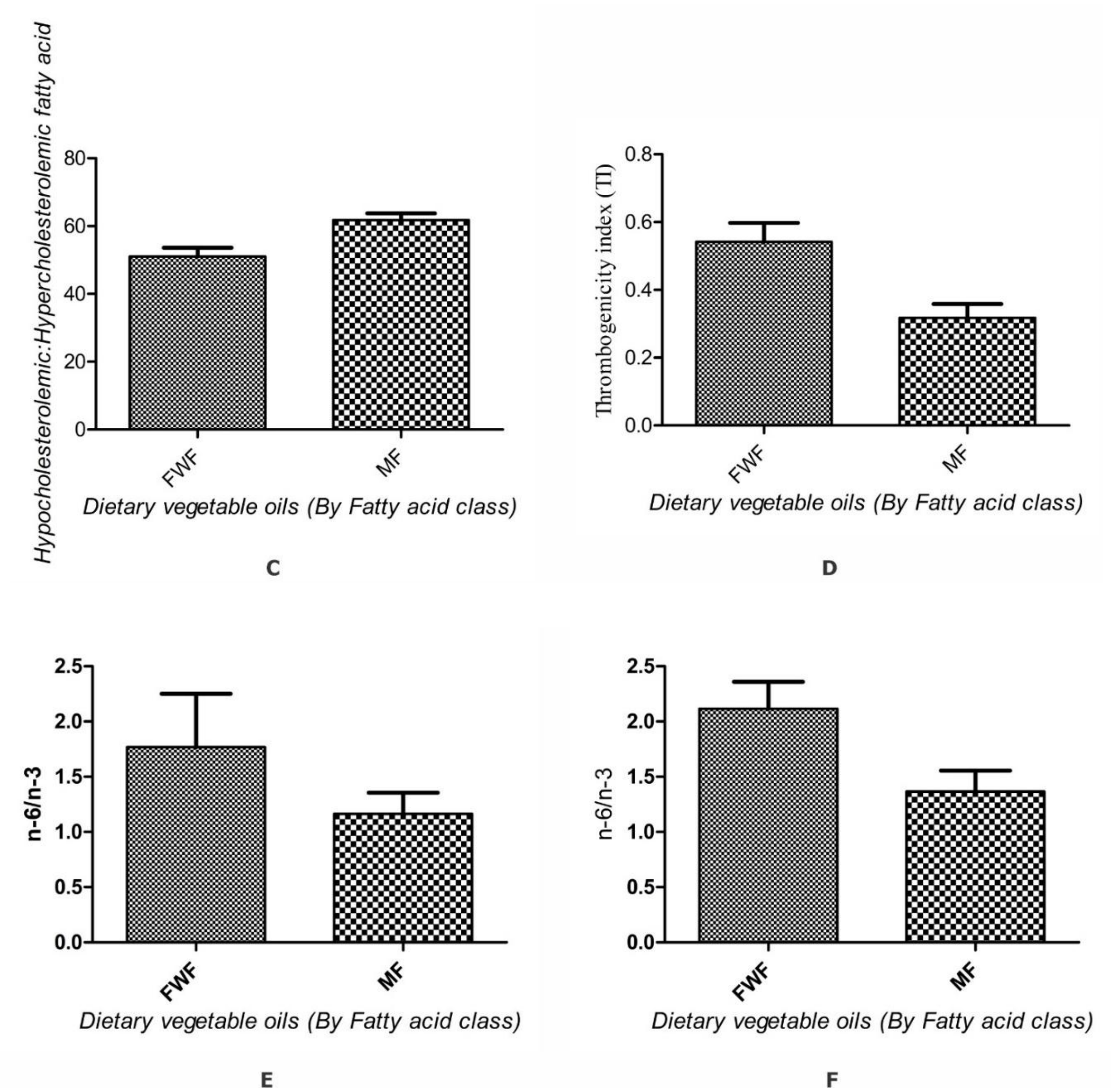

Figure 2. Mean values of AI (A), PI (B), H:H (C), TI (D), n-3/n-6 (E) AND n-6/n-3 (F) of freshwater (FWF) and marine water (MF) fed diets with 100% Vegetable oils.

3.2. Classes of fatty acids

The influence of using different vegetable oils in fish feed on parameters evaluated in this study are shown in fig 3 (A-F). Using vegetabl

e oils with different classes of fatty acids (n-3 PUFA, n-6 PUFA, MUFA and SFA dominant) does not significantly influence atherogenic index (AI), polyene index (PI) as well as hypocholesterolemic and hypercholesterolemic fatty acids (H:H). Thrombogenic index (TI), n-3/n-6 and n-6/n-3 were however influenced significantly ($p<0.05$). TI of fish fed vegetables dominant in SFA were significantly higher ($p<0.05$) than those fed n-3, n-6 and MUFA dominant vegetable oils (Fig 3D). Feeding fish with vegetable oils dominant in n-6 fatty acids had significantly higher ($p<0.05$) n-6/n-3 mean values compared to those fed n-3, MUFA and SFA dominant vegetable oils (Fig 3F). There was a significant higher n-3/n-6 values in fish fed n-3 dominant vegetable oils compared to those fed n-6 dominant vegetable oils. Fish fed n-3 dominant vegetable oils had non-significantly higher levels of PI ($p>0.05$). Mean values for AI, PI, H:H, TI, n-3/n-6 and n-6/n-3 recorded in this study ranged between 5.55-10.05, 1.90-3.28, 49.51-61.60, 0.24-0.80, 0.75-2.70 and 0.71-2.76 respectively.

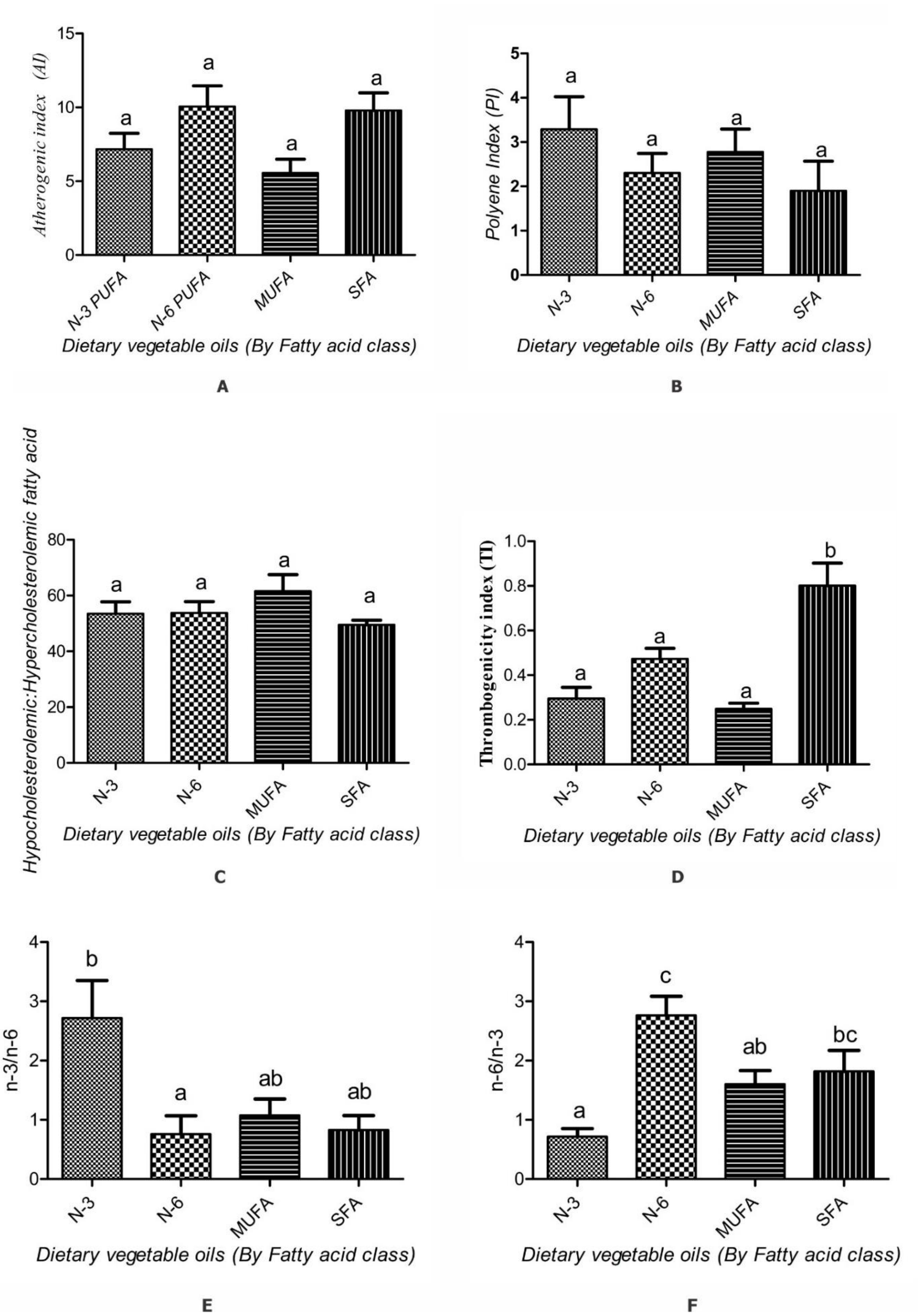

Figure 3. Mean values of AI (A), PI (B), H:H (C), TI (D), n-3/n-6 (E) AND n-6/n-3 (F) of fish fed diets with 100% Vegetable oils with different classes of vegetable oils.

4. Discussion

In this study, we evaluated the effects of total replacement of fish oil with different vegetable oils have on the nutritional status of fish using six different parameters. According to (Department of Health and Social Security, 1984), n-6/n-3 ratio below the threshold of 4.0 in diets is desirable for prevention of cardiovascular related issues. Our results indicate n-6/n-3 ratio of fish fed different classes of vegetable oils ranged between 0.71-2.76. Also, n-6/n-3 ratio for marine species and freshwater species were 1.36 and 2.11 respectively irrespective of the fatty acid class. The results suggests that using vegetable oil totally in place of fish oil in diets of fish could be beneficial for human consumption. Fresh water species recorded almost twice the n-6/n-3 ratio value of marine species. This could be attributed to the fact that marine fish are a source of n-3 long-chain polyunsaturated fatty acids and contain a higher proportion of this nutrient than freshwater fish (Huynh & Kitts, 2009; Ozogul & Ozogul, 2007).

Similarly, n-3/n-6 ratio is a good index for assessing nutritional value of fish since higher ratios are crucial for preventing coronary heart disease and reduces the risk of cancer (Kinsella et al. 1990). This index has been suggested as a useful indicator to compare the relative nutritional values of fish and food. A ratio ranging between 1:1 to 1:5 in diets has been suggested to be essential for human health (Apraku et al., 2017). The n-3/n-6 ratio for FWF and MF in this study were 1:1.76 and 1:1.16 respectively whiles that of different classes of fatty acids were 1:2.7, 1:1.07, 1:0.82 and 1:0.75 for n-3, MUFA, SFA and n-6 dominant vegetable oils respectively. This imply feeding fish with dietary vegetables dominant in n-3 and MUFA fatty acids could provide final product that are best for human consumption and could prevent coronary heart diseases as well as reducing the risk of certain cancers.

AI and TI are usually used to define the nutritional status of food items including fish. According to (Turan et al., 2007), the atherogenicity (IA) and thrombogenicity (IT) indexes indicate potential for stimulating platelet aggregation. Thus, the smaller the IA and IT values, the greater the protective potential for coronary artery. In this study, TI ranged between 0.24-0.80. Apart from SFA dominant vegetable oils that recorded a TI of 0.80, all other vegetable oil classes/sources recorded values lower than the expected values of 0.5. Also, TI for freshwater and marine fish were 0.54 and 0.31 respectively irrespective of the vegetable class. These values suggests feeding fish with vegetable oils could be beneficial in providing protective potentials for coronary artery.

In conclusion, the study documents that using dietary vegetable oils in aquaculture has the prospects to maintain good nutrition and guard consumers from certain diseases per the parameters evaluated. Also, different classes of fatty acids obtained from different vegetable oils affects the nutritional status of fish with respect to n-3/n-6, n-6/n-3 and thrombogenic index. From the results, there seems to be no clear distinction with respect to how different vegetable oils affect the evaluated parameters, being it freshwater or marine species.

Conflict of interest

The authors declare no conflict of interest. This study does not intend to promote one vegetable oil against another.

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