DOI: https://doi.org/10.54393/mjz.v5i02.98

MARKHOR
THE JOURNAL OF ZOOLOGY
https://www.markhorjournal.com/index.php/mjz
ISSN (P): 2790-4377, (E): 2790-4385
Volume 5, Issue 2 (April-June 2024)

Original Article

OPEN ACCESS

A Comparative and Quantitative Analysis of Macronutrients and Micronutrients in Tilapia and Chicken Meat

Sadia Afzal[1*], Anbreen Bibi[1], Sana Shahbaz[1], Hafiza Sonia Bibi[1] and Sehar Fatima[1]

[1]Department of Biology, Lahore Garrison University, Lahore, Pakistan

ARTICLE INFO

Keywords:
Chicken, Macronutrients, Micronutrients, Tilapia, Omega-3 Fatty Acids

How to cite:
Afzal, S., Bibi, A., Shahbaz, S. ., Bibi, H. S., & Fatima, S. (2024). A Comparative and Quantitative Analysis of Macronutrients and Micronutrients in Tilapia and Chicken Meat: Nutrient Analysis of Tilapia and Chicken Meat. MARKHOR (The Journal of Zoology), 5(02). https://doi.org/10.54393/mjz.v5i02.98

***Corresponding Author:**
Sadia Afzal
Department of Biology, Lahore Garrison University, Lahore, Pakistan
buttsadi20@gmail.com

Received Date: 25th March, 2024
Acceptance Date: 21st June, 2024
Published Date: 30th June, 2024

ABSTRACT

Poultry and fish meat play an important role in human nutrition by providing all the essential amino acids and nutrients and more importantly they are economically reliable or cheap. This study is a comprehensive approach for the comparative and quantitative analysis of macronutrients and micronutrients in Tilapia and chicken meat. **Objectives:** To evaluate the nutritional profiles and potential health benefits of Tilapia and chicken meat. **Methods:** This study utilized a randomized sampling approach to collect a diverse range of Tilapia and chicken meat samples from local markets. Analytical techniques, Lowery assay (Protein analysis), Soxhlet apparatus (fat content) for macronutrients and spectrophotometry were employed to determine micronutrients (vitamins, minerals, and essential trace elements) in each meat type. The SPSS version 21.0 was used for the comparison of mean with T-Test and at probability level ($p<0.05$). **Results:** The results showed that the Tilapia meat have high protein content as compared to chicken which was recorded as (22.167±0.44 g) and (18.667 ± 0.66 g), respectively. The Tilapia meat has low amount of fat (g) content in all the tested samples as compared to chicken meat which was recorded as (2.5 ± 0.28 g) and (4.7 ± 0.43 g), respectively. The mean value of minerals in Tilapia and chicken meat samples was recorded as 1.33 ± 0.06 and 1.2 ± 0.053 g which is not significantly different from each-others. Tilapia meat have high amount of all the tested vitamins as compared to chicken. Tilapia fish meat demonstrated higher levels of high-quality protein, omega-3 fatty acids, vitamin A, B3, B6 C and E and certain essential minerals, such as selenium, calcium, potassium, iron, sodium and iodine. **Conclusions:** It was concluded that due to distinctive nutritional attributes of fish and chicken meat, individuals can adapt their diets to meet specific health goals and achieve a balanced intake of essential nutrients.

INTRODUCTION

The skyrocketing increase in the human population demands food and nutrients. Chicken and fish meat play a key role in providing a cheap source of food and value-able micro or macronutrients [1]. The carbohydrates, lipids and protein are considered as macronutrients, while minerals and vitamins are the micronutrients [2]. These are the vital component of human. The sources of food from plant origin have carotenoids, polyphenols, ascorbic acid, tocopherols and anthocyanins types of bioactive substances [3], while, these constituents cannot fulfill the nutritional requirements of human. Therefore, these essential nutrients get form animal source, because animal's flesh are the by-products of amino acids, nitrogenous compounds, enzymes, coenzymes, fats, carbohydrates and minerals [5]. That's why, more focus has been placed recently on the dietary and practical advantages of eating meat (a good source of protein). Poultry and fish meat is playing an important role in human nutrition by providing all the essential amino acids and nutrients [1] and more importantly they are economically reliable or cheap. Chicken flesh has been shown to have the highest antioxidant capacity due to its abundance in histidyl dipeptides, including carnosine and anserine [5]. Poultry meat fulfil the variety of nutritional needs as they provide carbohydrates, fats, vitamins and minerals [6]. It is also rich in niacin (known as vitamin B3), the B6 vitamin, and vitamin A. Therefore, poultry can plays an important role in overcoming the gap between protein supply and demand [7]. The poultry meat has high nutritional value and it is very necessary to increase its production [1]. It is also

DOI: https://doi.org/10.54393/mjz.v5i02.98

inexpensive globally [8]. Similarly, comparison of fish to other sources of food prominently shows that fish has sufficient micronutrients and macronutrients and is more beneficial and better [2]. It is also rich in protein as compared to other land animals and has omega-3 poly unsaturated fatty acids. Fat content is less than red meat and its range is from 0.2-15% [9]. The beneficial effects of fish intake have largely been attributed as it contains other nutrients such as taurine, vitamin D, vitamin B12 (B12), iodine and selenium [10]. Small indigenous species of fish which are eaten wholly can provide many minerals (iodine, zinc, iron, phosphorous, selenium and potassium) in sufficient amount. Thus, most of dietary guidelines recommend fish in the diet [11]. The food quality evaluations are challenging, since they involve analyzing every food's molecular makeup in light of biological receptors. Quality will depend on other factors after the meat or fish has been processed, including nutritional factors (such as a balanced amino acid composition), sanitary factors (such as the variety and number of bacteria present in it, the existence of worms, and preservatives), processing factors (such as size, texture, etc.), and sanitary factors (such as the involvement of preservatives) [12]. Thus, to meet the consumer demand and to fulfill the need of growing population (in all over the word), the production of fish and chicken meat with high nutritional values with good quality and quantity is an important concern now a days. Moreover, a major issue arises; which meat is more effective in term of macro and micro nutrients.

The aim of study was to assess and compare the macronutrient composition, including protein, fat, and carbohydrates, in Tilapia *(Oreochromis niloticus)* and chicken meat samples and to determine significant differences in micronutrient content between the two types of meat. To assess the nutritional significance of consuming fish and chicken meat as sources of macronutrients and micronutrients in the human diet.

METHODS

The total 12 samples were collected from poultry farms and local poultry shops from Lahore region, and fish (Tilapia) samples were collected form fish market Lahore. There were two chicks about three weeks old with 1.5 kg of size (sample 1), two adults (sample 2) and two old chickens of about twenty-two weeks of age about 2.50 kg of weight (sample 3). The Nile Tilapia samples included two adult fishes of about six weeks (400 g of weight) (sample 1), two fishes of twenty weeks of age (about 350 g of weight) (sample 2) and two comparably older Nile of about forty-four weeks older with 420-500 g of weight (sample 3). All the samples abbreviated as Sample 1 (S1), Sample 2 (S2) and Sample 3 (S3). The Lowry method [13] was utilized to determine protein content in chicken and Tilapia meat and then measured the absorbance at 750 nm. The meat of the both fish and chicken was converted into very small pieces using mortar and pestle so that sample can make a homogenized mixture in the solvent. The mixture was centrifuged at 5000 rpm for 20 minutes and collected supernatant was stored at 4oC. The 0.2 ml of bovine serum albumin working standard was added in 5 test tubes and make up to 1ml using distilled water. The test tube with 1 ml distilled water serves as blank. And 4.0 ml of copper sulphate was added and incubated for 10 minutes. After incubation 0.5 ml of Folin reagent was added and incubated for 30 minutes. Measured the absorbance at 750 nm. Graph is plotted and estimated the amount of protein present in the sample from the standard graph. Similarly, Soxhlet extraction was carried out to find the concentration of crude fat in the sample. n-hexane was used as a solvent for extraction of lipids from the sample and reflux rate, in the Soxhlet extractor, was set to 5 drops/sec. Fat was collected after getting separated from n-hexane. The weighted samples of 5g were placed into a cellulose thimble and dried to eliminate any excess moisture. The n-Hexane was added for extracting of fat. The extraction process was continued for about 4 hours at 70°C. After complete extraction, the solvent was evaporated, dried, and weighed. A porous thimble loaded with a solid sample is placed inside the main chamber of the Soxhlet extractor. By refluxing the solvent through the thimble using a condenser and a siphon side arm. Flask was rotated to evaporate extra n-hexane. Then, the flask was transferred to dry air oven for more purification. Temperature of oven was set to 110oC for 30 minutes. Dried flask was taken from oven and put into desiccators to cool. After flask got cooled, final weight of the flask was measured and noted down to determine the percentage of fat content. The extraction cycle is typically repeated many times.

Following formula was used to calculate crude fat content of the sample.

$$Crude\ Fat\ (\%) = \left[\frac{W_2 - W_1}{W_s}\right] x\ 100$$

W_1= weight of flask, W_2 =weight of flask with fat, Ws =weight of sample

Next, the micronutrients were determined. The ash content was determined by dry aching method in which sample was placed in muffle furnace at 7000 C for 02 hours. Final weight of the sample was noted and put in formula to calculate percentage of ash.

$$\%\ Ash = \left[\frac{(W_1 + W_s) - W_2}{W_s}\right] x\ 100$$

W_1= weight of crucible, Ws = weight of sample, W_2 = weight of crucible with ash

The Spectrophotometric method of has been utilized for Vitamin Analysis in both fish (Tilapia) and chicken meat. The 10.0 grams of sample was weighed. The sample was ground and homogenized for extraction of vitamin. This

DOI: https://doi.org/10.54393/mjz.v5i02.98

experiment used the hexane as extraction solvent for vitamin A (retinol) and vitamin E (tocopherol), methanol for vitamin B3(niacin) and B6 (pyridoxine), water for vitamin C (ascorbic acid) in the ratio of 1:10 (sample weight to solvent volume). The absorbance of the sample containing the vitamin A was set at 325 nm, 260 nm for vitamin B3. 290 nm for vitamin B6. 245 nm for vitamin C and 315 nm for vitamin E, and then concentration of the vitamin was calculated using the Beer-Lambert Law, which relates the absorbance (A) to the concentration (C) and molar absorptivity (ε) of the analyte.
Formula: $C = A / (\varepsilon \times b)$.
Where C is the concentration, A is the absorbance, ε is the molar absorptivity (specific to the vitamin and wavelength), and b is the path length (typically the cuvette's width, in cm). All the collected data were arranged in MS Excel. The mean and standard errors was calculated. The SPSS version 21.0 was used for the comparison of mean with T-Test and at the probability level ($p<0.05$).

RESULTS

The current study was done for the Comparative and Quantitative analysis of macronutrients and micronutrients in Tilapia and Chicken meat. The laboratory testing was done using recognized analytical methods specific for each nutrient. The results are demonstrated in table 1.

Table 1: Comparative Analysis of Protein, Fat, Minerals and Vitamins Content in Chicken and Tilapia *(O. niloticus)*(g), T-Test for the Comparison of Fish and Chicken (mean per 100 g of meat)

Groups	t-value	df	Sig. (2-Tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Protein Content						
Tilapia	50.269	2	0.000**	22.16667	20.2694	24.0640
Chicken	28.000	2	0.001**	18.66667	15.7982	21.5351
Fat Content						
Tilapia	8.487	2	0.014**	2.45000	1.2079	3.6921
Chicken	10.668	2	0.009**	4.65000	2.7745	6.5255
Minerals						
Tilapia	19.250	2	0.003**	1.28333	0.9965	1.5702
Chicken	19.919	2	0.003**	1.15000	0.9016	1.3984
Vitamins						
Tilapia	1.261	4	0.0276*	1.74200	-2.0934	5.5774
Chicken	1.112	4	0.0328*	1.66600	-2.4928	5.8248

Sample size n = 3, p-value, p<0.05 *=Non-Significant, **=significant, ***=highly significant

The results showed the comparative analysis of protein content in Fish (Nile Tilapia) and chicken meat (Figure 1). The value of t-test showed that amount of protein per 100g of both Tilapia and Chicken meat was significantly different from each other, as $p<0.05$ (Table, 3.1). The mean value of protein content in Tilapia meat samples was recorded as (22.167 ± 0.44 g) which was significantly high as compared to chicken samples and recorded as 18.667 ± 0.66g. The amount of protein in Tilapia was recorded as 22.5, 22 and 23 g in sample S1, S2 and S3, respectively. Similarly, the amount of protein in Chicken was recorded as 18, 18 and 20 g in samples S1, S2 and S3, respectively.

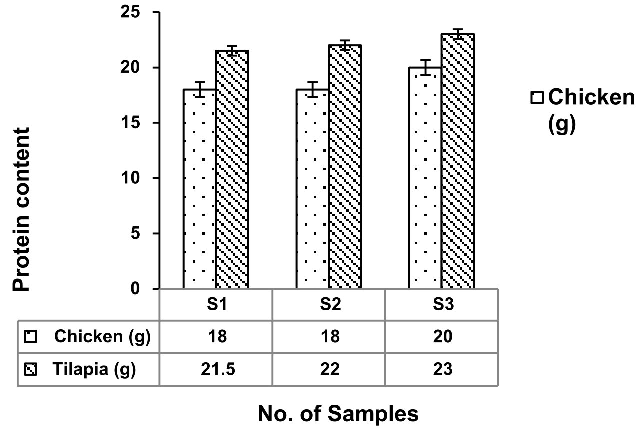

Figure 1: Comparison of Mean Values of Crude Protein in Chicken and Tilapia per 100g of Meat Sample

The protein amount in all the tested samples of fish *(O. niloticus)* is comparatively high as compared to chicken meat, which is significantly different form each other (t-test, $p<0.05$).

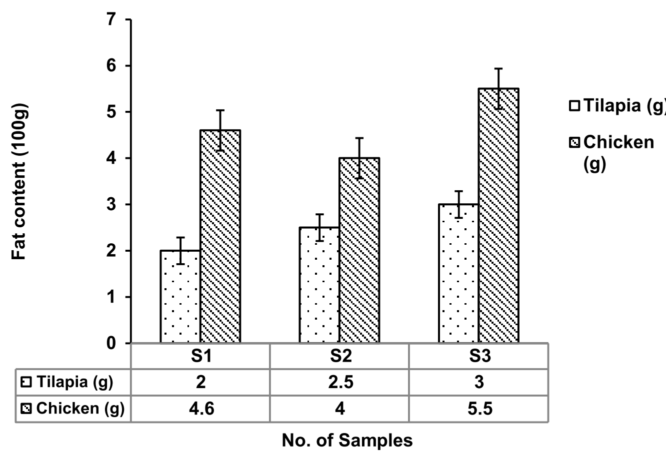

Figure 2: Comparison of Mean Values of Crude Fat in Chicken and Tilapia per 100g of Meat Samples

The fat amount in all the tested samples of fish (*O. niloticus*) is comparatively lower as compared to chicken meat, which is significantly different form each other (t-test, $p<0.05$).

The ash test was performed to analyze the minerals profile in both Tilapia and chicken meat. The results in figure 3 showed the comparative analysis of ash content in Fish (*O. niloticus*) and chicken meat. The value of t-test showed that mean value of amount of minerals per 100g of both (*O. niloticus*) and chicken meat samples was not significantly different from each other, as $p<0.05$ (Table 1). The mean value of minerals in fish (Tilapia) meat samples was recorded as (1.33 ± 0.06 g), which was not significantly

DOI: https://doi.org/10.54393/mjz.v5i02.98

different from chicken meat samples (1.2 ± 0.053g).

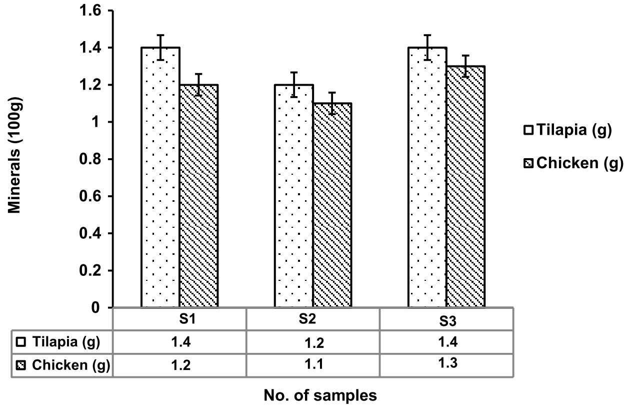

Figure 3: Comparison of Mean Values of Ash (minerals) in Chicken and *O. niloticus* Meat per 100g of Meat Sample

The minerals amount in all the tested samples of fish is comparatively high as compared to chicken meat, which is significantly different form each other (t-test, $p<0.05$).

The results in table 2 showed the comparative analysis of vitamin content in Fish and chicken meat. The T-test sowed that Tilapia meat have high amount of vitamins in all the tested samples as compared to chicken meat ($p<0.05$), except vitamin B3. The mean value of vitamin A, B3, B6 C and E in Tilapia meat samples was recorded as 0.0 4 ± 0.0057, 7.33 ± 1.45, 0.35 ± 0.086, 0.67 ± 0.088 and 0.616±0.06g, respectively, which was significantly different from chicken meat samples. The mean value of vitamin A, B3, B6, C and E in chicken meat samples was recorded as 0.02 ± 0.005, 7.7 ± 1.45, 0.15 ± 0.028, 0.23 ± 0.072 and 0.48 ± 0.1 respectively.

Table 2: Mean Comparison of Vitamins Content in Fish (*O. niloticus*) and Chicken Meat (g)

Sample Type	Sample Size	Type of Vitamins	Mean ± SE
Tilapia	N=3	Vitamin A	0.04 ± 0.0057
		Vitamin B3	7.33 ± 1.45
		Vitamin B6	0.35 ± 0.086
		Vitamin C	0.67 ± 0.088
		Vitamin E	0.616 ± 0.06
Chicken	N=3	Vitamin A	0.02 ± 0.005
		Vitamin B3	7.7 ± 1.45
		Vitamin B6	0.15 ± 0.028
		Vitamin C	0.23 ± 0.072
		Vitamin E	0.48 ± 0.1

DISCUSSION

Nutrition plays a pivotal role in maintaining human health and well-being. Two commonly consumed sources of animal protein, fish, and chicken, offer distinct nutritional profiles. Understanding the differences in micronutrients and macronutrients between these two sources is crucial for making informed dietary choices. Inadequate or excessive consumption of one or more nutrients is considered malnutrition [2]. As, little data are available about the meat quality of chicken and fish. For this purpose, the current study was conducted for the comparative and quantitative analysis of macronutrients and micronutrients in Tilapia and Chicken meat. In this study, a comprehensive examination was directed to evaluate the nutritional content of chicken and Tilapia meat. Protein is an essential macronutrient. The current study showed that the protein content in fish meat samples was recorded as (22.167 ± 0.44 g) which was significantly high as compared to chicken meat samples (18.667 ± 0.66 g). The current study agreement with Madhukar who stated that the average cane of tuna meat can provide 42 g of protein, which was significantly higher, because 100g of chicken meat can provide 21 g of protein [14]. However, both are the good source of protein. Similarly, Iqbal *et al.*, reported that as a result of its high protein content and low cost of production, Tilapia has the ability to satisfy the daily nutritional needs of a vast population, including the underprivileged and malnourished [15]. Fats are also essential component of meat. It is saturated and trans-fat. The current study showed that the mean value of fat in fish meat samples was recorded as (2.5 ± 0.28 g), which was significantly lower than chicken meat samples (4.7 ± 0.43 g). The current study agreement with Mozaffarian and Wu who stated that fish is considered a safer and healthier whole food option compared to chicken due to its lower fat ratio, mostly fish contains lower levels of saturated fats, while the chicken meat have high saturated fat [16]. High consumption of saturated fats has been associated with an increased risk of cardiovascular issues. Generally speaking, Karl *et al.*, stated that Tilapia had a better fatty acid profile than Pangasius catfish [17]. Similarly, Jung *et al.*, narrated that the inexpensive source of meat in the world is chicken [18]. The current study showed that the value of t-test of the amount of minerals per 100g of both Tilapia and Chicken meat samples was not significantly different from each other, as $p<0.05$. Similar to current study the Martinac state that small amounts of calcium, iron, potassium, and magnesium are provided by a meat of fish or chicken [19]. The Huang *et al.*, stated that when given a diet containing Zn in feed of Nile Tilapia (O. niloticus) attained a maximum Zn level of 12.80 mg/kg in its muscle and enhanced its minerals profiles [20]. The Aksu *et al.*, stated that chicken meat has 8 mg of copper (Cu) as copper sulfate ($CuSO_4$), 40 mg of zinc (Zn) as zinc sulfate ($ZnSO_4$), and 60 mg of manganese (Mn) as manganese oxide (MnO) per kilogram (kg) of the diet [21]. The results showed that the fish meat have high amount of all the vitamins in all the tested samples as compared to chicken meat. The current study agreement with Solhelm who stated that aquatic animals which are utilized as food have higher amount of fat- and water-soluble vitamins as compared to terrestrial animals [22].

CONCLUSIONS

Tilapia meat has high amount of protein content as compared to chicken. The Tilapia meat has low amount of fat. The mean value of minerals in Tilapia and chicken meat

DOI: https://doi.org/10.54393/mjz.v5i02.98

samples is not significantly different from each-others. Tilapia meat has high amount of all the tested vitamins as compared to chicken. In most of cases fish meat has an excellent nutritional profile as compared to chicken. However, chicken meat can also provide a significant source of protein and essential vitamins like B3 and B12. Incorporating a variety of protein sources into one's diet can help ensure a well-rounded intake of macronutrients and micronutrients. Furthermore, both fish and chicken offer unique nutritional benefits, and the choice between them should be guided by individual dietary preferences and health goals. Nonetheless, specific dietary requirements and individual preferences should be considered when making food choices, ensuring a well-rounded and nutritionally sound diet.

Authors Contribution

Conceptualization: SA, SS
Methodology: SA
Formal analysis: SA, HSB
Writing, review and editing: SA, AB, SF

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Source of Funding

The author received no financial support for the research, authorship and/or publication of this article.

REFERENCES

[1] Ochi EB, Elbushra ME, Fatur M, Abubakr O, Ismail HA. Effect of Moringa (Moringa oleifera Lam) seeds on the performance and carcass characteristics of broiler chickens. Journal of Natural Sciences Research. 2015 Jun; 5(8): 66-73.
[2] Lilly TT, Immaculate JK, Jamila P. Macro and micronutrients of selected marine fishes in Tuticorin, South East coast of India. International Food Research Journal. 2017 Mar; 24(1).
[3] Altemimi A, Lakhssassi N, Baharlouei A, Watson DG, Lightfoot DA. Phytochemicals: Extraction, isolation, and identification of bioactive compounds from plant extracts. Plants. 2017 Sep; 6(4): 42. doi: 10.3390/plants6040042.
[4] Jayasena DD, Jung S, Bae YS, Park HB, Lee JH, Jo C. Comparison of the amounts of endogenous bioactive compounds in raw and cooked meats from commercial broilers and indigenous chickens. Journal of Food Composition and Analysis. 2015 Feb; 37: 20-4. doi: 10.1016/j.jfca.2014.06.016.
[5] Serpen A, Gökmen V, Fogliano V. Total antioxidant capacities of raw and cooked meats. Meat Science. 2012 Jan; 90(1): 60-5. doi: 10.1016/j.meatsci.2011.05.027.
[6] Vaarst M, Steenfeldt S, Horsted K. Sustainable development perspectives of poultry production. World's Poultry Science Journal. 2015 Dec; 71(4): 609-20. doi: 10.1017/S0043933915002433.
[7] Elhadi DA, Elgasim EA, Mohamed Ahmed IA. Microbial and oxidation characteristics of refrigerated chicken patty incorporated with moringa *(Moringa oleifera)* leaf powder. CyTA-Journal of Food. 2017 Apr; 15(2): 234-40. doi: 10.1080/19476337.2016.1242157.
[8] Garg S, Suyesh R, Sukesan S, Biju SD. Seven new species of Night Frogs *(Anura, Nyctibatrachidae)* from the Western Ghats Biodiversity Hotspot of India, with remarkably high diversity of diminutive forms. PeerJ. 2017 Feb; 5: e3007. doi: 10.7717/peerj.3007.
[9] Mohanty BP, Ganguly S, Mahanty A, Sankar TV, Anandan R, Chakraborty K *et al*. DHA and EPA content and fatty acid profile of 39 food fishes from India. BioMed Research International. 2016 Oct; 2016. doi: 10.1155/2016/4027437.
[10] Lund EK. Health benefits of seafood; is it just the fatty acids? Food Chemistry. 2013 Oct; 140(3): 413-20. doi: 10.1016/j.foodchem.2013.01.034.
[11] Cámara M, Giner RM, González-Fandos E, López-García E, Mañes J, Portillo MP *et al.* Food-based dietary guidelines around the world: a comparative analysis to update AESAN scientific committee dietary recommendations. Nutrients. 2021 Sep; 13(9): 3131. doi: 10.3390/nu13093131.
[12] Röhr A, Lüddecke K, Drusch S, Müller MJ, Alvensleben RV. Food quality and safety––consumer perception and public health concern. Food Control. 2005 Oct; 16(8): 649-55. doi: 10.1016/j.foodcont.2004.06.001.
[13] Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin phenol reagent. Journal of Biological Chemistry. 1951 Nov; 193(1): 265-75. doi: 10.1016/S0021-9258(19)52451-6.
[14] Madhukar K. Fish Vs. Chicken: Which One is Healthier? 2022. [Last cited: 26th Mar 2024]. Available at: https://krishijagran.com/health-lifestyle/fish-vs-chicken-which-is-one-is-healthier/.
[15] Iqbal S, Atique U, Mahboob S, Haider MS, Iqbal HS, Al-Ghanim KA *et al.* Effect of supplemental selenium in fish feed boosts growth and gut enzyme activity in juvenile tilapia (Oreochromis niloticus). Journal of King Saud University-Science. 2020 Jul; 32(5): 2610-6. doi: 10.1016/j.jksus.2020.05.001.
[16] Mozaffarian D and Wu JH. Omega-3 fatty acids and cardiovascular disease: effects on risk factors, molecular pathways, and clinical events. Journal of the American College of Cardiology. 2011 Nov; 58(20): 2047-67. doi: 10.1016/j.jacc.2011.06.063.
[17] Karl H, Lehmann I, Manthey-Karl M, Meyer C, Ostermeyer U. Comparison of nutritional value and

DOI: https://doi.org/10.54393/mjz.v5i02.98

microbiological status of new imported fish species on the G erman market. International Journal of Food Science & Technology. 2014 Nov; 49(11): 2481-90. doi: 10.1111/ijfs.12543.

[18] Jung YK, Jeon HJ, Jung S, Choe JH, Lee JH, Heo KN *et al.* Comparison of quality traits of thigh meat from Korean native chickens and broilers. Food Science of Animal Resources. 2011; 31(5): 684-92. doi: 10.5851/kosfa.2011.31.5.684.

[19] Martinac P. Nutrients in fish and chicken, a comparison. 2018. [Last cited: 26th Mar 2024]. Available at: https://www.weekand.com/healthy-living/article/nutrients-fish-vs-chicken-18018487.php.

[20] Huang F, Jiang M, Wen H, Wu F, Liu W, Tian J *et al.* Dietary zinc requirement of adult Nile tilapia *(Oreochromis niloticus)* fed semi-purified diets, and effects on tissue mineral composition and antioxidant responses. Aquaculture. 2015 Mar; 439: 53-9. doi: 10.1016/j.aquaculture.2015.01.018.

[21] Aksu T, Aksu MI, Yoruk MA, Karaoglu M. Effects of organically-complexed minerals on meat quality in chickens. British Poultry Science. 2011 Oct; 52(5): 558-63. doi: 10.1080/00071668.2011.606800.

[22] Solhelm W. Sea of health: nutritional content and health benefits of seafood. Tromso, Norway: NOFIMA. 2010.