Heliyon 10 (2024) e36474

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Proximate composition, fatty acid characteristics, amino acid profile and mineral content of fish *Acanthurus sohal*

Lafi Al Solami [a,*], Mohamed Korish [b]

[a] Department of Marine Biology, Faculty of Marine Sciences, King Abdulaziz University, P.O. Box: 80208, Jeddah, 21589, Saudi Arabia
[b] Department of Agriculture, Faculty of Environmental Sciences, King Abdulaziz University, P.O. Box: 80208, Jeddah, 21589, Saudi Arabia

ARTICLE INFO

Keywords:
Red sea
Sohal
Fat
Protein
and Minerals

ABSTRACT

The study's objective was to explore the chemical composition of *Acanthurus sohal* fish flesh and their nutritional quality. Fish samples were caught in the Red Sea, prepared, and analysed for proximate composition, fatty acid, amino acid and mineral content. The results revealed that fish flesh contained 71.1 % moisture, 20.7 % crude protein, 5 % crude lipids and 1.7 % ash. The fatty acids were dominant by 61.93 % saturated fatty acids. Palmitic was the most common (40.35 %) saturated fatty acids, while monounsaturated fatty acids and polyunsaturated fatty acids accounted for 22.59 % and 15.48 %, respectively. The fish fat consisted of appreciable amounts of odd-numbered fatty acids heptadecanoic and heptadecenoic acids standing for 1.62 % and 1.45 %, respectively. The fatty acids were predominated by C16, C18 and C20 fatty acids. The percentage of n-6/n-3 reached 2.26. Seventeen amino acids were identified in *A. sohal* flesh protein, eight of which were essential amino acids (EAAs); they amounted to 375.47 mg/g crude protein. Lysine was the most common EAA (64.49 mg/g crude protein). Aromatic amino acid and sulphur amino acid constituted 112.43 and 47.56 mg/g protein, respectively. The following macroelement concentration ranking was identified: Ca > P > K > Na > Mg, while the concentration of vital elements was Fe > Zn > Cu > Cr > I > Se > Co.

1. Introduction

Recently, fish have received much interest as a food source due to their essential nutrient content that can fulfil a considerable portion of the daily requirements of humans. For instance, fish contain polyunsaturated fatty acids (PUFAs), high-quality protein and essential minerals. The n-3 PUFA family has been extensively documented for its ability to protect against various conditions associated with cardiovascular diseases, excessive body weight, inflammation, diabetes mellitus [1] and certain forms of cancer growth [2]. In addition, n-6 PUFA fatty acids produce positive health impacts on the circulatory system [3,4] Nutritionists suggest that the desirable ratio of n-3: n-6 PUFAs should fall between 1/1 and 1/2. However, a ratio above this range increases the risk of cardiovascular diseases [5]. Therefore, the fat content of fish and the PUFA composition must be considered to suggest fish for consumption. *Acanthurus sohal* is an exclusive species found in abundance in the Red Sea area of KSA, Jeddah Fisheries, and is one of the prevalent herbivorous fish on coral reefs. To our knowledge, there is no information about the chemical composition of *A. sohal*. Hence, this research was performed to explore the chemical composition of *A. sohal* fish flesh and its implications for human well-being. The current investigation aimed to characterize the fatty acid and amino acid profiles and mineral content of *A. sohal* flesh. The nutrient

* Corresponding author.
E-mail addresses: lalsulami@kau.edu.sa (L. Al Solami), mmkorish@yahoo.com (M. Korish).

https://doi.org/10.1016/j.heliyon.2024.e36474
Received 3 May 2024; Received in revised form 11 August 2024; Accepted 15 August 2024
Available online 16 August 2024

Table 1
Proximate composition of *Acanthurus sohal* flesh.

Component	*A. sohal* % Wet Basis [a]Means ± SD	*A. sohal* % dry weight [a]Means ± SD	[b]*A. leucopareius*	[c]*A. monroviae*
			% wet weight	% [b]dry weight
Moisture	71.1 ± 0.07		81.7	13.2
Crude protein	20.7 ± 0.05	71.4 ± 0.10	14.3	65.4
Crude lipids	5 ± 0.01	17.1 ± 0.07	0.7	6.25
Ash	1.7 ± 0.02	5.81 ± 0.02±	1.3	8.58

[a] Values are mean ± standard deviation of three pooled samples.
[b] [14].
[c] [15].

profile of this fish would provide guidelines for dieticians and medical practitioners in prescribing diets for individuals.

2. Materials and methods

2.1. Obtaining and preparing samples

Fifteen *A. sohal* fishes were caught each month (January–March 2023) from the Red Sea, Jeddah Fisheries, Saudi Arabia, immediately stored in an icebox and transported to the laboratory of Marine Biology, Faculty of Marine Science, King Abdulaziz University where they were identified. The fish sample of each month was split into three groups, each having five fish. A pool sample of each group was collected and used as a replicate sample. The fish's wet mass and size were 660–733 ± SD g and 41.51–42.15 ± SD cm, respectively. The fish samples were cleaned in distilled water and filleted, and the meat was chopped before being dried to a consistent weight in an oven with heated air at 50 °C. Before chemical analysis, the dried samples were crushed into a fine powder and preserved in sealed plastic bags at 4 °C.

2.2. Proximate composition analysis

The standard methods of AOAC [7] were used for the determination of crude lipids, crude protein (N × 6.25), moisture and ash contents.

2.3. Fatty acid analysis

The lipid content was determined following previous methods [8,9]. In brief, 10 g of sample powder was added to 10 mL of concentrated HCl and subjected to digestion by employing a bath of boiling water and vigorous stirring before the substance turned brown. Three times of vigorous shaking with 30 mL of diethyl ether were used to separate the lipid fraction from the mixture. Following the evaporation of the solvent, the amount of lipid was determined. To turn fatty acids into their equivalent methyl esters, the procedure described by Radwan [10] was employed. Samples consisting of 50 mg of lipids were dissolved in 2 mL of benzene followed by the addition of 2 mL aliquots of methanolic sulphuric acid (1 %, v/v). The tubes were sealed with nitrogen and heated at 90 °C in a water bath for 90 min. Subsequently, 8 mL of water was added, and it took 5 mL of petroleum ether to extract the methylated fatty acids. This combination was then dried by evaporation. Injecting 2 μL of the fatty acid methyl ester solution was done into an HP (Hewlett Packard) 6890 GC system. The GC system was equipped with a splitless injector mode, a flame ionization detector (FID) and

Table 2
Fatty acid profile of *Acanthurus sohal* fat.

Fatty acids	[a]% of total fatty acids	Fatty acids	[a]% of total fatty acids
C14:0	3.21 ± 0.03	C16:1n7	7.57 ± 0.06
C16:0	40.35 ± 0.14	C16:1n9	0.64 ± 0.02
C17:0	1.62 ± 0.02	C17:1	1.45 ± 0.02
C18:0	8.98 ± 0.06	C18:1n9c	9.10 ± 0.07
C20:0	3.62 ± 0.02	C18:1n9t	2.20 ± 0.01
C22:0	4.15 ± 0.01	C20:1	1.63 ± 0.05
∑SFA	61.93	∑MUFA	22.59
C18:2n6	4.47 ± 0.02	∑IFA	100
C18:2n6t	1.10 ± 0.02	∑PUFAn-3	4.72
C18:3n6	5.19 ± 0.01	∑PUFAn-6	10.76
C18:3n3	1.41 ± 0.01	∑PUFAn-3:∑PUFAn-6	0.44
C20:3n3	3.31 ± 0.02	∑PUFAn-6:∑PUFAn-3	2.26
∑PUFA	15.48	∑ONFA	3.07

[a] Values are means ± standard deviation of three pooled samples.

Table 3
Amino acid composition of *Acanthurus sohal* flesh protein.

Essential amino acids	Content (mg/g crude protein) [a]Mean ± SD	% of total individual amino acids	FAO pattern 2013	Non-essential amino acids	Content (mg/g crude protein) [a]Mean ± SD	% of total individual amino acids
Histidine	24.93 ± 0.07	2.56	15	Aspartic	117.62 ± 0.11	12.08
Isoleucine	46.02 ± 0.05	4.72	30	Alanine	72.00 ± 0.09	7.45
Leucine	55.24 ± 0.03	5.67	59	Arginine	53.98 ± 0.06	5.54
Lysine	64.49 ± 0.03	6.62	45	Cysteine	8.99 ± 0.02	0.92
Methionine	38.57 ± 0.03	3.961	16	Glutamic	140.89 ± 0.10	14.47
Phenylalanine	44.05 ± 0.06	4.52	–	Glycine	41.18 ± 0.03	4.22
Threonine	39.01 ± 0.04	4.00	23	Proline	53.38 ± 0.03	5.48
Valine	63.16 ± 0.02	6.48	39	Serine	41.84 ± 0.04	4.29
[b]∑ EAA	375.47			Tyrosine	68.38 ± 0.02	7.02
% EAA		38.56		[f]∑ NEAA	598.26	
[c]∑ AAA	112.43			% NEAA		61.44
[d]∑ IAA	973.73			[e]∑SAA	47.56	
				% SAA		4.88

[a] Values are mean ± standard deviation of three pooled samples.
[b] Essential amino acids.
[c] Aromatic amino acid.
[d] Individual amino acids.
[e] Sulphur amino acid.
[f] Nonessential amino acids.

an HP-5 column. The HP-5 column had a composition of 5 % diphenyl and 95 % dimethyl polysiloxane, with dimensions of 30 m length, 0.32 mm inner diameter and a film thickness of 0.25 μm. The operating parameters were set as follows: the injector was maintained at a temperature of 220 °C, and the temperature programme for the oven consisted of a primary temperature of 150 °C for 2 min. Subsequently, the temperature was ramped up at a rate of 10 °C/min. The final temperature was 250 °C, and the carrier gas used was nitrogen, flowing at a rate of 1 mL/min. A mixture of fatty acid standards underwent the same procedures as the samples and was utilized for the recognition and quantification of the fatty acids present in the samples.

2.4. Amino acid analysis

The samples (0.2 g) were defatted, kept in a sealed tube and hydrolysed with 6 N HCl (10 mL) at 100 °C for 24 h. Deionized water was put into the hydrolysates to a terminal volume of 25 mL. Five millilitres of each hydrolysate was evaporated to remove any HCl and then dissolved in citrate buffer [11]. To identify and quantify amino acids, the amino acid analyser AAA-400 (INGOS, Czech Republic) was used. It was equipped with a 200 × 3.7 mm ion-exchange column (OSTION LG ANB, INGOS) and a flow photometer detector. Different pH gradients of sodium citrate buffers were employed for elution. AMIK software 3.0 (Czech Republic) was applied for processing chromatographic data, including peak areas of separated amino acids and retention time calculations. As external standards, a mixture of amino acids (INGOS, Czech Republic) was employed.

2.5. Mineral analysis

Digestion of fish flesh was performed as outlined by Amin et al. [12]. In brief, the procedure involved the following steps: 0.5 g of fish flesh powder was subjected to digestion using 4 mL of concentrated nitric acid and 1 mL of $HClO_4$. After cooling and filtration using filter paper Whatman No. 4, the resulting supernatant was diluted to 50 mL using distilled water. The same process was executed for blank samples. Inductively coupled plasma-optical emission spectrophotometry ICP-OES (Varian, 720-ES, Varian Inc., Palo Alto, CA, USA) was used to estimate the mineral concentrations of the digested diluents. A standard multi-element solution from Campro Scientific (Berlin, Germany) was used for calibration. Additionally, the spectrophotometric method elucidated by Hua et al. [13] was adopted to determine the phosphorus content.

Table 4
Mineral contents of *Acanthurus sohal* flesh.

Minerals	[a]Mean ± SD mg kg^{-1}	Minerals	[a]Mean ± SD mg kg^{-1}
Phosphorus	7100	Iodine	0.21
Potassium	2700	Zinc	18.07
Calcium	7400	Chromium	0.24
Sodium	1800	Cobalt	0.11
Magnesium	428.83	Copper	3.93
Iron	35.16	Selenium	0.15

[a] Values are mean ± standard deviation of three pooled samples.

3. Results and discussion

3.1. Proximate composition

The nutritional compositions of *A. sohal* flesh are shown in Table 1. The contents of moisture, crude protein, lipids, and ash were 71.1 %, 20.7 % 5 %, and 1.7 %, respectively. These nutritional element values were comparatively higher than those of *Acanthurus leucopareius* and *Acanthurus monroviae*, which were (wet weight) moisture 81.7 ± 0.0, crude protein 14.3 ± 0.1, crude fat 0.7 ± 0.0 and ash 1.3 ± 0.0 [14]; and (dry weight) moisture 13.2 %, crude protein 65.4 %, crude fat 6.25 % and ash 8.58 % [15], respectively. The results suggest that protein constituted the largest quantity of dry matter in *A. sohal* fish flesh. According to the Ackman [16] classification of fish based on their fat content, *A. sohal* belonged to the medium-fat category. The abundance of ash suggested that *A. sohal* might be a good source of minerals.

3.2. Fatty acid composition

The data in Table 2 reveal that 17 fatty acids were recognized in the fat of *A. sohal*. Saturated fatty acids (SFAs) were the dominant (61.93 %). SFAs may raise the likelihood of developing atherogenic diseases [19]. Palmitic acid (C16:0) was the major SFA, constituting 40.35 % of the total detectable fatty acids. Various studies also stated that palmitic acid was predominant in *A. nigrofuscus*, explaining 45–52 % [17], in the fats of *Acanthurus lineatus* and *A. bariene* (24.3–39.0 %) [18] and in pomfret fats, signifying 30.3 % [20]. Among the detectable fatty acids, monounsaturated fatty acids (MUFAs) were the second most abundant, with a prevalence of 22.59 % in the total composition. Contrarily, PUFAs were the least prevalent, denoting 15.48 % of the total detectable fatty acids. Oleic acid (C18:1n9) and palmitoleic acid (16:1n7) were the most common MUFAs, comprising 9.10 % and 7.57 %, respectively. The main PUFA was γ-linolenic acid (C18:3n6), describing 5.19 % of the total detectable fatty acid, followed by linoleic acid (C18:2n6) (4.47 %). Appreciable amounts of the odd-numbered fatty acids (ONFAs) heptadecanoic acid (C17:0) and heptadecenoic acid (C17:1), 1.62 % and 1.45 % of the total detectable fatty acids, respectively, were identified in *A. sohal* fat. Such fatty acids have been stated to enhance insulin efficiency and decrease the risk of type 2 diabetes [21,22], while they are inversely related to the likelihood of developing cardiovascular disorders [6]. The findings also claim that the fatty acids of *A. sohal* fat were predominated by C16, C18 and C20 fatty acids. The quality of dietary fat can be assessed based on n-6 to n-3 fatty acid ratio. When the n-6: n-3 ratio is lower in the fat consumed in the human diet, it can lead to a reduction in cholesterol levels in the blood, thereby helping to prevent coronary heart disease. Conversely, a higher ratio of n-6: n-3 may elevate the risk of cardiovascular disease. This information was highlighted by Simopoulos [23]. In the case of fat measurements from *A. sohal*, it was determined that the ratio of n-6: n-3 was 2.26. This ratio aligns with the recommendation set by the UK Department of Health [24], which suggests maintaining a ratio below 4.0 to prevent cardiovascular disease. Therefore, consuming *A. sohal* flesh may be beneficial for health, as it meets the recommended n-6: n-3 ratio.

3.3. Amino acid composition and protein quality

The analysis of amino acids of *A. sohal* flesh protein (Table 3) identified 17 amino acids, eight of which were essential amino acids (EAAs) and nine were nonessential amino acids (NEAAs). Glutamic acid was the predominant NEAA, followed by aspartic acid in the *A. sohal* flesh protein. This composition of AA may be due to the amino acid-related genes in *A. sohal* fish. These findings agreed with those of Mohanty et al. [25] who indicated that the variation in the amino acid composition of fishes of the same species from different locations was not appreciable. Lysine was the prevalent EAA; this finding is similar to that of Gencbay and Turhan [26,27], who studied anchovy (*Engraulis encrasicolus*). Lysine, the limiting amino acid in grain, is hence abundant in the protein of *A. sohal*'s meat; it can serve as a good protein and lysine supplement in cereal diets for children in poorer populations [28]. All of the EAAs in the *A. sohal* meat protein (Table 2) corresponded satisfactorily to the equivalent amino acid reference that was suggested for adults by the FAO [29], with the exception of leucine, which had a score somewhat below the suggested level. In addition, EAA amounted to 375.47 mg/g crude protein, which exceeded the recommended value of the FAO [29] for adults (277 mg/g protein). The percentage of EAAs equalled 38.56 % of the total individual amino acids (IAA). The study also displayed that the *A. sohal* flesh protein contained a considerable amount of both aromatic amino acid (AAA) (112.43 mg/g protein) and sulphur amino acid (SAA) (47.56 mg/g protein), which both significantly outperform the scoring pattern recommended by the FAO [29] for adults (38 and 22 mg/g protein, respectively). Due to its destruction during acid hydrolysis, tryptophan was eliminated in this study. The outcomes clearly show that meat protein from *A. sohal* can be regarded as an excellent source of high-quality protein.

3.4. Mineral content of A. sohal flesh

The contents of macro- and essential elements in *A. sohal* flesh are illustrated in Table 4. The most abundant element in *A. sohal* meat (7400 mg/kg) is calcium that is required for the formation of bones and the operation of the nervous system [30]. The adult's daily need for calcium could be satisfied by a modest intake of 135.13 g of *A. sohal* meat each day (1000 mg/day) [31]. In addition, it could be recommended for assisting hypocalcaemia therapy. Phosphorus was the second most abundant element in *A. sohal* flesh, accounting for 7100 mg/kg. An intake of 98.6 g of *A. Sohal* flesh per day would fulfil the recommended dietary allowance of phosphorus for adults of 700 mg [31]. Moderate concentrations of sodium and potassium were determined in *A. sohal* flesh, and they play a great role in regulating arterial pressure and pH balance [32,33]. With a Na/K ratio (0.66) that was lower than the advised value (1), sodium was discovered to be present in lower concentrations than potassium [34], indicating that an *A. sohal* flesh diet is healthy for

hypertension patients. An appreciable concentration (428.83 mg/kg) of magnesium was found in *A. sohal* flesh, which is needed for preventing heart diseases and growth retardation [35]. *A. sohal* flesh can be regarded as a substantial supply of iron; hence, consuming 170.64 g of *A. sohal* flesh could provide the adult dietary reference requirement (6 mg/day) of iron, which is in line with previous guidelines [31]. The amount of zinc (18.07 mg/kg) in the *A. sohal* flesh under study was moderate. Zinc is a mineral that is a part of numerous enzymes and a variety of cellular and metabolic processes [36,37]. Copper and chromium in *A. sohal* flesh were estimated to account for 3.93 and 0.24 mg/kg, respectively, and they are components of many respiration enzymes [38,39] and glucose tolerance factors [40,41]. Appreciable concentrations of iodine, selenium and cobalt were found in *A. sohal* flesh, accounting for 0.21, 0.15 and 0.11 mg/kg, respectively, and they play a crucial part in continuously occurring regeneration processes, coping with persistent oxidative stress in the bodily tissues and maintaining adequate immunity against infections [42]; [43].

4. Conclusion

The present study reports for the first time the nutritional profile of *A. sohal* flesh from the Red Sea. *A. sohal* flesh contains high levels of protein, which is composed of well-balanced amino acid compositions containing eight essential amino acids, seven of them meet the amino acids requirements for adults, that was suggested by FAO. *A sohal* lipid is rich in unsaturated fatty acids, mainly from the n-6 family, with a ratio of n-6: n-3 was 2.26. The lipid also contains appreciable amounts of the odd-numbered fatty acids heptadecanoic acid and heptadecenoic acid, such fatty acids have been stated to enhance insulin efficiency and decrease the risk of type 2 diabetes. In addition, *A. sohal* flesh is a rich source of important macro and microelements. Thus *A. sohal* flesh is of a high nutritive value and, its intake can contribute to a healthy and well-balanced diet.

Informed consent statement

Not applicable.

Data availability statement

All data generated or analysed during this study are included in this manuscript and its information files.

CRediT authorship contribution statement

Lafi Al Solami: Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Mohamed Korish:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This project was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University under grant no. IFPIP: 1278-150- 1443. The authors also acknowledge DSR for technical support.

References

[1] S. Lorente-Cebrian, A. G Costa, S. Navas-Carretero, M. Zabala, J.A. Martinez, M.J. Moreno-Aliaga, Role of omega-3 fatty acids in obesity, metabolic syndrome, and cardiovascular diseases: a review of the evidence, J. Physiol. Biochem. 69 (3) (2013) 633–651, https://doi.org/10.1007/s13105-013-0265-4.
[2] S. Sakr, A.R. Munkarah, T.E. Buekers, R.T. Morris, S. Giri, R. Rattan, Omega-3 lipid metabolites inhibit the growth of ovarian cancer cells, Gynecol. Oncol. 149 (1) (2018) 69, https://doi.org/10.1016/j.ygyno.2018.04.157.
[3] S.J. Baum, P.M. Kris-Etherton, W.C. Willett, A.H. Lichtenstein, L.L. Rudel, Maki, K.C. Whelan, C.E. Ramsden, R.C. Block, Fatty acids in cardiovascular health and disease: a comprehensive update, J Clin Lipidol 6 (3) (2012) 216–234, https://doi.org/10.1016/j.jacl.2012.04.077.
[4] D. Mozaffarian, J.H.Y. Wu, Omega-3 fatty acids and cardiovascular disease, J. Am. Coll. Cardiol. 58 (20) (2011) 2047–2067, https://doi.org/10.1016/j.jacc.2011.06.063.
[5] H. Zhu, C. Fan, F. Xu, C. Tian, F. Zhang, K. Qi, Dietary fish oil n-3 polyunsaturated fatty acids and alpha-linolenic acid differently affect brain accretion of docosahexaenoic acid and expression of desaturases and sterol regulatory element-binding protein 1 in mice, J. Nutr. Biochem. 21 (10) (2010) 954–960, https://doi.org/10.1016/j.jnutbio.2009.07.011.
[6] K.T. Khaw, M.D. Friesen, E. Riboli, R. Luben, N. Wareham, Plasma phospholipid fatty acid concentration and incident coronary heart disease in men and women: the EPIC-Norfolk prospective study, PLoS Med. 9 (7) (2012) e1001255, https://doi.org/10.1371/journal.pmed.1001255.
[7] AOAC, Association of Official Analytical Chemist, Official Methods of Analysis, eighteenth ed., AOAC international, Gaithersburg, Maryland, USA, 2005, pp. 20877–22417, suite 500, 481 north Frederick avenue.
[8] H. Egan, R.S. Kirk, R. Sawyer, Pearson's Chemical Analysis of Foods, eighth ed., Churchill Livingstone, Edinburgh, Scotland, 1981.
[9] V. Gressler, N.S. Yokoya, M.T. Fujii, P. Colepicolo, J.M. Filho, R.P. Torres, E. Pinto, Lipid, fatty acid, protein, amino acid and ash contents in four Brazilian red algae species, Food Chem. 120 (2010) 585–590.

[10] S.S. Radwan, Coupling of two-dimensional thin-layer chromatography with gas chromatography for the quantitative analysis of lipid classes and their constituent fatty acids, J. Chromatogr. Sci. 16 (11) (1978) 538–542, https://doi.org/10.1093/chromsci/16.11.538.
[11] E. Csomos, L. Simon-Sarkadi, Characterisation of Tokaj wines based on free amino acids and biogenic amines using ion-exchange chromatography, Chromatographia 56 (2002) 185–188, https://doi.org/10.1007/BF02494136.
[12] N.U. Amin, A. Hussain, S. Alamzeb, S. Begum, Accumulation of heavy metals in edible parts of vegetables irrigated with waste water and their daily intake to adults and children, District Mardan, Pakistan, Food Chem. 136 (3–4) (2013) 1515–1523, https://doi.org/10.1016/j.foodchem.2012.09.058.
[13] K. Hua, L. Liu, D. P Bureau, Determination of phosphorus fractions in animal protein ingredients, J. Agric. Food Chem. 53 (5) (2005) 1571–1574, https://doi.org/10.1021/jf048401b.
[14] P. Romero, C. Nalda Robert, S. Paz Masson, L. Lilia, Pineda, Rafael, Fatty and proximal acid composition of seven species of fish from Easter Island, Arch. Latinoam. Nutr. 50 (3) (2000) 304–308. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0004-06222000000300016&lng=es&tlng=es. (Accessed 16 September 2023).
[15] E.I. Adeyeye, T. Jegede, Z. Mashood, Proximate, mineral and mineral safety index of *Acanthurus monroviae* and *Lutjanus goreensis* fishes, JBINO 5 (1) (2016) 107–122. ISSN 2277-8330 (Electronic).
[16] R.G. Ackman, Seafood lipids and fatty acids, Food Rev. Int. 6 (4) (1990) 617–646, https://doi.org/10.1080/87559129009540896.
[17] L. Fishelson, W.L. Montgomery, A.A. Jr Myrberg, Biology of surgeonfish Acanthurus nigrofuscus with emphasis on changeover in diet and annual gonadal cycles, Mar. Ecol. Prog. Ser. 39 (1987) 37–47.
[18] W. Montgomery, T. Umino, H. Nakagawa, I. Vaughn, T. Shibuno, Lipid storage and composition in tropical surgeonfishes Teleostei, Acanthuridae Mar Biol 133 (1999) 137–144, https://doi.org/10.1007/s002270050452.
[19] P.B. Addis, T.P. Carr, C.A. Hassel, Z.Z. Huang, G.J. Warner, Atherogenic and anti-atherogenic factors in the human diet, Biochem. Soc. Symp. 61 (1995) 259–271, https://doi.org/10.1042/bss0610259.
[20] F. Zhao, P. Zhuang, C. Song, Z. Shi, L. Zhang, Amino acid and fatty acid compositions and nutritional quality of muscle in the pomfret, *Pampus punctatissimus*, Food Chem. 118 (2) (2010) 224–227, https://doi.org/10.1016/j.foodchem.2009.04.110.
[21] S. Venn-Watson, R. Lumpkin, E.A. Dennis, Efficacy of dietary odd-chain saturated fatty acid pentadecanoic acid parallels broad associated health benefits in humans: could it be essential? Sci. Rep. 10 (1) (2020) 8161, https://doi.org/10.1038/s41598-020-64960-y.
[22] L.I. Hellgren, P. Nordby, Chapter 17 - bioactive lipids in dairy fat, in: Ronald Ross Watson, Robert J. Collier, Victor R. Preedy (Eds.), Dairy in Human Health and Disease across the Lifespan, Academic Press, 2017, pp. 233–237, https://doi.org/10.1016/B978-0-12-809868-4.00017-0. ISBN 9780128098684.
[23] A.P. Simopoulos, Omega-3 fatty acids in inflammation and autoimmune diseases, J. Am. Coll. Nutr. 21 (6) (2002) 495–505, https://doi.org/10.1080/07315724.2002.10719248.
[24] U. Hmso, Nutritional Aspects of Cardiovascular Disease (Report on Health and Social Subjects, HMSO, London, 1994. No. 46.
[25] B. Mohanty, A. Mahanty, S. Ganguly, T.V. Sankar, K. Chakraborty, A. Rangasamy, B. Paul, D. Sarma, S. Mathew, K.K. Asha, B. Behera, M. Aftabuddin, D. Debnath, P. Vijayagopal, N. Sridhar, M.S. Akhtar, N. Sahi, T. Mitra, S. Banerjee, P. Paria, D. Das, P. Das, K.K. Vijayan, P.T. Laxmanan, A.P. Sharma, Amino Acid compositions of 27 food fishes and their importance in clinical nutrition, J. Amino Acids (2014) 269797, https://doi.org/10.1155/2014/269797. Epub 2014 Oct 14. PMID: 25379285; PMCID: PMC4213980.G. Gencbay, S. Turhan, Proximate Composition and Nutritional Profile of the Black Sea Anchovy (Engraulis encrasicolus) Whole Fish, Fillets, and By-Products. J Aquat Food Prod 25: 6, (2016) 864-874.
[26] O. Ozden, Changes in amino acid and fatty acid composition during shelf-life of marinated fish, J. Sci. Food Agric. 85 (2005) (2005) 2015–2020, https://doi.org/10.1002/jsfa.2207.
[27] I.A. Khalil, S. Khan, Protein quality of Asian beans and their wild progenitor, *Vigna sublobata* (Roxb), Food Chem. 52 (1995) 327–330.
[28] FAO, Dietary protein quality evaluation in human nutrition. Report of an FAO Expert Consultation. Food and Nutrition, Food and Agriculture Organization of the United Nations Rome, Italy, 2013 paper 92.
[29] M. Brini, T. Calì, D. Ottolini, E. Carafoli, Intracellular calcium homeostasis and signaling, Met Ions Life Sci 12 (2013) 119–168, https://doi.org/10.1007/978-94-007-5561-1_5.
[30] Institute of Medicine, Food and Nutrition Board, Dietary Reference Intakes for Calcium and Vitamin D, National Academies Press, Washington, 2011.
[31] M.J.V. Clausen, H. Poulsen, Sodium/potassium homeostasis in the cell. Ch. 3, in: L. Banci (Ed.), Metallomics and the Cell (Metal Ions in Life Sciences 12), Springer, Dordrecht, 2013, p. 41.
[32] P. Siddhuraju, K. Becker, H.P.S. Makkar, Chemical composition, protein fractionation, essential amino acid potential and anti-metabolic constituents of an unconventional legume, Gila bean (Entada phaseoloides Merrill) seed kernel, J. Sci. Food Agric. 82 (2001) 192–202.
[33] V. Perez, T. Ellen, V. Chang, Sodium-to-potassium ratio and blood pressure, hypertension, and related factors, Adv. Nutr. 5 (2014) 712–741.
[34] V.C. Chaturvedi, R. Shrivastava, R.K. Upreti, Viral infections and trace elements: a complex interaction, Curr. Sci. 87 (2004) 1536–1554.
[35] Z.A. Karcioglu, Zinc in the eye, Surv. Ophthalmol. 27 (1982) 114–122.
[36] J. Coleman, Zinc proteins: enzymes, storage proteins, transcription factors, and replication proteins, Annu. Rev. Biochem. 61 (1992) 897–946.
[37] M.L. Failla, M.A. Johnson, J.R. Prohaska, Copper. Ch. 35, in: B.A. Bowamn, R.M. Russell (Eds.), Present Knowledge in Nutrition, ILSI Press, Washington, 2001, p. 373.
[38] L.M. Kelvay, Cu dietary and risk of coronary heart disease, Am. J. Clin. Nutr. 71 (2000) 1213–1214.
[39] J.S. Sands, M.O. Smith, Effects of dietary manganese proteinate or chromium picolinate supplementation on plasma insulin, glucagon, glucose and serum lipids in broiler chickens reared under thermoneutral or heat stress conditions, Int. J. Poultry Sci. 1 (5) (2002) 145–149, https://doi.org/10.3923/ijps.2002.145.149.
[40] W. Mertz, Chromium in human nutrition: a review, J. Nutr. 123 (1993) 626–633.
[41] L. Chapple, G.R. Brock, M.R. Milward, N. Ling, J.B. Matthews, Compromised GCF total antioxidant capacity in periodontitis: cause or effect? J. Clin. Periodontol. 34 (2) (2007) 103–110.
[42] C.O. Enwonwu, R.S. Phillips, Jr W.A. Falkler, Nutrition and oral infectious diseases: state of the science, Comp. Cont. Educ. Dent. 23 (5) (2002) 431–448.