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Comparative Studies on the Nutrition of Two Species of Sardine, *Sardinella longiceps* and *Sardinella fimbriata* of South East Coast of India

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Abstract

S. fimbriata has greater moisture content, protein, carbohydrate, and fibers, whereas *S. longiceps* have more lipid and ash content. Sardinella species has f 19 amino acids. Eight essential minerals are present in greater amounts in *S. Longiceps. S. longiceps* has six vitamins, but *S. fimbriata* has only five. The findings of this study extend our knowledge of the nutritional value of commonly consumed sardine fishes. Regular consumption of sardines could considerably reduce nutritional deficiency.

Keywords: *Sardinella Longiceps*; *Sardinella Fimbriata*; Amino Acids; Fatty Acids; Vitamins; Minerals

Introduction

Fish has been accepted as a staple food for man, providing essential nutrients [1]. The high nutritional value of fish meat is its proteins, long-chain polyunsaturated fatty acids, minerals, and vitamins [2]. Fish provides many health benefits not found in any other food. Regular fish intake improves retinal and brain development and reduces the risk of chronic afflictions like cardiac diseases, autoimmune disorders, multiple sclerosis, psoriasis, diabetes, and even cancer [3].

According to Love [4] the principal composition of fish includes protein (16-21%), fat (0.2-25%), minerals (1.2-1.5%), carbohydrates (0-0.5%), and moisture (66-81%). Still, the composition differs greatly from species to species and from individual to individual depending on feeding habit, sex, environment, and season [5]. The variation of lipid content is wider than that of protein [6]. Fishes face continuous changes in their environment, including their food, throughout the year [5]. Furthermore, proteins and lipids are mobilized from muscle and transferred to the gonads in the reproductive period [7].

Sardines belong to the genus Sardinella of the family Clupeidae. Except for *S. longiceps,* all other sardines are called lesser sardines. Sardines contribute about 1/3rd of the total marine fish production in Indian costs globally; lesser sardines comprise 26 species of Sardinella, whereas the Indian coast having ten sardine species. The lesser sardines like *S. fimbriata* and *S. gibbosa* are important in inshore fisheries, contributing 20-35 % of the total clupeoid catches. The oil sardine *S. longiceps*is the most important fishery, and it contributes 20-30 % of India's total marine landings. Clupeids ranks second amongst the commercial food fishes of the world. *S. longiceps* is one of the most important commercial marine fishes in India, popularly consumed in all parts of South India [8]. Sardines form a significant fishery resource among the marine pelagic finfishes of the Indian seas, of which *S. fimbriata* dominate the commercial catches landed in and around Tuticorin. *S. longiceps* form little fishery on the east coast, whereas it is caught in huge quantities in India's west coast. Even though data on the proximate composition is critical for many applications, studies on these lines had been carried out from as early as the 1880s. Today there is greater awareness about healthy food, and fish finds more acceptances because of its unique nutritional qualities. Nutritionists and dieticians have a greater need for a proper understanding of the biochemical constituents of fish. Sardine, abundant and inexpensive, is consumed most in the east and west coast of India. In this context, the current study evaluates and compares the nutritional profiles of *S. longiceps* and *S. fimbriata*.

Meterals and Methods

Collection and Preparation of Samples

The lesser and oil sardine species *S. fimbriata* and *S. longiceps* (Figure 1) were collected from the fishing harbor of Tuticorin For nutritional analysis. About 100 g of flesh tissues were sampled from 15 individuals of each species. The flesh samples were divided into three sub-samples (five for each fish). Each fish tissue subsample was then homogenized, wrapped in polyethylene film, sealed within plastic zipper bags, and frozen (-18°C) until the analyses.

Figure 1: Samples of lesser and oil sardine species *S.*

Nutritional Evaluation

The moisture content was estimated by drying the fresh fish sample in a hot air oven at 100 -105°C for 16 hours [9] until a constant weight was obtained. The percentage of protein present in the sample was estimated by following Lowry's method [10]. Total lipids were analyzed by following the gravimetric method of Folch, et al. [11]. The total carbohydrate contentwas estimated using Dubois, et al. [12]. Ash content was estimated according to the method of AOAC [9] by combusting the samples in a muffle furnace at 550°C until the white color appearance. Fiber content was analyzed by following the technique of Maynard [13]. The non-saponifiable lipids such as cholesterol were analysed spectrometrically according to Zlatkis, et al. [14]. The total phospholipid in the tissue was estimated as described by Wagner, et al. [15]. The experimental samples were dried at 60°C for 24 hours in a hot air oven, and the dried samples were finely ground for the estimation of amino acids in an HPLC system with a fluorescent detector (FLD-6A) with amino acid standard as described by Baker & Han [16]. The fatty acid was analysed by homogenizing the sample with chloroform: methanol mixture (2:1 v/v), and the fat content was extracted. It was esterified with 1% H_2SO_4, and fatty acid methyl esters were prepared, which were subject to using gas chromatography [17]. The fatty acid peaks were detected by flame ionization detection, and individual methyl esters were identified by comparison to known standards. Mineral contents were determined quantitatively by AAS (Agilent) following the method [18]. Vitamin content was analyzed using High-Performance Liquid Chromatography (HPLC) as described in Nollet & Leo [19].

Data Analysis

All analyses were accompanied in triplicates, and the results are expressed as mean values ± standard deviation (SD). An independent t-test was used to find statistical significance between the two species using the SPSS program, version 17.0 for Windows (SPSS inc. Chicago, IL, USA). A significant level was set at a P-value < 0.05.

Results

Proximate Composition

The results of the present study are represented in Table 1. All nutrient components, namely moisture, protein, lipid, carbohydrate, fiber, and ash, differ significantly ($P < 0.05$) between the two species. The difference in lipid content is especially significant. The moisture content is 78.2% in *S. fimbriata* and 69.8% in *S. longiceps*. The total proteins in *S.*

fimbriata and *S. longiceps* are 22.5% and 20.3%, respectively. The lipid contents are 2.7% and 12.9% in *S. fimbriata* and *S. longiceps,* respectively. The lipid contents are 2.7% in *S. fimbriata* and 12.9% in *S. longiceps*. The ash and carbohydrate contents are low in these fishes and vary between 1.6 and 2.1% (*S. fimbriata)* and 2.83 and 1.2% (*S. longiceps)*. Values of moisture, protein, carbohydrate and fibre are higher in *S. fimbriata* (78.2%, 22.5%, 1.75% and 2.83%, respectively) than in *S .longiceps* (69.8%, 20.3%, 0.44% and 1.2%, respectively). The values for flesh lipid and ash content are higher in *S. longiceps* (12.9% and 2.1%, respectively) than in *S. fimbriata* (2.7% and 1.6%)

Proximate composition (%)	*S. fimbriata*	*S. longiceps*	Significance
Moisture	78.2 ± 0.31	69.8 ± 0.41	P < 0.05
Protein	22.5 ± 0.66	20.3 ± 0.51	P < 0.05
Lipid	2.7 ± 0.72	22.9 ± 0.84	P < 0.05
Ash	1.6 ± 0.22	2.1 ± 0.74	P < 0.05
Carbohydrate	1.75 ± 0.42	0.44 ± 0.19	P < 0.05
Fibre	2.83 ± 0.06	1.2 ± 0.07	P < 0.05

Table 1: Proximate composition of *S. fimbriata* and *S. longiceps*.
Values were reported as means ± S.D. of triplicate groups of 5 fish (n = 15); Significant (P<0.05); Non significant (P>0.05).

Fatty Acids Composition

Table 2 the fatty acid percentage distributions (% w/w of total fatty acids) in both the species' muscles were summarized in Table 2. The percentage of fatty acids varies widely between the species. It ranges from 2.315 to 19.502% for SFAs, 0.165 to 2.949% for MUFAs, and 36.61 to 46.67% for PUFAs. *S. longiceps*has higher proportions of fatty acids than *S. fimbriata.* For omega-3 fatty acids, *S. longiceps* has more eicosapentaenoic acid (EPA), whereas *S. fimbriata* has more docosahexaenoic acid (DHA).

Fatty acid composition (%)	Classification	*S.fimbriata*	*S. longiceps*	Significance
Saturated fatty acids (SFA)				
Myristic acid	C14:0	1.318 ±0.03	10.343±0.07	P < 0.05
Palmitic acid	C16:0	0.375 ±0.07	4.616 ±0.52	P < 0.05
Stearic acid	C18:0	0.422 ±0.14	1.963 ±0.18	P < 0.05
Arachidic acid	C20:0	0.200 ±0.05	2.580 ±0.09	P < 0.05
Total SFA		2.315	19.502	
Mono-unsaturated fatty acids (MUFA)				
Palmitoleic acid	C16:1	0.031 ±0.45	0.204 ±0.69	P < 0.05
Oleic acid	C18:1	0.094 ±0.17	1.225 ±0.09	P < 0.05
Gadoleic acid	C20:1	0.040 ±1.08	1.520 ±0.09	P < 0.05
Total MUFA		0.165	2.949	
Poly-unsaturated fatty acids (PUFA)				
Linoleic acid	C18:2	0.020 ±1.11	0.330 ±0.58	P < 0.05
á-Linolenic acid	C18:3n3	0.010 ±0.02	0.400 ±0.01	P < 0.05
ë-Linolenic acid	C18:3n6	0.020 ±0.07	4.260 ±0.82	P < 0.05
Eicosadienoic acid	C20:2n6	0.22 ±1.02	1.24 ±0.74	P < 0.05
Eicosatrienoic acid	C20:3n3	0.03 ±0.24	0.2 ±0.05	P < 0.05
Arachidonic acid	C20:4	3.32 ±0.12	2.41 ±0.84	P < 0.05
Eicosapentaenoic acid	C20:5	11.58 ±1.54	18.25 ±2.41	P < 0.05
Docosahexaenoic acid	C22:6	21.41 ±2.36	19.58 ±2.54	P < 0.05
Total PUFA		36.61	46.67	

Table 2: Fatty acid composition of *S. fimbriata* and *S. longiceps*.
Values were reported as means ± S.D. of triplicate groups of 5 fish (n = 15); Significant (P<0.05); Non significant (P>0.05)

Phospholipid and Cholesterol

The mean values of phospholipid and cholesterol contents of the fish samples are presented in Table 3. Mean phospholipid ranges from 6.58±0.88 % to 29.20±0.91% in *S. fimbriata* but in *S. longiceps,* mean cholesterol content ranges from 36± 2.27 mg/100 g to 62±27.11 mg/100 g. Values of phospholipid and cholesterol contents of the fishes indicate the nutritional values of commercial fishes. More phospholipid and cholesterol contents are found in *S. longiceps* than in *S. fimbriata.*

Fishes	Mean Phospholipid (%)	Mean Cholesterol (mg/100g)	Significance
S. fimbriata	6.58 ±0.88	36 ± 2.27	P < 0.05
S. longiceps	29.2±0.91	62±27.11	P < 0.05

Table 3: Composition of lipid classes in the fishes (% of dry weight basis).
Values were reported as means ± S.D. of triplicate groups of 5 fish (n = 15); Significant (P<0.05); Non significant (P>0.05)

Amino Acids Composition

The amino acid composition of *S. fimbriata* and *S. longiceps are* shown in Table 4. Altogether 19 amino acids are present, of which 12 are essential and 7 are non-essential. Both the species contain higher amount of essential amino acids. The amino acid compositions are significantly different (P<0.05) between the two species, except for methionine, norleucine and serine (P>0.05). The essential amino acids are high in *S. fimbriata* and *S. Longiceps* are arginine and phenyl alanine. The content of arginine is higher in *S. fimbriata* (1,474.3 mg/kg) than *S. longiceps* (1,031.6 mg/kg). Similarly the content of phenyl alanine is higher in *S. longiceps* (1,097.7 mg/kg) than *S. fimbriata* (863.6 mg/kg). The most abundant essential amino acids in *S. fimbriata* are arginine (1,474.3 mg/kg) followed by phenyl alanine (863.6 mg /kg), histidine (290.2 mg/kg), threonine (215.5 mg/kg), lysine (156.6 mg/kg), valine (148.2 mg/kg), ornithine (107.1 mg/kg), isoleucine (105.5 mg/kg), leucine (24.4 mg/kg), norleucine (24.2 mg/kg), tryptophan (1.5 mg/kg) and methionine (0.8 mg/kg). The predominant non-essential amino acids in *S. fimbriata* are glutamic acid (1,656.4 mg/kg), alanine (899.0 mg/kg), tyrosine (619 mg/kg), glycine (170.3 mg/kg), aspartic acid (22.4 mg/kg) and cysteine (6.5 mg/kg). The most abundant essential amino acids in *S. longiceps* are phenyl alanine (1,097.7 mg/kg), arginine (1,031.6 mg/kg), threonine (243.3 mg/kg), histidine (205.6 mg/kg), lysine (198.1 mg/kg), valine (198.1 mg/kg), ornithine (178.9 mg/kg), isoleucine (135.5 mg/kg), leucine (112.3 mg/kg), norleucine (24.5 mg/kg), tryptophan (2.5 mg/kg) and methionine (0.7 mg/kg). The predominant non-essential amino acids in *S. longiceps* are glutamic acid (1,921.2 mg/kg), alanine (1,009.1 mg/kg), tyrosine (883.5 mg/kg), glycine (152.6 mg/kg), serine (143.8 mg/kg), cysteine (77.0 mg/kg) and aspartic acid (23.5 mg/kg). The most abundant amino acid in both the species is glutamic acid, alanine, arginine and phenyl alanine, whereas the least abundant are methionine and tryptophan.

Aminoacids composition (mg/kg)	EAA/NEAA	*Sardinella fimbriata*	*Sardinella longiceps*	Significance
L-Alanine	NEAA	899.0±56.3	1009.1±58.9	P < 0.05
L-Arginine	EAA	1474.3±34.7	1031.6±56.4	P < 0.05
L-Aspartic acid	NEAA	22.4±12.4	23.5±11.9	P < 0.05
L-Cysteine	NEAA	6.5±3.4	77.0±4.8	P < 0.05
L-Glutamic acid	NEAA	1656.4±23.8	1921.2±34.6	P < 0.05
L-Glycine	NEAA	170.3±16.8	152.6±15.86	P < 0.05
L-Histidine	EAA	290.2±34.5	205.6±38.5	P < 0.05
L-Leucine	EAA	24.4±12.3	26.2±18.5	P < 0.05
L-Isoleucine	EAA	105.5±45.6	112.3±49.8	P < 0.05
L-Lysine	EAA	156.6±37.8	198.1±45.4	P < 0.05
L-Methionine	EAA	0.8±0.1	0.7±0.2	P > 0.05
L-Norleucine	EAA	24.2±12.5	24.5±15.3	P > 0.05
L-Ornithine	EAA	107.1±23.4	135.5±25.6	P < 0.05
L-Phenylalanine	EAA	863.6±34.6	1097.7±55.3	P < 0.05

L-Serine	NEAA	145.6±45.3	143.8±35.7	P > 0.05
L-Threonine	EAA	215.5±35.8	234.3±45.3	P < 0.05
L-Trytophan	EAA	1.5±1.2	2.5±1.0	P < 0.05
L-Tyrosine	NEAA	619.0±67.9	883.5±55.4	P < 0.05
L-Valine	EAA	148.2±32.5	178.9±22.8	P < 0.05

Table 4: Amino acid composition of *Sardinella fimbriata* and *Sardinella longiceps*.
Values were reported as means ± S.D. of triplicate groups of 5 fish (n = 15); significant (P<0.05); Non significant (P>0.05) AA/ NEAA: Essential aminoacid / Non-essential amino acid.

Mineral content

The mineral profiles of both species are shown in Table 5. The concentrations of all elements vary significantly (P < 0.05) between the species. Both the species are having eight minerals, of which calcium and magnesium are the most abundant. All the minerals are more abundant in *S. longiceps* than *S. fimbriata*, whereas Copper is deficient in both species.

Mineral content (mg/100g)	*S. fimbriata*	*S. longiceps*	Significance
Calcium	81.2 ± 0.18	96.7 ± 0.12	P < 0.05
Magnesium	58.6 ± 0.04	88.2 ± 0.06	P < 0.05
Zinc	15.2 ± 0.04	42.2 ± 0.01	P < 0.05
Copper	1.22±0.02	1.73±0.68	P < 0.05
Iron	11.2± 0.68	15.6±2.35	P < 0.05
Potassium	65.7±5.22	77.8±22.3	P < 0.05
Sodium	24.2± 3.5	47.3±23.1	P < 0.05
Iodine	1.28±1.22	3.14±1.11	P < 0.05

Table 5: Mineral content of *S. fimbriata* and *S. longiceps* species.
Values were reported as means ± S.D. of triplicate groups of 5 fish (n = 15). Significant (P<0.05); Non significant (P>0.05).

Vitamins

Six vitamins are present in *S. longiceps*and five in *S. fimbriata* (Table 6). The vitamin contents vary significantly (P < 0.05) between the species. Vitamin A is the most abundant in both species. Vitamins B1, B2, and B3 are absent in *S. fimbriata,* whereas Vitamin A, B6, and C are abundant. Vitamin E, B12, C, B1, B2, and B3 and other vitamins are abundant in *S. longiceps.*

Vitamin content (mg/100g)	*Sardinella fimbriata*	*Sardinella longiceps*	Significance
Fat soluble vitamins			
Vitamin A	49.22 ± 0.08	18.2 ± 0.02	P < 0.05
Vitamin E	0.92 ± 0.46	2.95 ± 0.27	P < 0.05
Water soluble vitamins			
Vitamin B1	-	0.55±0.11	-
Vitamin B2	-	1.22±0.14	-
Vitamin B3	-	0.45±0.24	-
Vitamin B6	5.11±1.22	1.77±0.35	P < 0.05
Vitamin B12	1.27±0.25	0.29±0.02	P < 0.05
Vitamin C	1.64±0.36	4.86±2.14	P < 0.05

Table 6: Vitamin content of *S. fimbriata* and *S. longiceps*.
Values were reported as means ± S.D. of triplicate groups of 5 fish (n = 15). Significant (P<0.05); Non significant (P>0.05)

Discussion

Fish has been a chief food source for humankind worldwide from time immemorial, especially as a cheap source of animal protein [20]. It is well understood now that fish is a source of vitamins, fatty acids, and high-quality, balanced, and easily digestible protein. Fishes also have energy depots in the form of lipids. Therefore, the proximate biochemical composition of a species helps assess its nutritional and edible values in energy units vis-à-vis other species.

The biochemical composition of fishes varies from species to species, including feeding and breeding habits, fishing season, and fish migration [21,22]. The largest constituent of fish is the moisture content. In this study, *S. fimbriata* contains more moisture (78.2%) than *S. longiceps* (69.8%). Edirisinghe, et al. [23] Reported the lowest percentage of moisture (69.4%) in white sardine (*S. albella*) from Sri Lankan waters. According to Castrillon, et al. [24], the moisture content of *Clupeapil chardus* is 60.7%. Oil sardines have 69.8% of moisture, but earlier, Gopakumar [25] and Ravichandran, et al. [26] reported 67.01% and 70.02% in oil sardines. Protein is the second principal constituent in fish, falling in the range of 10-25% (the average being 19 %). The variations of protein in different species are influenced by their feeding and breeding habits [22]. *S. fimbriata* has more protein (22.5%) than *S. longiceps* (20.3%) in the present study. Palani et al. [27] report that fatty fishes landed in the Thoothukudi Coast of India has 14% protein. Bahurmiz, et al. [27] reported 18.1% protein in *S. longiceps* on a wet weight basis. Marques & Botelho, said a protein content of 16.6 1g in *S. pilchardus* of Portugal. (These values show that the two sardine species have comparatively more protein.

As for lipid Shehawy, et al. [28] report that the Indian oil sardine has the highest lipid value (38%), while other sardinella fishes have the least lipid value, 1.17%. In the present study also the lipid content of *S. longiceps* (22.9%) is more than *S. fimbriata* (2.7%). The lipid and moisture contents in sardine show inverse proportions. This inverse relationship has been reported in *Mugilcephalus* [29]. Both the species analyzed in our study may be termed as fatty (> 2%) according to the classification of Ackman [30]. Fat contents in fishes depend on age, sex, habit, and seasonal changes [31]. Christolite, et al. [32] report lipid content of *S. gibbosa* at 1.25 to 6.77%. A similar high variation (from 1.9% to 8.4%) was found in the fat contents in the sardine of Karachi coast, Pakistan [33]. A high-fat concentration is reported in *S. longiceps* and *S. fimbriata* from Cochin waters [34]. The results of the present analysis agree with the above studies about the fat contents of fish species.

Carbohydrates form a minor percentage of the total composition of the muscle. In the present study, carbohydrates have a small presence because glycogen, in general, does not contribute much to the reserves in marine animals [35]. Ramaiyan, et al. [36] report similar findings in 11 species of Clupeids. Phillips, et al. [37] report that carbohydrates are utilized for energy in trout and protein is thus spared for building the body. The percentage of ash content in the fishes analyzed indicates the ample mineral contents in fish. The mean value of the flesh ash content is high in *S. longiceps*. The concentrations of minerals and trace elements that make up the total ash contents are known to vary in fishes, depending on their feeding behavior, environment, ecosystem, and migration even within the same area [38-40]. Peiris & Grero [41] report the ash content of herring, Dorab wolf herring, and Toothpony to be 4.4%, 2.3%, and 1.7%, respectively. According to Hatano, et al. [42] Chum salmon's ash content decreases during spawning migration. Ash values recorded for *S. longiceps*, *Chirocentrus dorab, Stolephorus devisi, and Rastrelliger kanagurta* by Gopakumar [25] are similarto the values obtained in this study. Fiber content is higher in *S. fimbriata* than *S. longiceps*, and the difference is significant ($p<0.05$ The proportion of polyunsaturated fatty acids (PUFAs) in the sardine species ranges between 36.61 and 46.67%. The highest proportion of PUFAs is found in *S. longiceps*. In terms of absolute amounts of fatty acids, both the fishes contain larger n-3 PUFAs than n-6 PUFAs. Linoleic acid is the most representative n-6 fatty acid in both species. Osman, et al. [43] also report high linoleic acid values vis-à-vis other n-6 fatty acids for fish species with high-fat contents from tropical marine waters. *S. longiceps* contain abundant n-3 and n-6 fatty acids. Indeed, the (*n*-3)/(*n*-6) ratio is considered a useful marker for comparing nutritional values of fish oils, being the most significant fish fat indicator quality and best reflects the quality of fish as food. Furthermore, it is known that marine fish cannot synthesize DHA and EPA either de novo. Based on this statement, variances found in DHA and EPA proportions of same species by different authors may be ascribed to several factors like food availability, location of catch, fish size, individual variability, fishing season, or even undernourishment. The major contributors to the n-3 PUFA composition in all specimens studied are DHA and EPA, with low linolenic acid concentrations (<2%). In terms of the absolute amount of DHA, the highest DHA content is found in *S. fimbriata*. The concentration of EPA in the selected fishes ranges between 11.58 and 18.25%. In absolute terms, the amount of DHA is higher than EPA. The same tendency has been detected in other fishes from the Pacific Ocean, such as Pacific hake, walleye pollock, and canary rockfish [44]. The accumulation of fatty acids in fish muscle is influenced by several factors besides diet and genetics, such as sexual maturity, geographic location, and the catch season. One relevant aspect of the present research is the nutritional quality of the fish species in their contribution to the daily dietary intake of bioactive EPA+DHA acids and n-3/n-6 ratio.

The US Department of Agriculture [45] proposed a daily intake of 250 mg of EPA+DHA. To meet this daily requirement, it would be necessary to consume approximately 30 g of *S. longiceps* and 45 g of *S. fimbriata*. The n-3/n-6 ratio index has been suggested for assessing the nutritional value of fish oils, and an increase in human dietary n-3/n-6 fatty acids helps reduce cancer and cardiovascular risks [1,46]. The notably cheap *S. fimbriata* and *S. longiceps* fish have the highest nutritional value in the n-3/n-6 ratio. In general, both fish species can be considered beneficial to health in their n-3/n-6 proportion.

According to their lipid contents, fishes are classified as Lean fish (< 2% fat), Low-fat fish (2-4 % fat), Medium fat fish (4-8 % fat), and High-fat fish (> 8% fat) [47]. This classification *S. fimbriata* comes under the medium-fat category and *S. longiceps* under the high-fat class. The major lipid storage sites in fish vary in different species. However, lipids are primarily located in the subcutaneous tissue, belly flap, muscle tissue, liver, mesenteric tissue, and head. The amount of lipid dispersed through the flesh decreases from the head to the tail, where the muscles used for swimming are located. There is also a considerable amount of lipid found in the myosepta surrounding the muscles [48], So for the lipid analysis in this study, lipid was extracted from the muscle tissue [49,50]. Phospholipids are major components of cell membranes as they can form lipid bilayers. Mukhopadhyay, et al. [51] reported that phospholipids constitute a significant portion of lipids fish body tissue. In the present study also phospholipids are the most dominant lipid class. Fraser, et al. [52] showed that phospholipid is a source of metabolic energy and a source of essential n-3 fatty acids. Our results indicate that both the sardine species are good sources of essential fatty acids. Jhingran [53] reported that fish comprises critical nutrients, good fish having high phospholipid with essential fatty acid. Bechtel, et al. [54] attributed the high palatability of fish muscles to the high phospholipid content in them. Our study results corroborate this fact. Johannes [55] reported the phospholipid content of Capelin fish at 24%. To sum up, the phospholipid is present in considerable amounts in fishes, and fishes, in general, have good amounts of essential PUFA, which makes the sardines highly palatable.

Cholesterol is the most common member of a group of sterols in animal tissues, and it has an essential role in sustaining membrane fluidity. Cholesterol esters are imperative forms of long-term energy stores [56]. In the liver, cholesterol is transformed to bile, which is then stored in the gall bladder. Some previous investigation shows cholesterol might act as an antioxidant [57,58]. Tapas Mukhopadhyay & Santinath Ghosh [59] reported that fatty fishes like salmon, sardine, herring, mackerel, whitefish, and bluefin tuna have high 'good' cholesterol (HDL) and low triglycerides.

Similarly fish oil capsules have the same features. In the present study also the fishes show good cholesterol value and lower bad cholesterol and triglycerides. Mendez, et al. [60] reported a lipid content of 6.6% in the southwest Atlantic Hake *Merlucciushubbsi*) 27.6% were waxes, 42% triacylglycerols, 14% phospholipids, and 5.7% cholesterol. In our study also cholesterol content is lower than phospholipid. The highest value of cholesterol is noted in the muscle tissue of *S. longiceps* (62±27.11 mg/100g). In general, fish lipid contains cholesterol levels at a level of 140 mg/100g [61] and our results agree with this statement. The high-density lipoproteins found in Sardinella fishes are very good for human health. They help synthesize essential hormones for maintaining membrane fluidity and act as natural antioxidants in the human body.

Fish meat has both Essential Amino Acids (EAA) and Non-Essential Amino Acids (NEAA). The ratio between EAA and NEAA is an index that can be used to define the protein's quality [62]. The biological importance of protein is reflected by the essential amino acid profile of the investigated species. The present works notes twelve essential and seven non-essential amino acids in sardine species. Similarly, Vignesh & Srinivasan [63] recorded 20 essential amino acids in *S. fimbriata,* and among that, 9 are essential amino acids. Phenylalanine, arginine, glutamic acid, and alanine are found in higher concentrations. Three conditional essential amino acids are present in both fish samples: arginine, tyrosine, and glycine. The total arginine content is high in *S. fimbriata,* and no significant variation is observed between the tyrosine and glycine contents of the two species. The same amino acids as detected in this study were reported by Kumaran, et al. [64].

Significant variations are observed in the amino acid composition between *S. fimbriata* and *S. Longiceps,* and this is in agreement with Osibona [65] and Mohanty, et al. [66]. Kumaran, et al. [64] were studied the essential and non-essential amino acid composition of *S. Longiceps* and reported ten essential amino acids and eight non-essential amino acids. Out of the eight non-essential amino acids, glutamic acid and alanine are a predominant component, which correlates well with our results. In this present study, EAA is high in both sardinella species. Amino acids, such as glutamic, aspartic, alanine, and glycine, contribute to the flavor and taste, and for this reason, they are essential [67]. In the present study, *S. fimbriata* and *S. longiceps* have a balanced distribution of all essential and non-essential amino acids in quantities sufficient to meet the daily requirement [68]. So these fishes may be recommended as a dietary supplement.

As components of hormones, enzymes and enzyme activators, Minerals are also essential in human nutrition [69]. Mineral deficiencies cause biochemical, structural, and functional pathologies depending on several factors, including the degree and duration of mineral deprivation. The present analysis finds five macro minerals and three trace minerals in the two Sardinella species. The concentrations of all these elements significantly vary between the species. This observation is supported by Windom, et al. [70] findings, which showed that the variations in concentrations of these mineral elements are due to the chemical forms of the elements and their concentrations in the local environment. The macromineral calcium is the most abundant of all elements in this study, followed by magnesium and sodium in both species. Its concentration is higher in *S. longiceps*. The least amount of mineral (copper) was observed, followed by iodine in both species. Srilatha, et al. [71] kept the maximum amount of calcium and minimum of Copper in *M. casta* from Parangipettai and Cuddalore coasts. Engin, et al. [72] Observed 289 to 296 mg of sodium in mussels. Gopakumar [73] observed that seafood, in general, is an excellent source of iron, calcium, potassium, sodium, iodine, and zinc. This observation holds well in the present study too. Sheril & Hindumathy [74] reported calcium, sodium, and potassium to be high in S. *longiceps*. Babalola, et al. [75] said in *S. aurita* to be rich in calcium, magnesium, and iron. Palani, et al. [27] reported *S. fimbriata* and *S. longiceps* of Tuticorin coast as having higher contents of calcium (123.4 mg/100g), magnesium (67 mg/100g), sodium (56 mg/100g), and iron (9.45 mg/100g) than *S. fimbriata*, which result in tallies with our finding. Iron is an essential constituent of the respiratory pigments, hemoglobin, and myoglobin. It is a necessary component of various enzyme systems, including cytochromes, catalases, peroxidases, the enzymes xanthine and aldehyde oxidase, and succinic dehydrogenase. The fish samples' iron contents are around the World Health standard of 25 mg/100g. Potassium is an essential body mineral for cellular and electrical functions. Sodium helps maintain normal blood pressure and for the normal functioning of muscles and nerves. Magnesium ions act as enzyme co-factors and regulate over 300 biochemical reactions in the body [76]. Calcium is an mportant element of bone and cartilage. It is necessary for the normal clotting of blood. It acts by stimulating the release of thromboplastin from blood platelets. Both *S. fimbriata* and *S. longiceps* contain higher levels of calcium. The relative preference of these species for the consumption of hard structures could be a contributing factor, as observed by Adewoye. The concentrations of minerals are within FAO mean concentration ranges for fish and comparable to previous studies' values. Fishes have an adequate supply of minerals and can enhance mineral intake and protect against mineral deficiencies. From the nutritional point of view, the recommended dietary allowances (RDA) of Fe, Ca, K, Na, and Mg are male and female [77]. For example, consumption of about 250 g of Indian oil sardine covers 100% of Fe RDA, and 500 g of the same fish covers about 30% of Ca RDA, while 500 g of gilthead bream cover about 11.7% of K, 1.5% of Na and 4.1% Mg of these minerals RDA, respectively.

Vitamins are complex organic molecules whose presence in trace amounts in food is essential for normal growth and other physiological activities. Totally eight vitamins were recorded in *S. longiceps* and five in *S. fimbriata* in this study. Among them, vitamin A is predominant over others. Vitamin A is essential for visual perception. Next to Vitamin A, Vitamins B6 and C are predominant in *S. fimbriata*, whereas Vitamins C and E are predominant in *S. longiceps*. Vitamin deficiencies lead to diseases, and vitamin C provides immunity against infections, and it also supports the process of growth by activating some intra-cellular enzymes. Vitamins B1, B2, and B3 are absent in *S. fimbriata,* and B12 is the vitamin found in the least quantity in both species. Marques et al., 20I9 reported a high amount of Vit A followed by Vit D in *Sardinapil chardus.* Srilatha, et al. [71] observed seven vitamins in *M. casta*, of which vitamins C and A being the most abundant ones.

Though the two sardine species are phylogenetically close, their feeding habits are different. *S. longiceps* favors a zooplankton diet [78] while *S. fimbriata* prefers phytoplankton [79]. Consequently, the nutritional profiles of the fishes are also different [80]. Their nutritional mismatch makes a classic model for trophic up-gradation in the seas. Zooplanktons (microplankton), the primary food source of *S. longiceps*, whereas phytoplankton is the chief food for *S. fimbriata*. These microplanktons, also known as heterotrophic protists, tropically improve algal quality for higher trophic organisms' consumption [81]. As intermediate prey, they improve the quality and quantity of nutrition in the food, especially lipids with a higher level of unsaturation [82]. The greater concentration of amino and fatty acids in zooplankton results from this preferential assimilation in planktonic food webs by microplanktons. From the nutrition point of view, zooplankton-feeding *S. longiceps* are preferable to *S. fimbriata*, and food products based on *S. longiceps* will optimize higher nutrition intake. From the perspective of the fish's nutritional value, the study results revealed that *Sardinella longiceps* and *S. fimbriata* are good healthy food rich in essential nutrients required for the maintenance of human health [83-92].

Conclusion

The data obtained from this work represent the first step toward the knowledge about the biochemical composition and nutritional value of important sardine species of Tuticorin. Consumer awareness is increasing worldwide regarding the nutritional value of food. Labeling all marketed food products with their nutrient contents to support consumer healthier regimes is becoming mandatory, particularly in developed countries. The consequences of this study extend the nutritional information of consumed species. Despite the differences in dietary contents, these species have high levels of omega-3 fatty acids, especially DHA and EPA. The nutritional variation between the species may be tailored depending on the fish's diet composition.

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