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Research Article

Comparison of the Nutritional Composition of Three Undervalued Fish Species in Sri Lanka

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ABSTRACT

Fish consumption is generally considered as healthy due to their nutritional benefits that they ensure food security in many low and middle-income countries. Especially the Omega-3 fatty acids and essential amino acids present in the fish had beneficial effects on the Coronary Heart Disease (CHD) and reduce the Protein Energy Malnutrition (PEM) in these countries. Being an island and expanding aquatic resources, Sri Lanka has plenty of fish resources, but, the consumption of small fish among the population has decreased in the country over the past 20 years. So, it is essential to be aware of the nutritional content of particular fish species that are assumed to be undervalued. This study, it was aimed to compare the nutritional composition of three local fish species namely, *Amblygaster sirm, Sardinella brachysoma* and *Oreochromis niloticus*. Proximate composition, pH and calorific values of the fish meat were determined by standard methods and other relevant protocols. The fatty acid profiles of oils of the fish were examined using the GC-MS method. Results showed that there were significant ($p<0.05$) differences among the three fish species with respect to the proximate parameters and fatty acid composition. When compared to the other two species, *S. brachysoma* exhibited the highest quantity of crude protein and fat, with 19.23% and 4.85% respectively. Among three fish species, the total mono-unsaturated fatty acid (MUFA) and poly-unsaturated fatty acid (PUFA) contents ranged from 31 to 38%; particularly, quantities of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were found to vary from 2.69 to 3.7% and 7.5% to 9.2%, respectively. Considering the Omega-6:Omega3 ratio, *A.sirm* (0.3), *S. Brachysoma* (0.69) and *O. niloticus* (6.5) were reported balanced values. In conclusion, these three fish species can be potential raw materials to produce high-value fish products.

Introduction

Sri Lanka is an Island nation surrounded by sea waters. In its long-stretched sea belt, Sri Lanka has got a host of sea harbors and jetties to support the growth of the fishing industry. Since fish is a nutrient-rich resource, the seafood sector can play a vital role in food and nutritional security in Sri Lanka. It is primarily made up of water, protein, and lipids in the range of 70 to 80%, 20 to 30%, and 2 to 12%, respectively (Maktoof et al., 2020). Fish protein is highly regarded when compared to those from other sources such as meat, egg, and milk (Comerford and Pasin, 2016). Fish is also a better source of polyunsaturated fatty acid (PUFA). The major PUFA in fish oil are omega-3 docosahexaenoic acid (DHA) and eicosapenaenoic acid (EPA) (Tocher et al., 2019).

Sri Lankan coast waters have got a wide variety of fish species like marlin, sailfish, wahoo, Spanish mackerel, giant trevally, bonito, queen fish, barracuda, grouper, cobia and tuna. According to recent statistics, the most commonly caught commercial groups in 2019 include sheer (narrow-barred Spanish mackerel), trevally, skipjack tuna, yellowfin tuna, tuna-like fishes, billfishes, skates, and rockfish (Anon, 2020). In the world's seafood market, Sri Lanka is a major provider of tuna. The two main species of tuna that can be found in Sri Lankan seas are yellowfin and bigeye. Although Sri Lanka has got a vast sea-boarder, the total output of the Sri Lankan seafood industry in 2019 was roughly about 505,830 × 10^4MT. Import of fish from other countries has become inevitable due to supply from the local industry is hardly sufficient to meet the growing demand. It is high time to emphasize the need to increase production is no more questionable. Additionally, an effort is also needed to popularize the use of under-utilized fish species in Sri Lanka.

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Amblygaster sirm (Fr – Spotted sardinella) *Sardinella brachysoma* (Fr – Deep body sardine) and *Oreochromis niloticus* (Nile Tilapia-a freshwater species) are three of the under-valued fish species, which need our immediate attention. Despite their high availability, they are undervalued due to various reasons. The spotted sardinella and the deep-body sardine are available in marine coastal areas during all seasons. These aren't purchased by busy consumers due to their low meat yield and small size. Nile tilapia is a freshwater fish species found in freshwater bodies and landlocked areas; its color and odor make it unpopular among consumers.

Spotted sardinella and deep body sardine are small, marine pelagic fish species that have a wide geographic range. They are captured for commercial and artisanal purposes for human consumption. *A. sirm* is identified with its specific 10 to 20 golden spots along the flank. For instance, it is the most significant source of DHA having 28.9% DHA (g/100g), 47% of the portion of n-3 fatty acid of total PUFA and 21 ± 0.6 (g/100g) of protein content (Reksten et al., 2020). Sardines are a good source of marine protein and fat comprising many nutrients for prolonging human health (Jacobsen, 2015). Nile tilapia is a low-cost freshwater fish with significant nutritional value balancing marine fish nutrition having 13-14% crude protein and 0.5% of crude fat during the off seasons (Chepkirui et al., 2021; Olopade et al., 2016). Despite these reports, there was hardly any effort in the past to determine the proximate, fatty acid composition and mineral content of these three species in Sri Lanka. This study attempted to compare the nutritional composition of the Spotted sardinella, Deep body sardine and Nile tilapia captured from the Eastern sea border of Sri Lanka.

Materials and Methods

Location of the study

The research study was conducted at the Department of Biosystems Technology, Faculty of Technology, South Eastern University of Sri Lanka, Sri Lanka and the National Institute of Fundamental Studies, Hanthana, Kandy, Sri Lanka from January 2021 to December 2021.

Materials

Three under-valued fish species namely, *A. sirm*, *S.brachysoma* and *O. niloticus* fish meat were used in this study. Around 5kg portion of fresh fish having uniform length and width (biometric data) of each species were purchased immediately after being landed at the shore. Except where noted, all chemical compounds employed in this study were of the analytical grade.

Sample preparation

The fish samples were stacked into a polystyrene box with layer of flaked ice cubes on top and bottom of the fish layer and brought quickly to the laboratory of the Department of Biosystems Technology. The fish then were thoroughly washed off with tap water and cleansed well. Then the biometric data of individual fish such as length, width and other morphological characters were measured. The fish species were identified with the morphological characters as mentioned in Munro (2000). The fish samples were de-headed, eviscerated, de-finned, descaled, deskinned and filleted. The fillets were once again rinsed with clean water to remove the blood and then kept for a while to facilitate the draining of excess water. The fillets were chopped into small particles and homogenized with a Blender (Model-GRT-1500B, China). The homogenized fish mass was divided in to three equal portion and named as A, B and C and then finally wrapped with aluminum foil and stored under frozen condition (-20°C) in a chest freezer (Model U9400-001, Germany) until further usage. The analyses were done drawing fish muscle from three individual mass lot (A, B and C) with the replication.

The pH and calorific value determination

The pH of the samples was determined by blending 20g homogenized fish samples with around 80 ml of distilled water as per described in Papadima and Bloukas (1999). The total energy value was determined using a Bomb Calorimeter (Digital Model- IKA®C 6000 global, Germany) by complete ignition of 1g of moisture-free sample (Basolo et al., 2020).

Proximate compositional analysis

The percent content of moisture, crude protein and ash were analyzed as prescribed in AOAC 2005, No. 934.01, AOAC 2005, No. 976.05 and AOAC 2005, No. 938.08 standard methods respectively. Determination of moisture was performed by oven-dry method with an Electric Oven (Model-WOF-155, Germany), the crude protein was determined with an Automated Kjeldahl analyzer (Model-C 6000 GS S000, Germany) and Muffle furnace (Model-mf2019040202B, China) was used for ash determination. The total percent of fat content was measured by Bligh and Dyer method as per described in Bligh and Dyer (1959) procedure. The total carbohydrates with fiber content in the samples were calculated as per mentioned in the equation Kanzler et al. (2015), as total carbohydrate = 100 – (% Ash) – (% Total Fat) – (% Moisture) – (% Protein).

Fatty acid profile analysis

The fatty acid profiles of the three fish species were analyzed using an Agilent Gas Chromatograph, (Model-7890B, China). Fatty acid methyl esters (FAME) were prepared by dissolving the extracted oil (50mg) in 0.9 ml hexane and 30%, 0.1ml sodium methoxide (PORIM Test Methods, 1995) and analyzed in the GC-MS fitted with a flame ionization detector (FID). A polar capillary column (100m×25μm×0.2μm, Agilent CP7489, China) was used under the column pressure of 39.512psi. The temperature of the column was maintained initially at 90°C, programmed to increase to 220°C at 15°C/min - 5min, 2°C/min-20min and 15°C/min -1min. The initial temperature of the injector and detector port was maintained at 240°C. The chromatogram readings were used for the determination of specified fatty acids in the fish oil by comparing the retention time with that of standard FAMEs (Supelco 37 Component FAME Mix Sigma, St. Louis, MO, USA). Each sample was chromatographed thrice and the percentage of fatty acid was calculated as the ratio of the partial area to the total area.

Statistical analysis

All experimental measurements were carried out in triplicate from each lot (n=9). Results were displayed as mean and standard deviation (SD). One-way analysis of variance (ANOVA) using Tukey's Test was used for the statistical analysis of data in MINITAB (version 20.3) software at a 0.05 probability level.

Results and Discussion

The pH and Calorific Value

As a dietary group, fish is an exceptional provider of various nutrients (Mendivil, 2021). Determining the nutritional values of fish is vital and useful to enhance consumption rates since different fish species might have varied in nutritional compositions with unique implications on nutrition. As shown in Table 1, the pH values of all the fish species analyzed were found to be in the range of 6 to 6.64; no significant ($p<0.05$) variation in the pH value of fish species was observed. According to some previous studies, the pH value of fish was neutral, within the range of 6.7 to 7.03% (Azam et al., 2004). Increasing the value of the pH of fish is one of the quality-deciding attributes. Generally, a pH of more than 7 signifies the beginning of putrefaction in fish (Chun et al., 2014). Thus, the fish used in this experiment were fresh and not deteriorated. According to data presented in Table 1, the calorific values were found to be decreasing in the order Deep body sardine> Spotted sardinella > Nile tilapia. According to statistical analysis, all three fish species showed significant ($p<0.05$) variations in their calorific values.

Proximate Composition

The analyses of the proximate composition of samples are shown in Table 2. In the case of fish, the variations in the percentage of fat, protein and ash content were dependent on exogenous and endogenous factors. Most often, the diet, frequency of feeding, salinity level and temperature of the water are the factors that influence the composition (Desta et al., 2019). Apart from this, season and other environmental conditions, age, sex, and harvesting period may also affect the nutritional composition (Haider et al., 2016). Moisture is an important parameter in all food products as it is connected to various quality attributes. According to previous studies, the moisture content of many different kinds of fish is generally around 75% (Akpambang, 2015; Pires et al., 2017; Wang et al., 2019). In this study, the moisture content of fish species ranged between 72%-80% and the value was in decreasing order from Nile tilapia, Spotted sardinella and Deep body sardine. Both Spotted sardinella and Deep body sardine showed no significant ($p>0.05$) differences in moisture content, but both were found to be significantly varied ($p<0.05$) from Nile tilapia.

Table 1. The pH and Calorie content of raw fish meat.

Parameters	Spotted sardinella (Mean ± SD)	Deep body sardine (Mean ± SD)	Nile Tilapia (Mean ± SD)
pH (Wet basis)	6.64 ± 0.04	6.14 ± 0.03	6.04 ± 0.45
Calorie content (kJ/g) (Dry basis)	$21.3987^a \pm 0.510$	$24.1947^b \pm 0.343$	$19.7643^c \pm 0.365$

Means in the same raw bearing superscripts are significantly different ($p<0.05$) from each other. SD=Standard deviation.

Table 2. Proximate nutritional composition of raw fish meat on a wet basis.

Parameters analyzed (%)	Spotted sardinella (Mean ± SD)	Deep body sardine (Mean ± SD)	Nile Tilapia (Mean ± SD)
Moisture content	$74.48^a \pm 0.73$	$72.63^b \pm 0.9$	$79.54^{ab} \pm 1.49$
Fat content	$2.04^a \pm 0.35$	$4.85^b \pm 0.2$	$1.43^c \pm 0.22$
Crude protein content	$17.20^a \pm 0.11$	$19.23^b \pm 0.27$	$11.65^c \pm 0.06$
Ash content	$4.49^a \pm 0.21$	$3.02^{ab} \pm 0.04$	$4.32^b \pm 0.45$
Carbohydrate content	$1.77^a \pm 0.65$	$0.36^a \pm 0.31$	$3.04^a \pm 2.21$

Means in the same raw bearing superscripts are significantly different ($p<0.05$) from each other. SD=Standard deviation.

Fish is a main source of essential amino acids that comes from proteins. According to Table 2, the maximum and minimum protein values were recorded for deep-body sardine and Nile tilapia, respectively. Significant ($p<0.05$) differences were observed in the protein contents of Spotted sardinella, deep-body sardine and Nile tilapia. The protein content of small marine fish was higher than that of freshwater fish species. These variations were found in the protein content of this study when compared to the whole fish protein content reported in previous studies. Because protein content varies with the types of fish used as well as the body portion of the fish used in sampling (Ramakrishnan et al., 2013). According to the report of some previous studies, the protein content of raw sardines was 18.4% while that of raw spotted sardines was 21% (Delgado et al., 2017; Reksten et al., 2020). The majority of raw marine finfish have 18-22% proteins and with seasonal fluctuations can decline by 2 to 3% (Venugopal and Shahidi, 1996). The feeding level of the diet can also influence the protein content of Nile tilapia and it can go up to 20 to 30% in some artificial cultures (El-Saidy and Gaber, 2005).

Fish oil beneficially improves the brain, heart and nervous system's functions (Jamshidi et al., 2020). Typically, sardines and sardinella species fall under the oily fish category where they store the lipid in the flesh while Nile tilapia is considered a lean fish (Calder, 2013; Emire and Gebremariam, 2010). As per given in Table 2, the fat content of oily fishes such as spotted sardinella and deep body sardine were higher (2.04% and 4.85% respectively) when compared to that of Nile tilapia (1.43%). Out of the three species analyzed, sardines showed the highest fat content. The fat content of fish muscle in this study was inconsistent with previous findings reported such as the fat content of *A. sirm* meat was 0.6 to 0.9% while that of *S. brachysoma* was 2.3 to 7.01% (Suseno et al., 2014). All 3 fish species showed significant ($p<0.05$) differences in terms of total lipid content in this study. The results of previous studies revealed that there was a negative relationship between moisture content and total lipid content (Zhang et al., 2014; Palmeri et al., 2007). In this present study too, the lipid and moisture contents of these three fish species exhibited strong negative correlations. There was a strong positive correlation between the value of fat and the calorific value of the fish samples analyzed (Tables: 1 & 2). According to the data from Table 2, the fat (+1206.473 J/g) molecules have contributed more to gain energy than protein (+523.809 J/g) molecules do.

Determination of ash content is also an important aspect to predict the mineral content of the product. As reported in Table 2, the ash contents of Spotted sardine and Nile tilapia showed significant ($p<0.05$) differences against that of deep body sardine. According to previous studies, the ash content of fish widely ranged between 0.8 to 2% for marine and freshwater fish species (Chandrashekar and Deosthale, 1993). Nonetheless, the ash content of fish in this study was quite high. It could be due to the fish samples utilized in this study for the ash determinations had many small fine fins, which could not be separated from the fish meat. Hence, the increased ash content could be partly attributable to the small fins' of higher mineral content (Calcium and Phosphorus) (Atkins et al., 2015; Yin et al., 2016). It may also vary with sex, age and the environmental condition of the fish (Akpambang, 2015).

The average carbohydrate content of finfish was almost nil except for a few fish species (Nurnadia et al., 2011). Among raw fish samples, crude fiber levels ranged from 0.16% to 0.3% (Adeyeye et al., 2015). As per reported in Table 2, with the exception of Nile tilapia fish, the carbohydrate and fiber levels of both marine fish species were seen within the range reported in previous studies. However, no significant ($p>0.05$) differences was found in the carbohydrate and fiber content of fish muscle. This variation noticed in Nile tilapia fish may be the result of its dietary patterns (Premarathna, 2018).

Fatty acid profiles

The fatty acid compositions of fish species analyzed in this study are given in Table 3. Overall this study showed that there were about twenty-five different fatty acids ranging from C8:0 to C22:6 composed of 99% of total fatty acids (Figure 1 to 3). When compared to the proportions of MUFA and PUFA, the total saturated fatty acids (SFA) content was found to be higher. The most common saturated fatty acids were myristic acid (C14:0), palmitic acid (C16:0), heptadecanoic acid (C17:0), stearic acid (C18:0). Among the saturated fatty acids, palmitic was the most dominant in spotted sardinella (38.01 %), deep body sardine (32.86 %) and Nile tilapia (34.59%). Nowadays, people are becoming more concerned about the implications of increased low-density lipoprotein (LDL) cholesterol levels in the body on cardiovascular disorders as a result of rising dietary SFA consumption rates (Dawczynski et al., 2015). However, palmitic acid plays a unique structural and functional role in prenatal and infancy. Palmitic acid is important for the infant's nutrition whereas human milk gives 10-12% of dietary energy by palmitic acid (16:0) (Mazzocchi et al., 2018). And stearic acid has a positive effect to reduce cardiovascular and cancer risk (Senyilmaz-Tiebe et al., 2018).

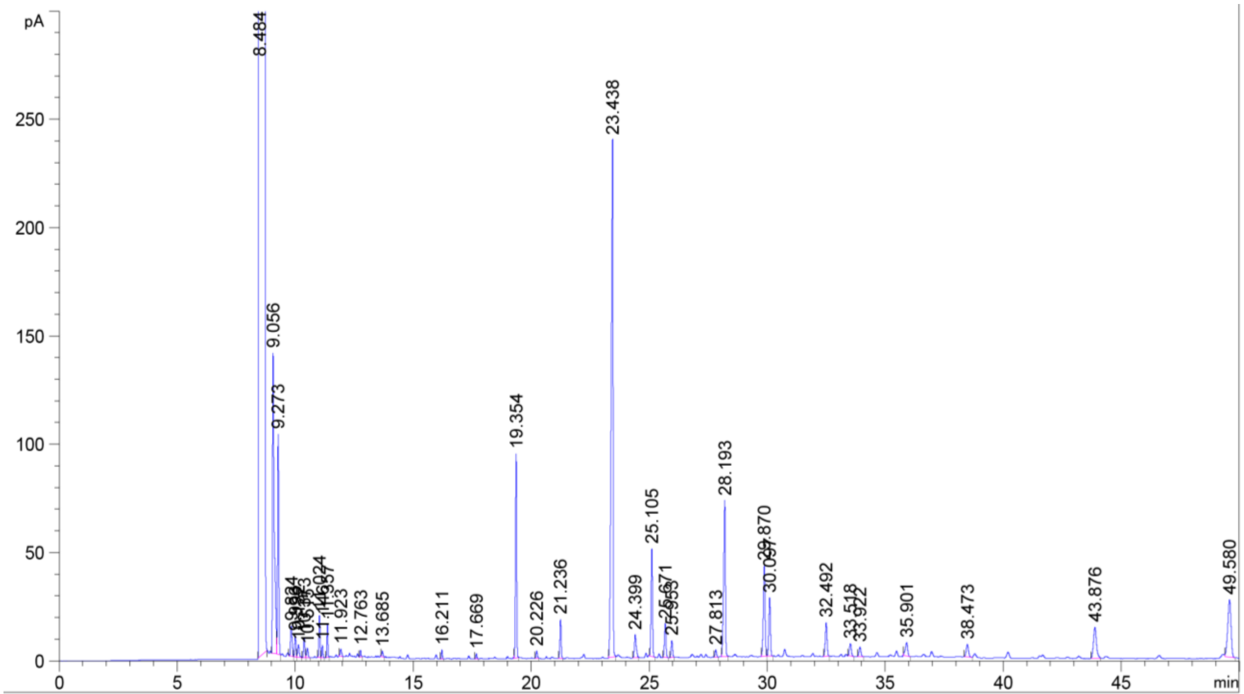

Figure 1. Fatty acid profile chromatogram of spotted sardinella fish oil

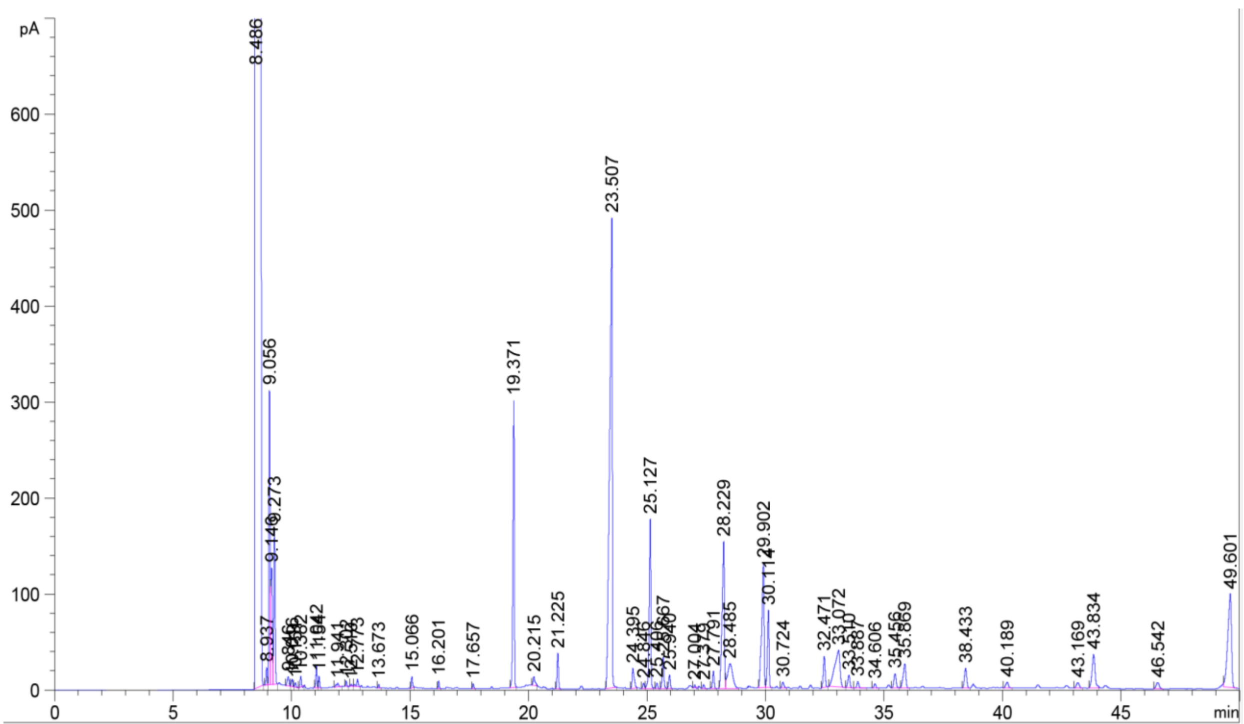

Figure 2. Fatty acid profile chromatogram of deep-body sardine fish oil

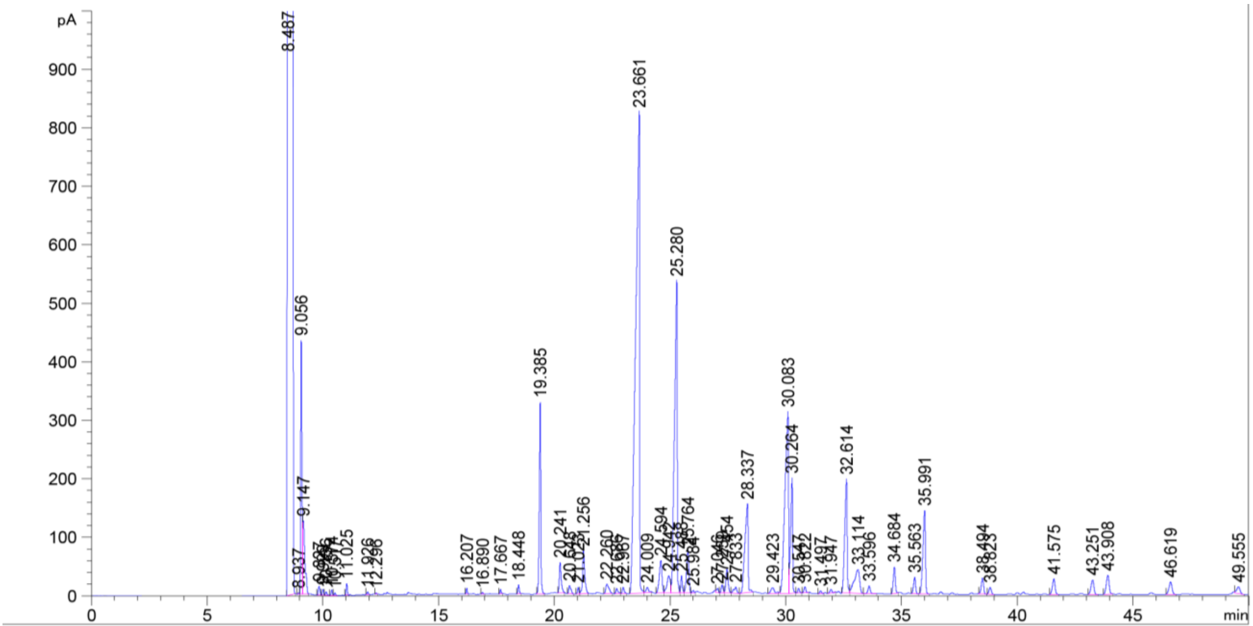

Figure 3. Fatty acid profile chromatogram of Nile Tilapia fish oil

Other than the SFA, these three fish species were found to have some amounts of MUFA and PUFA as well. The MUFA especially from fish oil is a healthier alternative to saturated animal fats and offers various health benefits (Keapai et al., 2016). Among the MUFA, elaidic acid (C18:1 t 9) (6.37 to 11.58 %) and Oleic acid (C18:1 c 9) (3.8 to 4.7 %) were found to exist in high amounts in these fish species. Among the PUFA, it had also been found to possess small proportions of EPA and DHA (Table 3). Sardines had the greatest PUFA content of all three species analyzed in this present study (Table 3). The EPA and DHA are Omega-3 very long-chain polyunsaturated fatty acids that have a significant impact on human health, particularly related to coronary heart disease (CHD) (Zárate et al., 2017). It has been already reported that Omega-3 fatty acids can lower the risk factors of coronary heart disease (CHD) by regulating a variety of biological activities (Ajith and Jayakumar, 2019). The EPA and DHA also have a wide range of biological impacts, including lipoproteins, blood pressure, cardiac function, endothelial function, vascular reactivity, and cardiac electrophysiology, as well as powerful antiplatelet and anti-inflammatory properties (Lopez-Huertas, 2010). Hence, the World Health Organization (WHO) recommends eating 200-500 mg of EPA and DHA-rich fish per week (Saini et al., 2021).

The ratio of ω-6 to ω-3 fatty acids as a biomarker for many clinical conditions and with lower ratio are preferable for better health conditions where higher ratios are negatively associated with cardiovascular disease, cancer, immunological issues, diabetics, asthma, arthritis and several cognitive related issues (Muriuki et al., 2011; Simopoulos, 2002). According to the total omega 6 and total omega 3 fatty acid content of fish species in this study (Table 3), spotted sardinella, deep-body sardine and tilapia were reported to have been found 0.3, 0.69 and 6.5 ratios respectively. A 1:1 to 5:1 ratio is optimal and can be lead to 20:1 with few risk measures in the western diet (Lupette and Benning, 2020; Patel et al., 2022). Therefore, both 2 small fish species in this study are healthy addition to the diet with respect to the omega 6: omega 3 ratio.

Table 3. Fatty acid compositions of fish oils from different fish species

Fatty acid	Spotted sardinella	Deep body sardine	Nile Tilapia
C8:0	0.43± 0.01	0.22±0.01	0.07±0.02
C10:0	0.28±0.01	0.1±0.00	0±0
C12:0	0.34±0.00	0.2±0.01	0.1±0.01
C14:0	9.62±0.00	10.54±0.03	5.28±0.01
C15:0	2±0.04	1.3±0.01	1.73±0.03
C16:0	38.01±0.69	32.86±0.04	34.59±0.04
C17:0	6.26±0.05	7.51±0.00	15.55±0.24
C18:0	11.14±0.01	9.03±0.00	5.33±0.06
C20:0	0.94±0.00	0.71±0.00	0.3±0.02
∑SFA	**69.02 ±0.77^{ac}**	**62.44 ±0.05^{ab}**	**62.95 ±0.25^{c}**
C14:1	0.37±0.00	0.43±0.01	1.08±0.19
C16:1	1.67±0.00	1.07±0.01	1.62±0
C17:1	2.03±0.03	1.38±0.01	1.9±0.01
C18:1 t 9	6.37±0.04	7.8±0.00	11.83±0.01
C18:1 c 9	3.8±0.01	3.42±0.01	4.17±0.01
C20:1 c 11	0.69±0.00	0.34±0.02	0±0
C24:1 c 15	0±0	0.52±0.02	0.69±0.03
∑MUFA	**14.93 ±0.08^{ac}**	**14.96 ±0.01^{b}**	**21.29 ±0.01^{bc}**
C18:2 t 9,12	2.44±0.02	1.53±0.02	5.14±0.01
C18:2 c 9,12	0±0	5.18±0.02	2.35±0.03
C18:3 c 6,9,12 gamma	0±0.003	0.21±0.02	0.99±0.00
C18:3 c 6,9,12 alpha	0±0	0.86±0.01	0.6±0.01
C20:2 c 11,14	1.26±0.00	1.33±0.00	3.83±0.01
C20:3 c 11,14,17	1.1±0.03	1.17±0.00	0.68±0.00
C20:4 c 5,8,11,14	0±0	0±0	0.74±0.04
C20:5 c 5,8,11,14,17 EPA	3.7±0.09^{a}	2.69±0.17^{b}	1±0.12^{c}
C22:6 c 4,7,10,13,16,19 DHA	7.53±0.02^{a}	9.24±0.01^{b}	0.42±0.00^{c}
∑PUFA	**16.03±0.08^{a}**	**22.21±0.19^{ab}**	**15.75±0.10^{b}**

Values are Mean ± SD of triplicates. Values in each row with different superscripts (a-c) indicate significant differences ($p<0.05$).

Conclusion

In this study, inter-species differences in the nutritional properties of three underutilized and locally available fish were compared. Among the different fish species, deep-body sardine showed significantly ($p<0.05$) higher content of calorific value, fat content, and protein content than Spotted sardinella and Nile tilapia. Among those, the total carbohydrate contents were very low; Nile Tilapia recorded a higher value. Fatty acid analysis showed that the total MUFA and PUFA contents ranged from 31 to 38%; both marine fish species were found as good sources of Omega-3 fatty acids where the existence of EPA and DHA is a salient feature. Being considered together with proximate nutritional parameters and Omega-3 fatty acids, deep-body sardines exhibited the best nutritional content out of the three fish species. Hence, it could be taken as a good source for the preparation of value-added fishery products.

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