

Research Article

Proximate composition and amino acid profile of the whole body of juvenile Persian sturgeon (*Acipenser persicus*)N. Arab¹, M. Shamsaei Mehrgan^{1,*}, F. Foroudi², M. Soltani³, M. Chamani⁴¹ Department of Fisheries, Science and Research Branch, Islamic Azad University, Tehran, Iran² Department of Animal Science, Islamic Azad University, Varamin-Pishva Branch, Varamin, Iran³ Department of Aquatic Animal Health, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran⁴ Department of Animal Science, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Abstract

The main objective of the current study was to analyze the proximate composition and the amino acid profile of the Persian sturgeon (*Acipenser persicus*). Forty-eight fish (with an initial weight of 96.60 ± 7.45 g) were randomly sampled from a local sturgeon farm in Mazandaran, Iran. The proximate analysis of the fish body showed 24.38 ± 1.62 g/100g ww of dry matter, 61.52 ± 1.65 g/100g dw of crude protein, 10.53 ± 0.18 g/100g dw of lipid, 16.48 ± 1.3 g/100g dw of ash, 0.94 ± 0.03 % of NH₃, and 2.45 ± 0.18 % of phosphorus. The essential and non essential amino acid composition provided the following values: Methionine: 1.57 ± 0.06 %, Threonine: 2.34 ± 0.08 %, Tryptophan: 0.56 ± 0.02 %, Arginine: 3.37 ± 0.12 %, Histidine: 1.32 ± 0.02 %, Isoleucine: 2.35 ± 0.05 %, Leucine: 4.27 ± 0.32 %, Lysine: 4.34 ± 0.27 %, Valine: 2.71 ± 0.09 %, Phenylalanine:

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2.22 ± 0.07 %, Glycine: 5.12 ± 0.17 %, Serine: 2.43 ± 0.05 %, Proline: 3.11 ± 0.06 %, Alanine: 3.85 ± 0.09 %, Cysteine: 0.53 ± 0.15 %, Asparagine: 5.08 ± 0.2 %, and Glutamine: 7.63 ± 0.16 % dry weight. Compared to a number of international standards for evaluating sturgeon body composition and amino acid profile, the present study showed identical results in sturgeon farms to those released by FAO in 2011. Overall, the Persian sturgeon is not only an invaluable source of protein (i.e., essential and non-essential amino acids), but it can also assist farmers and researchers in formulating fish diets based on their real nutrition needs.

Keywords: Proximate composition, Essential amino acid, Non-essential amino acid, Persian sturgeon, Nutritional value

Introduction

The proximate composition is a term usually used in the field of nutrition, mainly for components including moisture, protein, fat,

ash, and carbohydrates, which are expressed as content percentage (Hussain *et al.*, 2018; Hosseini Shekarabi *et al.*, 2020). The proximate composition and amino acid profile of fish should be evaluated to enhance the health status of the animal during the culturing period, while they are also necessary to determine the processing suitability of the final product (Hussain *et al.*, 2018). Numerous studies have demonstrated a relationship between the whole-body amino acids and an amino acid pattern for different fish species (Borlongan and Coloso, 1993; Mambrini and Kaushik, 1995; Mente *et al.*, 2002; Hosseini Shekarabi *et al.*, 2021). A positive correlation between the concentration of essential amino acids in the fish body and tissues and that of the feed regime was suggested by Cowey (1994), who conducted a similar study on this topic. These nourishing ingredients play an important role in the synthesis, the metabolism, and the immune response. For instance, glutamine performs a very important function in detoxification and excretion of toxic metabolites (Ip and Chew, 2010). In addition, methionine is one of the most important essential amino acids, which plays a key role in stimulating protein synthesis, preventing the green liver syndrome, increasing cell survival, and improving digestibility and growth (Espe *et al.*, 2008). Furthermore, leucine can increase resistance against diseases, especially under stressful conditions, such as during the breeding seasons, migration periods, and artificial cultivation (Machado *et al.*, 2019). Therefore, the evaluation of both essential and non-

essential amino acids can assist farmers and researchers in formulating a balanced diet, which meets the majority of the nutritional requirements of the fish (Wu *et al.*, 2013).

Fish possess high levels of total protein, essential amino acids, and fatty acids, and they are one of the most important sources of animal protein in the world (Okland *et al.*, 2005; Suvitha *et al.*, 2014; King *et al.*, 1990; Desai *et al.*, 2018;). While fish are considered as a reliable source of these nourishing ingredients, they differ from species to species in terms of the quality and quantity of such amino acids. The difference can be ascribed to age, the feeding regime, the species, environmental conditions, the hunting season, and sex (FAO, 2002; Suvitha *et al.*, 2014). Amino acids act as the building blocks of proteins, and as an intermediate in metabolism; hence, it is necessary to supplement the diet with sufficient protein to improve growth, survival, development, and reproduction, and to maintain health (Suvitha *et al.*, 2014). The composition of amino acids in fish and shellfish is not only important as an indicator for determining their nutritional value, but it is also important for the amelioration of both the quantity and the quality of these substances in fish products. However, free amino acids belong to non-protein nitrogen parts in crustaceans and fish, which are used as an index to evaluate the taste of fish and bivalves (Ikeda, 1980; Konosu and Yamaguchi, 1982). Some peptides and free amino acids function as flavoring materials (Kato *et al.*, 1989), many of which, such as alanine, glycine, and glutamic acid, are

responsible for the taste of the food (Yamanaka and Shimada, 1996). Extensive research has been conducted to determine the proximate composition and the amino acid profile of various fish species (Osibona *et al.*, 2006; Nurnadia *et al.*, 2013; Shirai *et al.*, 2002; Mol and Turan, 2008; Gunlu and Gunlu, 2014; Costa *et al.*, 2018); however, very limited data is available on sturgeons' amino acids profiles. The Persian sturgeon (*Acipenser persicus*) inhabits the southern and southwestern parts of the Caspian Sea, and it is one of the most important species because of its unique ecological and biological features (Afraei *et al.*, 2006). The fish has recently been introduced as a new cultivable species (Agh *et al.*, 2013). However, the morbidity and mortality of cultured fish can be high, which requires focusing on the nutritional requirements of the fish (Folorunso *et al.*, 2017; Shefat, 2018). Since there is no comprehensive report on the proximate composition of the Persian sturgeon, such research can provide nutritional data and fundamental information for the improvement of the health status of artificially-cultivated fish, and the compound feeding of this essential commercial fish. Hence, the present study investigates the proximate composition and amino acid profile of the whole body of the Persian sturgeon.

Materials and methods Fish samples

A total of 48 Persian sturgeons (96.60 ± 7.45 g and 31.36 ± 0.91 cm) were randomly selected from 24 pools (2 fish per pool) in the Qhareh-Boron Sari Cultivation Center in Hossein Abad, Mazandaran, Iran. In terms of the

physicochemical parameters of the water, its temperature was determined in the range of 18.2 to 18.6 °C, its dissolved oxygen was measured near saturation at 8.5 mg/L, its pH was shown to be in a neutral range of 7.47 to 7.56, its electrical conductivity (EC) was measured at 760.66 μ S/cm, and NH₃, NH₄, NO₃, and NO₂ were not significant. The fish were kept on ice with a ratio of 2:1 (w/w) and transferred to the Zakariya-Razi Laboratory, Tehran, Iran.

Proximate composition analysis

Proximate composition analysis was carried out according to the AOAC (1995) procedure. The fish were minced separately and dried in an oven (ED 115, Binder, Germany) for 24 hours at 60 °C. The dried samples were reweighted and kept in a freezer at -20 °C until the quantitative analysis of the lipids and proteins. The defined fractions of the proximate composition (i.e., protein, total lipid, ash, phosphorus, and NH₃) were measured using transmission spectra from a FoodScan NIR spectrophotometer (FOSS NIRSystems, Hillerød, Denmark) (Fontaine *et al.*, 2001), and the data were expressed as 91% dry matter.

Amino acids profile

Transmission spectra from a FoodScan NIR spectrophotometer (FOSS NIRSystems, Hillerød, Denmark) were used to analyze the amino acid profile of the samples (Fontaine *et al.*, 2001). In summary, after the extraction of lipids from the oven-dried samples, the extraction mixture was centrifuged at 14560 g for 20 minutes at 30 °C to separate the lipids. Then, the

FoodScan NIR spectrophotometer was calibrated, and the amino acids were measured through scanning and radiation at different wavelengths in the near-infrared range. The spectrum was matched with the calibration result of the high-performance liquid chromatography (HPLC; Evonik, Germany).

Statistical analysis

Data analysis was performed in SPSS (version 20). All findings are expressed in the form of

mean \pm standard deviation (SD). The Kolmogorov–Smirnov test was used to assess the normality and homogeneity of the data. Significant differences were determined using one-way ANOVA, followed by Duncan's test to compare the differences between the experimental fish groups. Differences were considered statistically significant when $p < 0.05$.

Table 1. Body composition, NH₃ and Phosphorus of Persian sturgeon, *Acipenser persicus*

	Dry matter (g/100 g ww)	Crude protein (g/100 g dw)	Ether extract (g/100 g dw)	Ash (g/100 g dw)	NH ₃ (%)	Phosphorus (%)
1	25.90±0.08	62.53±0.67	10.20±1.41	16.13±0.14	0.94±0.002	1.26±1.75
2	27.20±2.88	57.84±1.98	13.04±2.47	16.72±0.67	0.91±0.01	2.48±0.12
3	25.29±1.18	61.41±2.64	10.80±1.32	16.29±1.28	0.97±0.05	2.39±0.02
4	26.36±2.28	59.62±2.27	12.45±0.10	16.95±0.12	0.92±0.05	2.47±0.14
5	27.20±3.71	61.54±1.19	10.32±0.49	16.39±0.10	0.98±0.03	2.42±0.25
6	22.12±2.30	62.91±0.30	9.40±0.07	16.18±0.02	1.04±0.06	2.28±1.32
7	26.17±0.53	62.36±1.07	11.10±0.49	16.03±0.55	0.98±0.04	2.32±0.17
8	25.66±4.10	63.02±0.78	10.48±1.06	15.70±0.004	0.98±0.03	2.32±0.04
9	24.37±0.97	61.13±1.12	9.82±0.42	15.66±1.32	0.96±0.002	2.42±0.26
10	25.78±1.12	62.23±1.72	10.30±1.97	15.72±0.47	0.98±0.01	2.21±0.28
11	24.05±3.27	60.38±2.47	10.38±0.21	17.07±0.87	1.00±0.07	2.39±0.12
12	26.24±0.35	61.58±0.38	9.13±1.34	16.59±1.41	0.98±0.033	2.53±0.28
13	21.41±2.95	62.36±0.007	9.60±2.89	16.76±2.03	0.97±0.009	2.35±0.19
14	22.55±2.42	62.44±1.67	9.10±0.84	17.02±2.07	0.95±0.06	2.47±0.35
15	23.51±1.47	61.27±0.40	10.15±0.28	16.73±0.66	1.01±0.05	2.56±0.06
16	24.24±0.35	61.74±1.10	9.21±0.70	17.38±0.16	0.94±0.03	2.46±0.10
17	26.17±1.29	60.98±1.12	10.91±0.56	16.17±1.17	0.95±0.03	2.46±0.28
18	25.39±0.64	61.34±1.56	11.03±1.62	16.37±0.62	1.00±0.009	2.40±0.13
19	29.54±1.38	61.04±1.08	11.80±1.20	16.14±0.06	1.01±0.04	2.39±0.12
20	26.24±0.29	58.30±3.11	11.13±0.11	16.43±0.24	0.97±1.01	2.40±0.08
21	22.22±2.54	62.82±0.53	10.30±0.63	15.94±1.17	0.98±0.07	2.35±0.20
22	26.88±1.37	62.32±4.36	11.53±4.59	15.88±1.28	0.96±0.04	2.32±0.22
23	27.69±2.82	58.97±5.35	10.43±0.11	15.80±0.35	0.92±0.07	2.33±0.07
24	28.90±2.14	57.99±4.35	12.82±0.12	15.94±0.49	0.94±0.05	2.32±0.05

w.w. = wet weight; d.w.= dry weight.

Results are presented as means \pm SD ($n=2$), SD = Standard Deviation. Similar letters in the same column show no significant difference between results for each treatment ($P>0.05$).

Table 2. Whole body essential amino acid concentration (% dry weight) profile Persian sturgeon (*Acipenser persicus*)

	Methionine	Threonine	Tryptophan	Arginine	Histidine	Isoleucine	Leucine	Lysine	Valine	Phenylalanine	Sum
1	1.63±0.01	2.42±0.02	0.59±0.008	3.52±0.02	1.40±0.01	2.39±0.02	4.28±0.05	4.56±0.06	2.86±0.03	2.27±0.03	25.96
2	1.52±0.02	2.22±0.06	0.53±0.02	3.24±0.15	1.28±0.09	2.17±0.03	3.84±0.09	4.11±0.21	2.58±0.04	2.03±0.06	23.56
3	1.60±0.10	2.34±0.14	0.56±0.04	3.43±0.13	1.31±0.02	2.34±0.19	4.14±0.32	4.48±0.31	2.76±0.20	2.18±0.15	25.18
4	1.50±0.01	2.27±0.04	0.53±0.004	3.35±0.05	1.30±0.02	2.24±0.08	3.99±0.16	4.16±0.16	2.68±0.11	2.11±0.07	24.18
5	1.53±0.04	2.33±0.05	0.54±0.01	3.42±0.13	1.31±0.007	2.33±0.06	4.13±0.13	4.37±0.05	2.77±0.09	2.16±0.06	24.94
6	1.60±0.07	2.35±0.06	0.56±0.01	3.33±0.16	1.29±0.06	2.38±0.03	4.22±0.07	4.46±0.18	2.82±0.03	2.21±0.04	25.26
7	1.62±0.04	2.41±0.08	0.57±0.01	3.54±0.21	1.35±0.08	2.39±0.03	4.25±0.08	4.49±0.19	2.84±0.03	2.23±0.05	25.73
8	1.61±0.00	2.42±0.01	0.58±0.006	3.53±0.07	1.39±0.009	2.40±0.02	4.28±0.03	4.55±0.04	2.85±0.01	2.26±0.01	25.92
9	1.56±0.03	2.32±0.06	0.53±0.02	3.47±0.01	1.26±0.04	2.31±0.06	4.10±0.12	4.34±0.08	2.75±0.07	2.15±0.05	24.82
10	1.59±0.002	2.37±0.04	0.57±0.008	3.43±0.13	1.31±0.06	2.38±0.06	4.24±0.08	4.43±0.21	2.84±0.04	2.22±0.05	25.43
11	1.52±0.13	2.29±0.15	0.53±0.05	3.32±0.24	1.23±0.10	2.30±0.17	4.07±0.29	4.18±0.45	2.76±0.15	2.15±0.14	24.39
12	1.51±0.02	2.29±0.006	0.55±0.008	3.31±0.07	1.31±0.02	2.31±0.01	4.09±0.03	4.31±0.08	2.76±0.04	2.16±0.01	24.64
13	1.61±0.03	2.37±0.05	0.56±0.03	3.49±0.003	1.32±0.05	2.36±0.05	4.19±0.10	4.48±0.03	2.81±0.07	2.21±0.03	25.44
14	1.62±0.05	2.40±0.07	0.57±0.03	3.56±0.01	1.36±0.00	2.38±0.15	4.23±0.24	4.56±0.13	2.83±0.16	2.39±0.10	25.78
15	1.53±0.02	2.26±0.05	0.54±0.002	3.28±0.21	1.30±0.03	2.26±0.004	4.01±0.03	4.31±0.09	2.67±0.01	1.12±0.01	24.31
16	1.57±0.02	2.35±0.01	0.55±0.03	3.49±0.02	1.32±0.04	2.31±0.04	4.13±0.06	4.40±0.04	2.80±0.03	2.19±0.01	25.13
17	1.54±0.02	2.33±0.05	0.56±0.03	3.41±0.06	1.34±0.02	2.32±0.07	4.12±0.14	4.36±0.007	2.76±0.11	2.17±0.08	24.95
18	1.58±0.06	2.34±0.04	0.55±0.02	3.41±0.02	1.28±0.009	2.34±0.09	4.13±0.16	4.31±0.22	2.79±0.07	2.18±0.08	24.94
19	1.56±0.01	2.29±0.009	0.54±0.002	3.32±0.01	1.29±0.001	2.32±0.04	4.09±0.06	4.36±0.07	2.75±0.04	2.13±0.09	24.69
20	1.46±0.05	2.20±0.12	0.53±0.02	3.10±0.25	1.25±0.04	2.19±0.13	3.90±0.23	4.00±0.26	2.63±0.16	2.04±0.14	23.33
21	1.60±0.02	2.40±0.02	0.58±0.009	3.48±0.17	1.35±0.02	2.39±0.04	4.26±0.05	4.48±0.06	2.86±0.04	2.25±0.02	25.69
22	2.24±0.13	2.83±0.13	4.60±0.31	4.27±0.23	2.41±0.11	1.37±0.03	3.53±0.23	0.58±0.02	2.42±0.11	1.65±0.05	25.94
23	1.53±0.10	2.26±0.20	0.54±0.04	3.28±0.31	1.30±0.04	2.24±0.23	3.97±0.42	4.20±0.40	2.65±0.29	2.09±0.22	24.11
24	1.53±0.11	2.24±0.19	0.54±0.04	3.24±0.33	1.27±0.68	2.22±1.13	3.92±0.59	4.14±0.43	2.63±0.80	3.42±2.11	23.21

Results are presented as means±SD ($n=2$), SD = Standard Deviation. Similar letters in the same column show no significant difference between results for each treatment ($P>0.05$).

Table 3. Whole body non-essential amino acid concentration (% dry weight) profile Persian sturgeon (*Acipenser persicus*)

	Glycine	Serine	Proline	Alanine	Cysteine	Asparagine	Glutamine	Sum
1	5.11±0.03	2.52±0.01	3.15±0.05	3.93±0.05	0.56±0.01	5.41±0.08	7.94±0.14	28.64
2	4.94±0.30	2.34±0.05	2.99±0.16	3.68±0.18	0.49±0.01	4.86±0.22	7.14±0.32	26.47
3	5.09±0.18	2.49±0.12	3.12±0.05	3.90±0.007	0.55±0.04	5.21±0.36	7.67±0.49	28.03
4	5.16±0.08	2.40±0.06	3.15±0.09	3.79±0.12	0.52±0.02	4.98±0.12	7.62±0.15	27.41
5	5.19±0.12	2.48±0.05	3.22±0.02	3.87±0.007	0.54±0.02	5.14±0.11	7.62±0.15	28.08
6	4.97±0.13	2.46±0.07	3.07±0.09	3.94±0.03	0.55±0.02	5.22±0.19	7.73±0.73	27.97
7	5.13±0.30	2.56±0.09	3.19±0.13	3.88±0.10	0.55±0.005	5.31±0.22	7.79±0.29	28.44
8	5.09±0.05	2.54±0.04	3.18±0.02	3.93±0.07	0.56±0.01	5.37±0.01	7.89±0.07	28.59
9	5.27±0.17	2.51±0.03	3.20±0.05	3.85±0.04	0.54±0.01	5.12±0.11	7.57±0.18	28.10
10	5.01±0.22	2.49±0.04	3.12±0.15	3.90±0.10	0.55±0.01	5.25±0.16	7.79±0.20	28.14
11	4.97±0.06	2.40±0.16	3.10±0.05	3.74±0.17	0.54±0.03	5.02±0.41	7.43±0.54	27.21
12	5.14±0.21	2.40±0.01	3.18±0.05	3.90±0.05	0.54±0.001	5.09±0.07	7.57±0.10	27.85
13	5.16±0.29	2.52±0.30	3.17±0.08	3.93±0.05	0.55±0.003	5.28±0.05	7.80±0.05	28.45
14	5.25±0.33	2.54±0.04	3.24±0.09	3.95±0.01	0.56±0.02	5.35±0.14	7.87±0.19	28.80
15	5.14±0.28	2.37±0.10	3.10±1.32	3.89±0.06	0.52±0.01	5.01±0.13	7.42±0.19	27.49
16	5.27±0.05	2.49±0.05	3.23±0.007	3.90±0.04	0.55±0.008	5.22±0.04	7.74±0.10	28.43
17	5.05±0.32	2.45±1.32	3.14±0.12	3.82±0.01	0.54±0.01	5.15±0.08	7.59±0.14	27.76
18	5.03±0.02	2.48±0.04	3.15±0.02	3.81±0.14	0.54±0.02	5.13±0.17	7.56±0.27	27.73
19	5.00±0.009	2.42±0.02	3.07±0.01	3.81±0.04	0.52±0.00	5.05±0.04	7.41±0.05	27.32
20	4.70±0.23	2.28±0.10	2.93±0.18	3.63±0.16	0.51±0.03	4.75±0.33	7.07±0.48	25.90
21	5.11±0.33	2.51±0.07	3.17±0.11	3.92±0.03	0.55±0.01	5.32±0.07	7.58±0.09	28.46
22	5.04±0.45	2.52±0.11	3.10±0.26	3.91±0.30	0.55±0.04	5.38±0.36	7.89±0.64	28.45
23	4.91±0.23	2.38±0.20	3.01±0.22	3.75±0.25	0.51±0.07	4.94±0.51	7.27±0.78	26.80
24	4.79±1.12	2.63±0.60	2.95±0.16	3.64±0.18	0.50±0.05	4.88±0.49	7.16±0.66	25.65

Results are presented as means±SD ($n=2$), SD = Standard Deviation. Similar letters in the same column show no significant difference between results for each treatment ($P>0.05$).

Result

The proximate composition of the Persian sturgeon demonstrated no significant difference between the fish breeding ponds ($p>0.05$). The dry matter, total protein, ether extract, ash, NH₃, and phosphorus contents showed the values in the range of 24.38±1.62 g/100g ww, 61.52 ± 1.65 g/100g dw, 10.53 ± 0.18 g/100g dw, 16.48 ± 1.3 g/100g dw; 0.94 ± 0.03 %; and 2.45 ± 0.18 %, respectively (Table 1).

The highest and lowest concentrations of the essential amino acids showed for Methionine 1.57 ± 0.06 %, Threonine 2.34 ±

0.08 %, Tryptophan 0.56 ± 0.02 %, Arginine 3.37 ± 0.12 %, Histidine 1.32 ± 0.02 %, Isoleucine 2.35 ± 0.05 %, Leucine 4.27 ± 0.32 %, Lysine 4.34 ± 0.27 %, Valine 2.71 ± 0.09 %, Phenylalanine 2.22 ± 0.07 %, Glycine 5.12 ± 0.17 % dry weight (Table 2). Moreover, non-essential amino acids exhibited a range of concentrations in Persian sturgeon as follows: Serine 2.43 ± 0.05 %, Proline 3.11 ± 0.06 %, Alanine 3.85 ± 0.09 %, Cysteine 0.53 ± 0.15 %, asparagine 5.08 ± 0.2 % and Glutamine 7.63 ± 0.16 % dry weight. (Table 3).

Discussion

The whole body composition of the fish is investigated to evaluate their survival in nature, determine their nutritional requirements, and measure the nutrients (Jobling, 1980; Hung *et al.*, 1987). The nature and quality of the nutrients in most animal carcasses, such as fish, depend on their diet and habitat (Adewoye and Omotosho, 1997). Considering the significant role of amino acids in protein synthesis, Phillips and Brockway (1956) showed that the nutritional value of proteins in the diet depended on their amino acid profile. Proteins and the amino acid composition of the fish are quite similar to those of terrestrial animals; however, fish muscles possess less structural fibers than the muscles of terrestrial animals (Hultin, 1985).

The proximate analysis of the fish body showed 24.38 ± 1.62 g/100g ww of dry matter, 61.52 ± 1.65 g/100g dw of crude protein, 10.53 ± 0.18 g/100g dw of lipid, 16.48 ± 1.3 g/100g dw of ash, 0.94 ± 0.03 % of NH₃, and 2.45 ± 0.18 % of phosphorus. The essential and non-essential amino acid composition provided the following values: Methionine: 1.57 ± 0.06 %, Threonine: 2.34 ± 0.08 %, Tryptophan: 0.56 ± 0.02 %, Arginine: 3.37 ± 0.12 %, Histidine: 1.32 ± 0.02 %, Isoleucine: 2.35 ± 0.05 %, Leucine: 4.27 ± 0.32 %, Lysine: 4.34 ± 0.27 %, Valine: 2.71 ± 0.09 %, Phenylalanine: 2.22 ± 0.07 %, Glycine: 5.12 ± 0.17 %, Serine: 2.43 ± 0.05 %, Proline: 3.11 ± 0.06 %, Alanine: 3.85 ± 0.09 %, Cysteine: 0.53 ± 0.15 %, Asparagine: 5.08 ± 0.2 %, and Glutamine: 7.63 ± 0.16 % dry weight.

Fresh fish meat contains up to 80% water, while the average moisture content of fatty fish is about 70%, and the highest amount of moisture has been measured in *Harpadon nehereus* (about 90%). Moisture in breeding sturgeon (*Acipenser spp.*) ranges from 65.93% to 77.59% (Badiani *et al.*, 1996), while the moisture content in young breeding sturgeon (*Acipenser transmontanus*) has been reported between 72.1 and 79.4% (Hung *et al.*, 1987). Similar findings were reported by Song *et al.* (2014), who measured the moisture in the muscle (72.07%) and bone (78.4%) tissues of female Chinese sturgeons (*Acipenser sinensis*). The present study shows that the amount of dry matter in the Persian sturgeon varies from 21.49% to 29.54%.

The fat content of the fish depends on their species and catch season. It should be noted that fish meat contains less fat than red meat, and the fat content in the fish body varies from 0.2% to 25%. The higher the amount of fat, the lower the amount of water content expected in the fish body. These fish-based nutrients play vital roles in the prevention of human diseases (Simopoulos, 1997). By comparison with the published data for a wide range of fish species, lipid content is slightly more important as 100 g of sturgeon flesh can provide high levels of energy. Badiani *et al.* (1996) categorized the sturgeon species as a medium-fat fish since fat only accounts for 5-15 percent of the fish weight. The present study showed that the fat content of the Persian sturgeon was in the range of 9.06%-

13.04% dry weight. The results of the current study corroborate the findings of a great number of previous works in this field. For example, the fat content for inbreeding sturgeon species, including *Acipenser spp.* and *Acipenser transmontanus*, was reported about 2.66-15.31 and 3.4-7.4 g kg⁻¹ of fresh fish, respectively (Badiani *et al.*, 1996; Hung *et al.*, 1987). Moreover, the composition analysis of the Siberian sturgeon indicated 12.57% fat in the fish muscles (Pyz-Lukasik and Paszkiewicz, 2018).

In the present study, the Persian sturgeon showed an ash content of 15.70 to 17.38% in dry weight. In line with this finding, previous studies have reported ash contents of 0.80-0.21 and 4.5-2.5 g per 100 g wet weigh in white sturgeon (*Acipenser transmontanus*) (Hung *et al.*, 1987) and female Chinese sturgeon (*Acipenser sinensis*) (Song *et al.*, 2014), respectively.

The protein content of the fish muscles usually ranges from 16 to 21 percent wet weight (Alam, 2007); however, values lower than 16% or higher than 28% have also been reported for some species (Pyz-lukasik and Paszkiewicz, 2018). The amino acid composition and digestibility of the fish protein range from about 85 to 95%. In addition to their high nutritional value, fish proteins have proper functional properties, such as water retention capacity, gel ability, emulsion, and tissue properties for products such as surimi. Among these properties, the water retention capacity and the gel ability are among the most important qualitative characteristics (Venugopal, 1995). According

to the results of the current study, the amount of protein in the body of the Persian sturgeon was 57.63-84.02% of dry weight. Pyz-Lukasik and Paszkiewicz (2018) reported the protein content in Siberian sturgeon muscle as 15.69% by wet weight. With regard to the total protein content, the Persian sturgeon showed high levels, and this finding is close to the results reported for the breeding sturgeon (*Acipenser spp.*; 17.60%- 17.01%) by Badiani *et al.* (1996). Many parameters, including species, body size, gender, food source, season, salinity, and temperature, can directly change the protein content and amino acid composition of the fish (Borresen, 1992).

Amino acid profiling of the Persian sturgeon demonstrated the highest percentage for glutamic acid (7.63 ± 0.16 %), followed by aspartic acid (5.08 ± 0.2 %), glycine (5.12 ± 0.17 %), and lysine (4.34 ± 0.27 %). Similar results have been reported by Iwasaki and Harada (1985), who measured the highest levels of aspartic acid, glutamic acid, and lysine in the fish muscles. A further supportive study reported the highest levels of glutamic acid, glycine, aspartic acid, and lysine in the whole body of sturgeon (Ng and Hung, 1994). Such amino acids can not only increase the resistance of the fish against diseases, but they can also lead to an increased rate of breeding, survival, and maturation during all life stages, including larvae, fingerlings, juvenile, and adults (Mohanty *et al.*, 2014).

Moreover, the amino acid glycine plays a vital role in metabolic regulation, increasing antioxidant activity and protein synthesis, and enhancing immunity and the treatment of

metabolic disorders (Wang *et al.*, 2013). The highest level of tryptophan has been detected in the Putitor mahseer (*Tor putitora*), while the Persian sturgeon showed 0.53-0.55% of the amino acid. Although the content of tryptophan is usually less than those of other amino acids, it is nutritionally essential as a precursor of vital metabolites, such as serotonin and nicotinamide. In aquaculture, extensive research has been performed to regulate and create a balance among different levels of tryptophan to support neuroendocrine and the immune system with a range of 0.3 to 1.3 % protein in the diet (Hoseini *et al.*, 2019). This evidence is in line with our findings, showing 0.56 ± 0.02 % dry weight tryptophan in the Persian sturgeon amino acid profile. Moreover, in the Persian sturgeon, histidine exhibited a range of 1.23-1.40, and the highest level of this amino acid was observed in *Catla catla* (5.3 g per 100 g protein). Histidine performs a function in protein metabolism, growth, tissue repair, hemoglobin synthesis, and the removal of pollutants, such as heavy metals (Nasset and Gatewood, 1954; Liao *et al.*, 2013). Evidence shows that histidine plays an integral role in tissue formation and repair, as well as the maintenance of osmoregulation and myelin sheaths, which are critical for migratory fish, including the Persian sturgeon (A. Khan, 2018). Threonine was detected in the range of 2.2% to 20.42% in the Persian sturgeon. This amino acid is the second limiting one in the maintenance after the sulfur-containing amino acids (Said and Hegste, 1970; Fuller *et al.*, 1989). This essential amino acid can improve the

antioxidant and immune capacities of the fish, as reported by Habte-Tsion *et al.* (2016), who conducted an experiment to modulate the immune response, the antioxidant status, and gene expressions of antioxidant enzymes and antioxidant-immune-cytokine-related signaling molecules in juvenile blunt snout bream (*Megalobrama amblycephala*) (Habte-Tsion *et al.*, 2016). These findings can be very crucial in fish nutrition, particularly for the Persian sturgeon since it always faces various challenging conditions in both natural and artificial cultivating environments.

The nutritional value of a protein depends on its similarity to the available amino acid profiles. Although this concept cannot be extended for the amino acids used for metabolic needs, it is a reasonable starting point for defining the requirements of essential amino acids in the diet (Gurure *et al.*, 2007). Determination of the essential amino acid requirements can help the animal to be more resistant to stressful conditions and infectious diseases. Since the Persian sturgeon is a new cultivable species, this data can provide a more practical and comprehensive view of the fish nutrient requirements, which will help researchers and farmers manage the health of the wild juvenile sturgeon stocks and farmed sturgeons under aquaculture conditions more efficiently and sustainably. Our findings also provided a new vision to show the importance of the balance in the process of diet formulation for the fish, especially for essential amino acids, whose role in synthesis and metabolism cannot be neglected.

According to the results of this study, the total protein of the Persian sturgeon is in a remarkable range compared to other fish, while the amino acid profile showed a rich source of nourishing ingredients for humans. FAO has already reported numerous findings pertaining to the high rate of protein in sturgeon, especially those who live in the Caspian Sea. Therefore, such findings confirm the results of the present study as the Persian sturgeon contains a large group of both essential and non-essential amino acids.

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Conflicts of interest

The authors have no actual or potential conflicts of interest to report.

References

- Adewoye, S.O. and Omotosho, J.S., 1997. Nutrient composition of some Freshwater Fishes in Nigeria. *Resources Comm Stock*, 333 pp.
- Afraei, M. A., Safari, R. and Salmani, A., 2006. Distribution and density of juvenile *Acipenser persicus* at the lower 10-meter depth of the southern Caspian Sea. *Journal of Applied Ichthyology*, 22, 108-110.
- Agh, N., Asgari, R. and Noori, F., 2013. Optimizing the co-feeding strategy of Persian

sturgeon (*Acipenser persicus*) larvae using *Artemia nauplii* and formulated diet. *International Journal of Aquatic Biology*, 1(4), 158–166.

Alam, N., 2007. Structure of Fish Muscles and Composition of Fish. Participatory Training of Trainers- A New Approach Applied in Fish Processing, June 2007, 329.

AOAC International. 1995. AOAC (Association of Official Analytical Chemists) International; Arlington; 16th edition. Volume 2.USA.

Badiani, A., Anfossi, P., Fiorentini, L., Gatta, P.P., Manfredeini, M., Nanni, N., Stipa, S. and Tolomelli, B., 1996. Nutritional composition of cultured sturgeon (*Acipenser* spp.). *Journal of Food Composition and Analysis*, 9, 171–190.

Borlongan, I.G. and Coloso, R.M., 1993. Requirements of juvenile milkfish (*Chanos chanos* Forsskal) for essential amino acids. *Journal of Nutrition*, 123, 125-132.

Borresen, T., 1992. Quality of wild and reared fish. In: Huss, H.H., Jacobsen M. and Liston, J., (Eds.). Quality assurance in the food industry. Elsevier, Amsterdam. pp: 1- 17.

Costa, D.C., Takata, R., de Souza e Silva, W., Bessonart, M., Gadea, H.L., Magnone, L. and Kennedy Luz, R., 2018. Description of amino acid and fatty acid content during the initial development of *Lophiosilurus alexandri* (Siluriformes: Pseudopimelodidae), a carnivorous freshwater catfish. *Neotropical Ichthyology*, 16(2), e180014. 1-10.

- Cowey, C.B., 1994. Amino acid requirements of fish: a critical appraisal of present values. *Aquaculture*, 124, 1-11.
- Desai, A.S., Beibeia, T., Margaret A. Brennan, M.A., Guo, X., Xin-An Zeng, X-A. and Brennan, Ch-S., 2018. Protein, amino acid, fatty acid composition, and in vitro digestibility of bread fortified with *Oncorhynchus tshawytscha* powder. *Nutrients*, 10, 1923. 3-17.
- Espe, M., Hevrøy, E. M., Liaset, B., Lemme, A. and El-Mowafi, A. 2008. Methionine intake affect hepatic sulphur metabolism in Atlantic salmon, *Salmo salar*. *Aquaculture*, 274(1), 132-141.
- FAO, 2003. The state of world fisheries and aquaculture.2002;<http://www.fao.org/docrep/005/y7300e/y7300e04.htm>.
- Fontaine, J., Hörr, J. and Schirmer. B., 2001. Near-infrared reflectance spectroscopy enables the fast and accurate prediction of the essential amino acid contents in soy, rapeseed meal, sunflower meal, peas, fishmeal, meat meal products, and poultry meal. *Journal of Agricultural and Food Chemistry*, 49, 57–66.
- Fuller, M.F., McWilliam, R., Wang, T.C. and Giles, L.R., 1989. The optimum dietary amino acid pattern for growing pigs. 2. Requirements for maintenance and tissue protein accretion. *British Journal of Nutrition*, 62, 255–267.
- Folorunso, L., Emikpe, B., Falaye, E. and Dauda, A. B. 2017. Evaluating Feed Intake of Fishes in Aquaculture Nutrition Experiments with Due Consideration of Mortality and Fish Survival. *Journal of Northeast Agricultural University (English Edition)*, 24(2), 45–50.
- Gunlu, A. and Gunlu, N., 2014. Taste activity value, free amino acid content and proximate composition of Mountain trout (*Salmo trutta macrostigma* Dumeril, 1858) muscles. *Iranian Journal of Fisheries Sciences*, 13(1), 58-72.
- Gurure, R., Atkinson, J. and Moccia, R.D., 2007. Amino acid composition of Arctic charr, *Salvelinus alpinus* (L.) and the prediction of dietary requirements for essential amino acids. *Aquaculture Nutrition*, 13, 266–272.
- Hultin, H.O., 1985. Characteristics of muscle tissue. In: Fennema, O.R. (Ed.), *Food Chemistry*, 2nd ed. Marcel Dekker, New York.
- Hung, S.S.O., Lutes, P.B., Conte, F.S., 1987. Carcass proximate composition of juvenile white sturgeon (*Acipenser transmontanus*). *Comparative Biochemistry and Physiology*, 88, 269-272.
- Hussain, B., Sultana, T., Sultana, S., Ahmed, Z., Shahid Mahboob, Sh., 2018. Study on the impact of habitat degradation on proximate composition and amino acid profile of Indian major carps from different habitats. *Saudi Journal of Biological Sciences*, 25, 755–759.
- Hoseini, S. M., Pérez-Jiménez, A., Costas, B., Azeredo, R. and Gestó, M. 2019. Physiological roles of tryptophan in teleosts: current knowledge and perspectives for future studies. *Reviews in Aquaculture*, 11(1), 3–24.
- Hosseini Shekarabi, S. P., Abbasi Monjezi, M., Shaviklo, A. R. and Hussein Mohamed,

H. M., 2020. Physicochemical properties, electrophoretic patterns, and sensory attributes of fish burger incorporated with shrimp, camel, and ostrich meats. *Journal of Aquatic Food Product Technology*, 29(9), 912-924.

Hosseini Shekarabi, S. P., Shamsaie Mehrgan, M., Banavreh, A., & Foroudi, F., 2020. Partial replacement of fishmeal with corn protein concentrate in diets for rainbow trout (*Oncorhynchus mykiss*): Effects on growth performance, physiometabolic responses, and fillet quality. *Aquaculture Research*, 52(1), 249-259.

Habte-Tsion, H. M., Ren, M., Liu, B., Ge, X., Xie, J. and Chen, R., 2016. Threonine modulates immune response, antioxidant status and gene expressions of antioxidant enzymes and antioxidant-immune-cytokine-related signaling molecules in juvenile blunt snout bream (*Megalobrama amblycephala*). *Fish and Shellfish Immunology*, 51, 189-199.

Ikeda, S., 1980. Other organic components and inorganic components. In: *Advances in Fish Science and Technology*, J.J. Connell (Ed.), Fishing News Books Ltd., Farnham, Surrey, pp. 111-124.

Ip, Y. K. and Chew, S. F., 2010. Ammonia production, excretion, toxicity, and defense in fish: A review. *Frontiers in Physiology*, 1, 1-20.

Iwasaki, M. and Harada, R., 1985. Proximate and amino acid composition of the roe and

muscle of selected marine species. *Journal of Food Science*, 50, 1585-1587.

Jobling, M., 1980. Effects of starvation on proximate chemical composition and energy utilization on plaice, *Pleuronectes platessa* L. *Journal of Fish Biology*, 17, 325-334.

Kato, H., Rhue, M. R. and Nishimura, T., 1989. Role of free amino acids and peptides in food taste. in: R. Teranishi, R.G. Buttery, F. Shahidi (Eds.), *Flavor chemistry trends and developments*, ACS Symposium Series, American Chemical Society, Washington, DC, 158P.

Khan, A. M., 2018. Histidine Requirement of Cultivable Fish Species: A Review. *Oceanography & Fisheries Open Access Journal*, 8(5), 1-7.

King, I., Childs, M.T., Dorsett, C., Ostrander, J.G. and Monsen, E.R., 1990. Shellfish: Proximate composition, minerals, fatty acids, and sterols. *Journal of the American Dietetic Association*, 90, 677-685.

Konosu, S. and Yamaguchi, K., 1982. The flavor components in fish and shellfish. In: Martin RE, Flick GJ, Ward DR (eds). *Chemistry & Biochemistry of Marine Food Products*. AVI Publishing, Westport. 367- 404.

Liao, S.M., Du, Q.S., Meng, J.Z., Pang, Z.W. and Huang, R.B., 2013. The multiple roles of histidine in protein interactions. *Chemistry Central Journal*, 7, 44.

Machado, M., Azeredo, R., Domingues, A., Fernandez-Boo, S., Dias, J., Conceição, L. E.

- C. and Costas, B., 2019. Dietary tryptophan deficiency and its supplementation compromises inflammatory mechanisms and disease resistance in a teleost fish. *Scientific Reports*, 9(1), 1–15.
- Mambrini, M. and Kaushik, S.J., 1995. Indispensable amino acid requirements of fish: correspondence between quantitative data and amino acid profiles of tissue protein. *Journal of Applied Ichthyology*, 11, 240–247.
- Mente, E., Coutteau, P., Houlihan, D., Davidson, I. and Sorgeloos, P., 2002. Protein turnover, amino acid profile and amino acid flux in juvenile shrimp *Litopenaeus vannamei*: effects of dietary protein source. *The Journal of Experimental Biology*, 205, 3107–3122.
- Mol, S. and Turan, S., 2008. Comparison of proximate, fatty acid and amino acid compositions of various types of fish roes. *International Journal of Food Properties*, 11, 669–677.
- Mohanty, B., Mahanty, A., Ganguly, S., Sankar, T. V., Chakraborty, K., Rangasamy, A., Paul, B., Sarma, D., Mathew, S., Asha, K. K., Behera, B., Aftabuddin, M., Debnath, D., Vijayagopal, P., Sridhar, N., Akhtar, M. S., Sahi, N., Mitra, T., Banerjee, S., Paria, P., Das, D., Das, P., Vijayan, D.D., Laxmanan, P.T. and Sharma, A. P., 2014. Amino Acid Compositions of 27 Food Fishes and Their Importance in Clinical Nutrition. *Journal of Amino Acids*, 3, 1-7.
- Nasset, E.S. and Gatewood, V.H., 1954. Nitrogen balance and hemoglobin of adult rats fed amino acid diets low in L- and D-histidine. *Journal of Nutrition*, 53,163–176.
- Ng, W.K. and Hung, S.O., 1994. Amino acid composition of the whole body, egg and selected tissues of white sturgeon (*Acipenser transmontanus*). *Aquaculture*, 126, 329-339.
- Nurnadia, A.A., Azrina, A., Amin, I., Mohd Yunus, A.S. and Mohd Izuan Effendi, H., 2013. Mineral contents of selected marine fish and shellfish from the west coast of Peninsular Malaysia. *International Food Research Journal*, 20(1), 431-437.
- Okland, H. M. W., Stoknes, I. S., Remme, J. F., Kjerstad, M. and Synnes, M., 2005. Proximate composition, fatty acid and lipid class composition of the muscle from deep-sea teleosts and elasmobranches. *Comparative Biochemistry and Physiology*, Part B, 140, 437-443.
- Osibona, A.O., Kusemiju, K. and Akande, G.R., 2006. Proximate composition and fatty acids profile of the African Catfish *Clarias gariepinus*. *Journal of acta SATECH*, 3(1), 85-89.
- Phillips, A.M. and Brockway, D.R., 1956. The nutrition of trout, II. Protein and carbohydrate. *Pro qve Fish Culture*, 18, 383-390.
- Pyz-Lukasik, R. and Paszkiewicz, W., 2018. Species variations in the proximate composition, amino acid profile, and protein

quality of the muscle tissue of grass carp, bighead carp, Siberian sturgeon, and wels catfish. *Journal of Food Quality*, 1-8.

Said, A.K. and Hegsted, D.M., 1970. The response of adult rats to low dietary levels of essential amino acids. *Journal of Nutrition*, 100, 1363–1376.

Shirai, N., Terayama, M. and Takeda, H., 2002. Effect of season on the fatty acid composition and free amino acid content of the sardine *Sardinops melanostictus*. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, 131(3), 387-393.

Shefat, S.H.T., 2018. Nutritional Diseases of Fish in Aquaculture and Their Management: A Review Acta Scientific Pharmaceutical Sciences (ISSN: 2581-5423) Nutritional Diseases of Fish in Aquaculture and Their Management: A Review. 2, 50–58.

Simopoulos, A.P., 1997. Omega-6/Omega-3 Fatty acid ratio and trans fatty acids in noninsulin-dependent diabetes mellitus, in lipids and syndromes of insulin resistance. From molecular biology to clinical medicine (Klimes, I., Haffner, S.M., Sebokova, E., Howard, B.V. and Storien, L.H. eds.) *Annals of the New York Academy of Sciences*, 827, 327–338.

Song, C., Zhuang, P., Zhang, L.Z., Zhang, T. and Liu, J.Y., 2014. Proximate composition and fatty acid profile in different tissues of wild female Chinese sturgeon (*Acipenser*

sinensis Gray, 1835). *Journal of Applied Ichthyology*, 1-4.

Suvitha, S., Eswar, A., Anbarasu, R., Ramamoorthy, K. and Sankar, G., 2014. Proximate, Amino acid and Fatty acid profile of selected two Marine fish from Parangipettai Coast. *Asian Journal of Biomedical and Pharmaceutical Sciences*, 4 (40), 38-42.

Venugopal, V., 1995. Methods for processing and utilization of low-cost fishes: A critical appraisal. *Journal of Food Science and Technology*, 32, 1-12.

Wang, W., Wu, Z., Dai, Z., Yang, Y., Wang, J. and Wu, G., 2013. Glycine metabolism in animals and humans: implications for nutrition and health,” *Amino Acids*, 45, 463- 477.

Wu, G., Wu, Z., Dai, Z., Yang, Y., Wang, W., Liu, C., Wang, B., Wang, J., and Yin, Y., 2013. Dietary requirements of “nutritionally non-essential amino acids” by animals and humans. *Amino Acids*, 44, 1107-1113.

Yamanaka, H. and Shimada, R., 1996. Postmortem biochemical changes in the muscle of Japanese spiny lobster during storage. *Fisheries Science*, 62(5), 821-824.