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Original paper

Optimization of some fish by-products using tilapia and mullet head fortification of rice

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Abstract Fish processing waste is either discarded or considered as a low-value raw material. The chemical composition and fatty acid profile of the tilapia and mullet by-products (heads, viscera, and liver) were determined. Also, the possibility of rice fortification with tilapia head flour (THF) and mullet head flour (MHF) and its effect on the chemical composition and sensory properties of rice were evaluated. Results indicated that, the tilapia and mullet by-products could be considered as a good source of protein and ether extract. Furthermore, the Head had significantly the highest content of crude protein, ash, crude fiber and unsaturated fatty acids among other different parts of tilapia and Mullet by-products. Apparent, fortification rice with various levels of THF and MHF lead to increased significantly protein, ether extract, and ash content. Also, Sensory properties were significantly (($P<0.05$) decrease in cooked rice sample fortified with mullet head at the 6 and 9 % compared with the control sample. Finally, THF and MHF is an inexpensive and environmentally friendly alternative source of protein, ether extract, and ash can be converted to the healthy value-added products to increase of the amount of protein, ether extract, and mineral content in food production.

Keywords Fish, by-Products, nutritional evaluation, rice, fortification

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Introduction

The total fish production in Egypt is 1.71 million tons annually where 1.4 million tons were produced through aquaculture, it represents more than 80% of the total fish production (Gafrd, 2018). tilapia and mullet are dominant species. They account for 85.1% of the total aquaculture production. In addition, Egypt is the world's top producer of cultured mullet **(EL-SAYED {1}).** A large number of fish meat-based consumer convenient products are emerging and thus a huge quantity of by-products are generated which accounts for about 65-70% of the weight of the raw material **(KUMAR *& al.* {2}).**

In the tilapia and Mullet processing procedure, only 30%-40% (weight) of the fish is consumed as a fillet, and the other party (heads, viscera, fins, and bones) are discarded. However, these by-products may be used to produce flour, pates, and soups. This application minimizes the production costs (lower costs of raw material) and reduces the environmental impact caused by fishery activity **(LEONHARDT *& al.* {3} and PETENUCI *&al.* {4}).** Generally, fish processing waste is either discarded or considered as a low-value raw material, which meets the demand of the fish meal industry **(GHALY *& al.* {5}).** However, fish by-products are increasingly being recognized as secondary raw material and being utilized for the production of high-value products with functional and bioactive properties such as gelatin, protein hydrolysate, and omega-3 fatty acids concentrate. Fish by-products could also be used as an important source of nutrition **(TAHERGORABI *& al.* {6}; RENUKA *& al.* {7}).**

Fish by-products can entail significant environmental and food-technical challenges due to their high microbial and endogenous enzyme load, rendering them susceptible to rapid degradation if not processed properly or stored in appropriate conditions **(ARVANITOYANNIS & KASSAVETI {8})** Fish by-products can be classified into two types: One that includes easily degradable products with high enzyme content, such as viscera and blood, and a second one that includes the more stable products (bones, heads, and skin) **(RUSTAD *& al.*{9}).**

Discarding these by-products caused two major problems. First, is not benefiting from a large number of nutrients such as protein, oil, minerals, and vitamins. Second, disposal of such large quantities that contains polluting organic matter causes many of the major environmental and economic problems. **(SAYANA & SIRAJUDHEEN {10})**. Hence, the efficient use of fish processing waste is gaining importance and nowadays fish processing waste is a secondary raw material due to the richness of proteins, fats, and minerals. Developing appropriate technology to recover or isolate valuable components can be of paramount importance. Among the various by-products are fish heads, viscera, and liver. Fish processing is an important need for large fish companies to reduce costs related to transporting inedible parts of fish, increase product stability and quality, and remove parts, such as offal, that may contain bacteria and enzymes, which present risks to fish processing and storage. **(GHALY *& al.* {5}).**

The known healthy compounds and properties associated with fish are also present in their by-products. A great number of bioactive compounds can be obtained from fish by-products: collagen, chitin, enzymes, gelatin, glycoseminoglycans , polyunsaturated fatty acids (PUFA), minerals, protein, and peptides, and vitamins. It should be noted that the long-chain omega-3 fatty acids (LC-PUFAs), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), are among the most successful compounds extracted from fish by-products, achieving a high value in the market due to their beneficial health effects **(FERRARO *& al.* {11}; OLSEN *& al.* {12}; ZAMORA-SILLERO *& al.* {13}).** These Fish by-products can also be used for the production of various value-added products such as proteins, oil, amino acids, minerals, enzymes, bioactive peptides, collagen, and gelatin. The fish proteins are found in all parts of the fish. The amino acids present in the fish can be utilized in animal feed in the form of fishmeal and sauce or can be used in the production of various pharmaceuticals **(ESTEBAN *& al.* {14}; ZHAO *&al.* {15}).**

Rice is considered one of the most important foods worldwide, as it is cultivated on a large scale in all continents and consistently consumed by more than half of the world's population. Cooked rice is known as an excellent source of energy due to its high content in starch, while it also contains rice proteins which offer all the essential amino acids to human nutrition, some of which, though, in limited quantities **(RYAN {16}).** The unique taste of rice provides an easy way to combine rice with the other food to achieve a better taste and nutritional balance **(WALTER *& al.* {17}).** Rice is also one of the foods which are considered to be a potential food vehicle for the fortification of micronutrients because of its regular consumption. Many studies tried to add iron and zinc to rice in order to reduce the nutritional problems, especially micronutrient deficiencies. A study in Bangladeshi children and their caregivers showed that rice was the main source of zinc intake, providing 49% of dietary zinc to children and 69% to women **(ARSENAULT *& al.* {18}).**

Fortification of main foods is generally accepted as an effective way for providing the daily requirements for a range of vitamins and minerals **(BABARYKIN *& al.* {19}).** Thus, the aim of this study was to evaluate the by-products of tilapia and mullet and studied the possibility of rice fortification with tilapia head flour (THF) and mullet head flour (MHF) and its effect on the chemical and sensory properties of rice.

Materials and Methods

Materials

The tilapia and mullet by-products (heads, viscera, and liver) used in this study were bought from the local market in Kaferelsheik city Egypt during April 2020.

Sex kg of rice variety "Sakha 106" was used in this study. Samples (Freshly harvested grains) from the 2020 season were dehulled and polished at the grain quality Lab., RRTC. Sakha, Egypt. All samples were taken and well mixed and cleaned.

Chemicals

All of the chemicals used in this study were obtained from EL-Gomhouria pharmaceutical company, of Tanta city at EL-Gharbia Governorate, Egypt. All other chemicals were analytical grads.

Methods

Preparation of tilapia and mullet by-products

The tilapia and mullet by-products (heads, viscera, and liver) were separated from the fish manually by the market vendors then were cleaned and carefully washed with tap water. After that, these samples were boiled in water for 10 min in order to prevent contamination by disease pathogens, and then dried in an oven at 60±5˚C overnight till complete drying. Finally, the sample was milled into a fine powder and packed in multilayer flexible packages, kept at -20˚C for further analyses**. (JAYASINGHE *& al.* {20}).**

Chemical composition of samples

Chemical compositions as moisture content, crude protein, ether extract, and the ash content were determined according to **AOAC {21}.** Total carbohydrates were determined by subtracting.

Fatty acid profile of samples

The fatty acids composition of the oil extracted from samples were determined at room temperature using the method described by **CONKERTON & al {22}.** The ISO 1995 method was used to prepare fatty acids methyl ester of samples, which were then, analyzed using a gas chromatograph (GC-1000, DANI, Italy) and a flame ionization detector that was slightly modified according to **AZADMARD & DUTTA {23}.** Fatty acids were identified by acquiring chromatograms and comparing their retention times to those of normal fatty acid methyl esters (Sigma Aldrich, St. Louis, MO).

Preparation of cooking rice

Cooking Rice fortification with levels (3, 6 and 9%) of tilapia head flour (THF) and mullet head flour (MHF) was produced as described by **PANAGIOTIS *& al.* {24}.**

Sensory evaluation of cooked rice

A semi-trained panel of twenty members using ten-point hedonic-scale ratings for color, taste, odor, texture, and overall acceptability in order to provide organoleptic characteristics for different fortification cooked rice, **EL-BANA *& al.* {25}.** Liked extremely 9, Like very much 8, Liked moderately 7, Liked slightly 6, Neither liked nor disliked 5, Disliked slightly 4, Disliked moderately 3, Disliked very much 2 and Disliked extremely 1.

Statistical analysis

Data were analyzed using analysis of variance (one way ANOVA), while comparisons were done by Duncan's test at $P<0.05$ level of significance using SPSS (2008) version 17 program for windows.

Results and discussion

Proximate Composition of tilapia by-products

The Gross chemical composition of tilapia by-products (Head, viscera, and Liver) are given in table (1). The results pointed to, significant differences ($p<0.05$) were found in the moisture, protein , ether extract , ash , crude fiber, and carbohydrate contents of tilapia by-Products (Head, viscera, and Liver). The results in Table (1) revealed that, tilapia By-Products could be considered as a good source of protein and ether extract. Where they recorded (15.42 and 42.23%) in the head, (8.95 and 55.92%) in viscera, and (9.61 and 23.33%) in the Liver. These values point to tilapia by-products flour as an important nutritional alternative, due to its high levels of proteins and minerals, as compared to other human foods. High values of protein, ether extract, and minerals are directly related to low moisture content, since a reduction in meal moisture content causes an increase in the concentration of other compounds. These results are in agreement with **STEVANATO *& al.* {26}.** Also, results presented in the above-mentioned Table, it could be observed that, Head had significantly the highest content of crude protein, ash and crude fiber (15.42, 20.25 and 18.87 %) respectively among other different parts of tilapia. while, Liver had a significantly higher percentage of Moisture and Carbohydrates (5.81 and 60.94%) respectively, meanwhile, viscera had a significantly higher percentage of ether extract (55.92%) among other different parts of tilapia. These results are in agreement with **SHIRAHIGUE *& al.* {27}.** The composition of the fish waste varies according to the type of species, sex, age, nutritional status, time of year, and health **(SUVANICH *& al.* {28}).**

Table 1. Chemical composition of different parts of tilapia (% on a dry weight basis)

Parts of tilapia	Chemical composition (%)					
	Moisture	Crude protein	Ether extract	Ash	Crude fiber	*Carbohydrates
Head	3.36^{c} ±0.15	15.42^{a} ±0.12	42.23^{b} ±0.23	20.25^{a} ±0.10	18.87^{a} ±0.18	3.23^{c} ±0.14
viscera	4.66^{b} ±0.19	8.95^{c} ±0.25	55.92^{a} ±0.22	5.57^{b} ±0.17	0.17^{b} ±0.09	29.39^{b} ±0.22
Liver	5.81^{a} ±0.13	9.61^{b} ±0.10	23.33^{c} ±0.26	5.87^{b} ±0.15	0.25^{b} ±0.15	60.94^{a} ±0.31

Each value is an average of three determinations ± standard deviation.
Values followed by the same letter in columns are not significantly different at $P<0.05$.
*Carbohydrates were calculated by differences.

Proximate composition of mullet by-products

The chemical composition of mullet by-Products analyzed is presented in Table (2). The different parts of Mullet showed a significant difference in ($p<0.05$) on the moisture, protein, ether extract, ash, crude fiber, and carbohydrate contents. Moisture values ranged between 3.25% and 5.88%, being liver the part that had higher percentages. The obtained results indicated that, the head had a significantly higher content of ether extract, ash, and crude fiber (49.61,20.25 and 5.63%) respectively compared to that of other by-products. Meanwhile, viscera had a significantly higher content of carbohydrate (40.66%) Following with liver (35.60%) and head (10.82%) These results are in agreement with **PATEIRO *& al.* {29}.** Ash contents in the head were higher than those found in other fish by-products. Regarding ash content, fish heads had large amounts of minerals. These results are in agreement with **HE *& al.* {30}; PATEIRO *&al.* {29}.**

Mullet by-Products could be considered as a good source of protein and ether extract where they recorded (13.69 and 49.61%) in the head, (12.02 and 39.90%) in viscera and (14.56 and 42.61%) in the Liver. These values point to mullet by-products flour as an important nutritional alternative, due to its high levels of proteins and minerals, as compared to other human foods. These results are in agreement with **ELAVARASAN *& al.* {31}.**

Table 2. Chemical composition of different parts of mullet (% on a dry weight basis).

Parts of Mullet	Chemical composition (%)					
	Moisture	Protein	ether extract	Ash	Fiber	* Carbohydrates
Head	$3.25^{c}\pm0.10$	$13.69^{b}\pm0.18$	$49.61^{a}\pm0.29$	$20.25^{a}\pm0.11$	$5.63^{a}\pm0.09$	$10.82^{c}\pm0.13$
viscera	$4.17^{b}\pm0.19$	$12.02^{c}\pm0.15$	$39.90^{c}\pm0.11$	$5.76b^{c}\pm0.10$	$1.66^{b}\pm0.04$	$40.66^{a}\pm0.31$
Liver	$5.88^{a}\pm0.12$	$14.56^{a}\pm0.17$	$42.61^{b}\pm0.23$	$6.26^{b}\pm0.13$	$0.97^{c}\pm0.08$	$35.6^{b}\pm0.24$

Each value is an average of three determinations ± standard deviation.
Values followed by the same letter in columns are not significantly different at $P<0.05$
* Carbohydrates were calculated by differences.

Fatty acids composition of tilapia by-products oil

The fatty acids composition of tilapia by-products oils is presented in Table (3). The evaluation of the fatty acid profile indicated significant differences ($p < 0.05$) among samples regarding the fractions of fatty acids. The results shown in Table (3) are illustrated that, the fatty acid composition of lipids extracted from the head, liver, and Viscera of tilapia had a higher amount of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) and a lower amount of polyunsaturated fatty acids (PUFA). Generally, the total saturated fatty acid of the viscera was higher (51.15%) than that of the head (43.01%) than the liver (39.46%). Among the saturated fatty acids, the highest concentration was Palmitic acid (32.30, 30.99, and 31.90% respectively) following by stearic acid (7.04,5.58 and 14.68% respectively) for head, liver, and viscera respectively. This agreement with found by **EL-SHERIF {32}.** As for unsaturated fatty acids, it could be cleared that, all tilapia by-products had higher oleic acid and linoleic acid (43.67and 6.88; 40.16 and 7.77; 33.77 and 5.46%) in the head, liver, and viscera respectively. Meanwhile, the liver contained a higher concentration of Linolenic acid (2.58%) comparing with other tilapia by-products. these results agree with **SUSENO *& al.* {33}; KHODDAMI *& al.* {34}; ABD EL-RAHMAN *& al.* {35}.**

Linoleic and oleic acids rich oils are particularly important for the human diet. They help maintain membrane fluidity at the water barrier of the epidermis, and can be further enzymatically oxidized to a variety of derivatives involved in cell signaling. Interestingly, the studied oils are rich in palmitic and stearic acids, which are at the origin of these two fatty acids, explaining the presence in small amounts, The presence of high amounts of the essential fatty acid linoleic acid suggests that these oils are highly nutritious oils due to the ability of unsaturated oils to reduce serum cholesterol **(OUASSOR *& al.* {36}).**

Fatty acids composition of mullet by-products oil

The nutritional importance of fish consumption is to great extent associated with its advantageous fatty acid profile. Lipids and fatty acids play an important role in the biochemistry of membranes and have a direct impact on membrane-mediated processes such as osmosis regulation and nutrient uptake and transport. On the other hand, the nature and quantity of these fats in fish varies according to species and habits **(KUMARAN *& al.* {37}).** A comparison of the fatty acid composition of lipids extracted from the head, liver, and Viscera of mullet is presented in Table (4). The obtained results show that, the fatty acid profile evaluation showed significant differences ($P < 0.05$) between samples with respect to the fatty acid fractions.

Table 3. Fatty acids composition of tilapia by-products oil

Type of Fatty acids		Different parts of tilapia		
		Head (%)	Liver (%)	Viscera (%)
C12 : 0	Laurie acid	0.47	0.26	0.10
C14:0	Myristic a cid	3.20	2.63	4.47
C16:0	Palmitic a cid	32.30	30.99	31.90
C18:0	Stearic a cid	7.04	5.58	14.68
Total saturated fatty Acids(SFA)		**43.01**	**39.46**	**51.15**
C16:1	Palmitaleic a cid	3.22	8.00	6.40
C18:1	Oleic a cid	43.67	40.16	33.77
C20:1	Arachidonic a cid	2.35	1.41	1.38
Total mono unsaturated fatty Acids (MUFA)		**49.24**	**49.57**	**41.55**
C18:2	Linoleic a cid	6.88	7.77	5.46
C18:3	Linolenic a cid	0.86	2.58	1.83
Total polyunsaturated fatty Acids (PUFA)		**7.74**	**10.35**	**7.29**
Unsaturated fatty Acids(UFA)		**56.98**	**59.92**	**48.84**
Total fatty Acids		**99.99**	**99.38**	**99.99**

Table 4. Fatty acid Composition of mullet by-products

Type of Fatty acids		Different parts of mullet by-products		
		Head (%)	Liver (%)	Viscera (%)
C12 : 0	Laurie acid	0.44	0.78	-
C14:0	Myristic a cid	10.05	4.23	9.11
C16:0	Palmitic a cid	31.14	31.26	33.6
C18:0	Stearic a cid	6.24	8.04	11.35
Total saturated fatty Acids(SFA)		**47.87**	**44.31**	**54.06**
C16:1	Palmitaleic a cid	12.57	5.13	9.66
C18:1	Oleic a cid	27.58	30.65	26.6
C20:1	Arachidonic a cid	4.43	5.49	0.50
Total mono unsaturated fatty Acids (MUFA)		**44.58**	**41.27**	**36.76**
C18:2	Linoleic a cid	5.60	12.87	2.60
C18:3	Linoleic a cid	0.57	1.04	4.75
Total polyunsaturated fatty Acids (PUFA)		**6.17**	**14.01**	**7.35**
Unsaturated fatty Acids(UFA)		**50.75**	**55.18**	**44.11**
Total fatty Acids		**98.62**	**99.59**	**98.17**

The results shown in Table (4) are illustrated that, the fatty acid composition of lipids extracted from the head, liver, and Viscera of mullet had a higher amount of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) and a lower amount of polyunsaturated fatty acids (PUFA). Furthermore, the total saturated fatty acid of the viscera was higher (54.06%) than that of the liver (44.31%) than the head (47.87%). Among the saturated fatty acids, the highest concentration was Palmitic acid and stearic acid (33.60 and 11.35% respectively) in viscera, while the highest concentration of Palmitic acid and stearic acid in the liver were (31.26 and 8.04% respectively) but, the highest concentration in the head was palmitic acid and meristic acid (|31.14 and 10.05% % respectively) this agreement with found by **KACEM *&al.* {38}; ELAVARASAN *& al.*{39}.** As for monounsaturated fatty acids (MUFA), it could be cleared that, the major types of (MUFAs) in all samples were oleic and Palmitoleic acid. The highest contents of the total (MUFAs) were in the Head (44.58%) while, the lowest content was observed in the viscera (36.76%). Furthermore, the contents of polyunsaturated fatty acids (PUFA) in the head, liver, and Viscera of mullet were 6.17, 14.01, and 7.35% respectively. The predominant (PUFA) in all samples was linoleic, these results this agreement with **PUDTIKAJORN & BENJAKUL {40}.**

Sensory evaluation of cooked rice fortified by different levels of tilapia head

The sensory properties of any food product are the major part of important attributes that affect the consumer choice (**SALEM {41}**). Sensory properties of cooked rice fortified by levels) 3.0, 6.0, and 9.0 %) of the tilapia head are shown in Table (5). From statistical analysis of these data, it could be noticed that there was no significant difference at (P<0.05) in Appearance, texture, odor, taste, color, and overall acceptability between the control sample and cooked rice fortified with tilapia head at the 3.0% level, while, Sensory properties were significantly (P<0.05) decrease in cooked rice sample fortified with tilapia head at the 6.0 and 9.0% compared with the control sample. The highest values of Appearance, Texture, Odor, Taste, Color, and Overall acceptability were noticed in control cooked rice (9.4,9.3 ,9.7, 9.5, 9.6, and 9.5 respectively) while, the lowest values were noticed in cooked rice fortified by tilapia head at level 9.0% (8.7, 8.4, 9.0, 8.7, 8.6 and 8.6 respectively) compared to all samples This result was agreements with **DE CESARO *& al.* {42}.**

Sensory evaluation of cooked rice fortified by different levels of mullet's head

Sensory properties of cooked rice fortified by levels) 3.0, 6.0, and 9.0 %) of Mullet's head are shown in Table (6). According to statistical analysis of these data, there was no significant change in Appearance, Texture, Odor, Taste, Color, and Overall Acceptability between the control sample and cooked rice fortified with mullet head at the 3.0% level (P<0.05). While, Sensory properties were significantly ((P<0.05) decrease in cooked rice sample fortified with mullet head at the 6.0 and 9.0% compared with the control sample. The highest values of Appearance, Texture, Odor, Taste, Color, and Overall acceptability were noticed in control cooked rice (9.2, 9.1, 9.5, 9.3, 9.4, and 9.3 respectively) while, the lowest values were noticed in cooked rice fortified by Mullet's head at level 9.0% (8.5, 8.2, 8.8, 8.5, 8.4 and 8.4 respectively) compared to all samples.

Table 5. Sensory evaluation of cooked rice fortified by different levels of tilapia head

Samples	Sensory properties					
	Appearance	Texture	Odor	Taste	Color	Overall acceptability
Control	9.4^{a} ±0.11	9.3^{a} ±0.15	9.7^{a} ±0.26	9.5^{a} ±0.11	9.6^{a} ±0.22	9.5^{a} ±0.17
3%	9.3^{a} ±0.21	9.2^{a} ±0.29	9.6^{a} ±0.13	9.3^{a} ±0.24	9.4^{a} ±0.21	9.3^{a}±0.12
6%	9.1^{ab} ±0.27	9.0^{b} ±0.39	9.3^{b} ±0.29	9.1^{b} ±0.38	9.1^{b} ±0.16	9.1^{b}±0.11
9%	8.7^{b} ±0.31	8.4^{c} ±0.17	9.0^{c} ±0.40	8.7^{c} ±0.29	8.6^{c} ±0.15	8.6^{c}±0.30

Each value is an average of twenty determinations ± standard deviation.
Values followed by the same letter in columns are not significantly different at P<0.05.

Table 6. Sensory evaluation of cooked rice fortified by different levels of mullet's head

Samples	Sensory properties					
	Appearance	Texture	Odor	Taste	Color	Overall acceptability
Control	9.2^{a}±0.41	9.1^{a} ±0.35	9.5^{a} ±0.56	9.3^{a} ±0.41	9.4^{a} ±0.32	9.3^{a}±0.19
3%	9.1^{a}±0.31	9.0^{a} ±0.49	9.4^{a} ±0.43	9.1^{a} ±0.14	9.2^{a} ±0.41	9.1^{a}±0.13
6%	8.9^{b}±0.47	8.8^{b} ±0.19	9.1^{b} ±0.19	8.9^{b} ±0.28	8.9^{b} ±0.26	8.9^{b}±0.28
9%	8.5^{c}±0.21	8.2^{c} ±0.37	8.8^{c} ±0.30	8.5^{c} ±0.39	8.4^{c} ±0.45	8.4^{c}±0.24

Each value is an average of twenty determinations ± standard deviation.
Values followed by the same letter in columns are not significantly different at P<0.05.

Nutritional composition of rice fortified by different levels of tilapia head

The tilapia head which presented high nutritional value, being considered a solution to waste disposal problems, as well as an ingredient that can be incorporated in different food product formulas with the purpose of enrichment, as performed on food product formulas (**IBRAHIM {43}).** The changes in the chemical composition of control cooked rice and cooked rice fortified by levels (3, 6 and 9%) of the tilapia head (% on a dry weight basis) are shown in table (7). From statistical analysis of these data, it could be noticed that there was a significant difference at (P<0.05) in Moisture, Crude Protein, ether extract, ash, and total carbohydrates between all samples. It should be noted from the given data that, the moisture contents ranged between 43.63 % in control to 49.01% in fortification rice with 9.0% tilapia head flour. The increased moisture content can be explained by the higher content of protein which also increases the water-binding capacity of dough with higher levels of tilapia head flour. It is also reported that, moisture content of bread increased resulted in the addition of tilapia-waste flour (**MONTEIRO *&* *al*. {44}**). Apparent also from the same Table that, fortification rice with various levels of tilapia head flour leads to increased significantly protein, ether extract, and ash content from 7.04, 2.35, and 2.30 % in control to 9.92, 7.24, and 5.05% in fortification rice with 9.0% tilapia head flour. The protein, ether extract, and ash content of fortification rice with tilapia head flour increase (P < 0.05) by increasing the concentrations of fortification tilapia head flour. This increment may be due to the tilapia head flour were high protein, ether extract, and ash content as compared to the cooked rice as reported by **WIDODO *&* SIRAJUDIN {45}.** The increase of protein content in each treatment was influenced by the protein content of the base ingredients used. On the other hand, the total carbohydrate content in cooked rice fortified by various levels of tilapia head flour was significantly decreasing by increasing tilapia head flour. It was decreased from 88.31% in control to 77.97 in fortification rice with 9.0% tilapia head flour. This is maybe due to tilapia head flour are rich in protein, ether extract, and ash. Data of the present study are in agreement with those found by **MONTEIRO *&* *al*. {44}.**

Table 7. Quality properties of rice fortified by different levels of tilapia head flour (on a dry weight basis)

Samples	**Quality properties (%)**				
	Moisture	Crud Protein	Ether extract	Ash	*Total carbohydrates
Control	43.63ᵃ±0.39	7.04ᵈ±0.19	2.35ᵈ ±0.11	2.30ᵈ ±0.07	88.31 ᵃ±0.53
3%	45.51ᵇ±0.22	8.00ᶜ ±0.10	4.11 ᶜ±0.14	2.93ᶜ ±0.11	84.96ᵇ±0.44
6%	46.83 ᶜ±0.13	8.96ᵇ ±0.15	5.55ᵇ ±0.18	3.77ᵇ ±0.09	81.72 ᶜ±0.36
9%	49.01ᵈ±0.18	9.92ᵃ ±0.17	7.24ᵃ ±0.11	5.05ᵃ ±0.10	77.79ᵈ±0.18

Each value is an average of three determinations ± standard division.
Values followed by the same letter in rows are not significantly different at P<0.05.
* Total carbohydrates were calculated by difference.

Nutritional composition of rice fortified by different levels of mullet's head

The changes in the chemical composition of control cooked rice and cooked rice fortified by levels (3, 6 and 9 %) of mullet's head (% on a dry weight basis) are shown in table (8). From statistical analysis of these data, it could be noticed that there were the significant differences at (P<0.05) in Moisture, Crude Protein, ether extract, ash, and total carbohydrates between all samples. From the same Table (6) it could be noticed that, the moisture contents ranged between 50.63 % in control to 49.66 % in fortification rice with 9.0% mullet head flour. The increased moisture content can be explained by the higher content of protein which also increases the water-binding capacity of dough with higher levels of Mullet head flour. It is also reported that, moisture content of bread increased resulted in the addition of Mullet head flour. These results agree with **EL-BELTAGI *&* *al*. {46} ; DE CESARO *&* *al.* {42}.** Apparent also from the same Table that, fortification rice with various levels of Mullet head flour leads to increased significantly protein, ether extract, and ash content from 7.04, 2.35, and 2.30 % in control to 9.83, 6.33, and 4.98% in fortification rice with 9.0% Mullet head flour . This increment may be due to the Mullet head flour were high protein, ether extract, and ash content as compared to the cooked rice. **EL-BELTAGI *&* *al*. {46} ; ABRAHA *&* al. {47}** reported that the nutritive value of cereal proteins can be increased when fortified with fish protein . On the other hand, the total carbohydrate content in cooked rice fortified by various levels of mullet head flour was significantly decreasing by increasing Mullet head flour. It was decreased from 88.31% in control to 78.86 in fortification rice with 9.0% Mullet head flour. This is maybe due to Mullet head flour are rich in protein, Ether extract, and ash. Data of the present study are in agreement with those found by **BASTOS *&* *al.* {48}.**

Table 8. Quality properties of rice fortified by different levels of mullet head flour (on a dry weight basis).

Samples	**Quality properties**				
	Moisture	Crud Protein	Ether extract	Ash	*Total carbohydrates
Control	50.63ᵃ ±0.30	7.04ᵈ±0.15	2.35ᵈ ±0.11	2.30ᵈ ±0.07	88.3ᵃ±0.53
3%	51.60ᵇ ±0.25	7.97ᶜ±0.12	3.82ᶜ±0.21	2.90ᶜ ±0.09	85.31ᵇ±0.34
6%	52.93ᶜ ±0.36	8.90ᵇ±0.17	5.01ᵇ ±0.10	3.70ᵇ ±0.13	82.39 ᶜ±0.41
9%	49.66ᵈ ±0.31	9.83ᵃ±0.19	6.33ᵃ±0.23	4.98ᵃ ±0.10	78.86ᵈ±0.33

Each value is an average of three determinations ± standard division.
Values followed by the same letter in rows are not significantly different at P<0.05.
* Total carbohydrates were calculated by difference.

Conclusions

The tilapia and mullet head flour had high nutritional value in relation to their protein, total lipids, and ash (minerals) contents. The omega-3 fatty acid content is proved to be satisfactory by the PUFA/SFA and the n-6/n-3 ratios and within the recommended levels. It is considered a solution to fish waste disposal problems as well as ingredients that can be fortification in different food products.

References

1. A. M. EL-SAYED. Regional review on status and trends in aquaculture development in the Near East and North Africa –2015, by. FAO Fisheries and Aquaculture Circular No. 1135/6. Rome, Italy. (2015)
2. A. KUMAR, K. ELAVARASAN, P. KISHORE, D. UCHOI, H. M. DEVI, G. NINAN, A. A. ZYNUDHEEN. Effect of dehydration methods on physico-chemical and 2 sensory qualities of restructured–dehydrated fish product. *J. Food Process. Pres.* DOI 10.1111/jfpp.13277. (2017).
3. J. H. LEONHARDT, M. CAETANO-FILHO, H. FROSSARD, A. M. MORENO. Morphometrics, fillet yield and fillet composition in Nile tilapia, Oreochromics niloticus, strains thai chitralada, Brazil local and their hybrid. Semina: Ciências Agrárias, 27(1), 125-132. (2006).
4. M. E. PETENUCI, F. B. STEVANATO, D. R. MORAIS, L. P. SANTOS, N. E. SOUZA, J. V. VISENTAINER. Composição e estabilidade lipídica da farinha de espinhaço de tilápia. Ciência e Agrotecnologia, 34 (5), 1279-1284. (2010).
5. A. E. GHALY, V. V. RAMAKRISHNAN, M. S. BROOKS, S. M. BUDGE, D. DAVE. Fish processing wastes as a potential source of proteins, amino acids and oils: A critical review. *J. Microb. Biochem. Tech*., 5: 107- 129. (2013).
6. R. TAHERGORABI, K.E. MATAK, J. JACZYNSKI. Fish protein isolate: development of functional foods with nutraceutical in-gredients. *J. of Functional Foods* 18: 746–756. (2015).
7. V. RENUKA, R. ANANDAN, M. SUSEELA, C.N. RAVISHANKAR, G.K. SIVARAMAN. Fatty acid profile of yellowfin tuna eye (Thunnus albacares) and oil sardine muscle (Sardinella longiceps). *Fish. Tech*., 53: 151-154. (2016).
8. I.S. ARVANITOYANNIS, A. KASSAVETI. Fish industry waste: Treatments, environmental impacts, current and potential uses. *Int. J. Food Sci. Technol*., 43, 726–745. (2008).
9. T. RUSTAD, I. STORRØ, R. SLIZYTE. Possibilities for the utilization of marine by-products. *Int. J. Food Sci. Tech*., 46, 2001–2014. (2011).
10. K. S. SAYANA, T. K. SIRAJUDHEEN. By-products from Tuna processing wastes an economic approach to coastal waste management. Proceedings of the International Seminar on Coastal Biodiversity Assessment, 411-420. (2017).
11. V. FERRARO, A.P. CARVALHO, C. PICCIRILLO, M.M. SANTOS, P.M. CASTRO, M.E. PINTADO. Extraction of high added value biological compounds from sardine, sardine-type fish and mackerel canning residues—A review. Mater. Sci. Eng. C, 33, 3111–3120. (2013).
12. R.L. OLSEN, J. TOPPE, I. KARUNASAGAR. Challenges and realistic opportunities in the use of by-products from processing of fish and shellfish. *Trends Food Sci. Tech*., 36, 144–151. (2014).
13. J.; ZAMORA-SILLERO, A. GHARSALLAOUI, C. PRENTICE. Peptides from fish by-product protein hydrolysates and its functional properties: An overview. Mar. Biotechnol., 20, 118–130. (2018).
14. M.B. ESTEBAN, A.J. GARCÍA, P. RAMOS, M.C. MÁRQUEZ. Evaluation of fruit–vegetable and fish wastes as alternative feedstuffs in pig diets. , 27(2), 193–200. (2007).
15. H. ZHAO, M. JIANG, S. XUE, S. XIE, X. WU, A. GUO. Fish meal can be completely replaced by soy protein concentrate by increasing feeding frequency in nile tilapia (Oreochromisniloticus). Department of Aquaculture Nutritional.16:648-655. (2011).
16. E. P. RYAN. Bioactive food components and health properties of rice bran. Journal of the American Veterinary Medical Association, 238(5), 593–600. (2011).
17. M. WALTER, E. MARCHESAN, P.F. SACHET MASSONI, D.A. PICOLLI L. SILVA, G. MENEGHETTI SARZI SARTORI, R. BRUCK FERREIRA. Antioxidant properties of rice grains with light brown, red and black pericarps colors and the effect of processing. *Food Res. Int*., 50, 698–703. (2013).
18. J. E. ARSENAULT, E. A. YAKES, M. B. HOSSAIN, M. M. ISLAM, T. AHMED, C. HOTZ, L. LEWIS, A. S. RAHMAN, K. M. JAMIL, K. H. BROWN. The Current High Prevalence of Dietary Zinc Inadequacy among Children and Women in Rural Bangladesh Could Be Substantially Ameliorated by Zinc Biofortification of Rice. *Journal of Nutrition* 140: 1683 - 1690. (2010).
19. D. BABARYKIN, I. ADAMSONE, D. AMERIKA, A. SPUDASS, V. MOISEJEV, N. BERZINA, L. MICHULE, R. ROZENTAL. Calcium enriched bread for treatment of uremic hyperphosphatemia. *J. of Renal Nutrition* 14: 149-156. (2004).
20. P. JAYASINGHE, I. ADEOTI, K. A. HAWBOLDT. study of process optimization of extraction of oil from fish waste for use as a low-grade fuel. *J. of the American Oil Chemists' Society*, 90: 1903- 1915. (2013).
21. AOAC. Official Methods of Analysis of AOAC International. 18th Edition, AOAC International, Gaitherburg, 2590. (2010).
22. E. J. CONKERTON, P.J. WAN, O.A. RICHARD. Hexane and heptane as extraction solvents for cottonseed: A laboratory-scale study. *J. of the American Oil Chemists' Society,*72: 963–965. (1995).
23. S. AZADMARD, P.C. DUTTA. Rapid separation of methyl- sterols from vegetable oils by solid- phase extraction. Lipid Technology,18 :231–234. (2006).

24. E. PANAGIOTIS, E. IGOUMENIDIS, V. LEKKA, T. KARATHANOS. Fortification of white milled rice with phytochemicals during cookingin aqueous extract of Mentha spicata leaves. An adsorption study. LWT - *Food Sci. and Tech*., 65: 589-596. (2016).
25. M. A. EL-BANA, R. A. GOMA, A.S. ABD EL-SATTAR. Effect of parboiling process on milling quality, physical and chemical properties of two rice varieties. Menoufia *J. Food and Dairy Sci*., 5: 35 – 51. (2020).
26. F. B. STEVANATO, M. E. PETENUCCI, M. MATSUSHITA, M. C. MESOMO, N. E. SOUZA, J. E. L. VISENTAINER, J.V. VISENTAINER. Fatty acids and nutrients in the flour made from tilapia (Oreochromis niloticus) heads. Ciênc. Tecnol. Aliment., Campinas, 28(2): 440-443. (2007).
27. L. D. SHIRAHIGUE, M. O. SILVA, A. C. CAMARGO, L. F. SUCASAS, R. BORGHESI, I. S. R. CABRAL, M. OETTERER. The feasibility of increasing lipid extraction in tilapia (Oreochromisniloticus) waste by proteolysis. *J. of Aquatic Food Product Tech.,* 25, 265-271. (2016).
28. V. SUVANICH, R. GHAEDIAN, R. CHANAMAI, E.A. DECKER, D.J. MCCLEMENTS. Prediction of proximate fish composition from ultrasonic properties: catfish, cod, flounder, mackerel and salmon. *J. of Food Sci*., 63: 966-968. (2006).
29. M. PATEIRO, P. E. S. MUNEKATA, R. DOMÃ¬NGUEZ, M. WANG, F.J. BARBA, R. BERMÃDEZ, J. M. LORENZO. Nutritional Profiling and the Value of Processing By-Products from Gilthead Sea Bream (Sparus aurata). Marine Drugs, 18(2), 101–.119. (2020).
30. S. HE, C. FRANCO, W. ZHANG. Characterisation of processing wastes of Atlantic Salmon (Salmo salar) and Yellowtail Kingfish (Seriola lalandi) harvested in Australia. *Int. J. Food Sci. Tech*., 46, 1898–1904. (2011).
31. K. ELAVARASAN, A. KUMAR, D. UCHOI, C. S. TEJPAL, G. NINAN, A. A. ZYNUDHEEN. Extraction and characterization of gelatin from the head waste of tiger tooth croaker (Otolithes ruber). Waste Biomass Valor. 8: 851-858. (2017).
32. S.A. EL-SHERIF. Utilization of Fayoum Fisheries by Products in the Production of Fish Meal High Nutritional Quality and Microbiological Safety. *Int. J. of Chem. Tech. Res*., 10 (5): 458-469. (2017).
33. H. S. SUSENO, Y. NURJANAH, A. SARASWATI. Determination of extraction temperature and period of fish oil from tilapia (Oreochromis Niloticus) by product using wet rendering method. The 1st International Symposium on Aquatic Product Processing .1:124-135. (2015).
34. A. KHODDAMI, A. A. ARIFFIN, J. BAKAR, H. M. GHAZALI. Fatty acid profile of the oil extracted from fish waste (Head, Intestine and Liver) (Sardinella lemuru). World *Appl. Sci. J*. 7:127-131. (2009).
35. F. ABD EL-RAHMAN, N.S. MAHMOUD, B. ABO EL – KHAIR, M. Y. SAMY. Extraction of Fish Oil from Fish Viscera. Egypt, J.Chem., 61(.2): 225 – 235. (2018).
36. I. OUASSOR, Y. AQIL, W. BELMAGHRAOUI, S. EL HAJJAJI. Characterization of two Moroccan watermelon seeds oil varieties by three different extraction methods. OCL, 27, 13–. doi:10.1051/ ocl/2020010. (2020).
37. R. KUMARAN, V. RAVI, B. M. GUNALAN, A. S. SUNDRAMANICKAM. Estimation of proximate, amino acids, fatty acids and mineral composition of mullet (Mugil cephalus) of Parangipettai, Southeast Coast of India. Adv. *Appl. Sci. Res*., 3(4):2015-2019. (2012).
38. M. KACEM, M. SELLAMI, W. KAMMOUN, F.FRIKHA, N. MILED, F. BEN REBAH. Seasonal Variations in Proximate and Fatty Acid Composition of Viscera of Sardinella aurita, Sarpa salpa, and Sepia officinalis from Tunisia. *J. of Aquatic Food Product Tech.,* 20 (2), 233–246. (2011).
39. K. ELAVARASAN, A. KUMAR, C. S. TEJPAL, K. D. SATHISH, G. N. UCHOI, A. A. ZYNUDHEEN. Quality and Fatty Acid Composition of Lipids from Head of Indian Mackerel (Rastreliger kanagurta) and Tigertooth Croaker (Otolithes ruber). Fishery Technology 54: 112 – 117. (2017).
40. K. PUDTIKAJORN, S. BENJAKUL. Simple Wet Rendering Method for Extraction of Prime Quality Oil from Skipjack Tuna Eyeballs. *Eur. J. Lipid Sci. Tech*.,122, 1–29. (2020).
41. R.H. SALEM. Quality characteristics of beef sausages with tomato peel as a color and functional additive during frozen storage. *J. World Applied Sciences,* 22 (8):1085-1093. (2013).
42. E. DE CESARO, F. MELINA, G. GISLAINE, M. G. JANE, P. GIULIANA, S. D. G. ELENICE. Evaluation of cookies with inclusion of different levels of barred sorubim (Pseudoplatystoma fasciatum) flour. *Brazilian Journal of Development, Curitiba*, 7(5), 47223-47238. (2021).
43. S.M. IBRAHIM. Evaluation of production and quality of salt-biscuits supplemented with fish protein concentrate. *World J. Dairy and Food Sci*. 4: 28-31. (2009).
44. M.L.G. MONTEIRO, E.T. MA´RSICO, M.S. SOARES JUNIOR, R. DELIZA, D.C.R. DE OLIVEIRA, C.A. CONTE-JUNIOR. Tilapia-waste flour as a natural nutritional replacer for bread: A consumer perspective. PLoS ONE 13(5): e0196665. https:// doi.org/10.1371/journal.pone.0196665. (2018).
45. S. WIDODO, S. SIRAJUDIN. Effect of Drying Time on Quality of Mozambique tilapia Fish (Oreochromis Mossambicus) and Round Sardinella (Sardinella Aurita) Flour, in International Conference ADRI -5 (“Scientific Publications toward Global Competitive Higher Education) .1:. 157–163. (2017).
46. H.S. EL-BELTAGI, N.A. EL-SENOUSI, Z.A. ALI, A.A. OMRAN. The impact of using chickpea flour

and dried carp fish powder on pizza quality. PLoS ONE 12(9): 1-15. (2017).

47. B. ABRAHA, A. MAHMUD, H. ADMASSU, F. YANG, N.T. SIGHE. Production and Quality Evaluation of Biscuit Incorporated with Fish Fillet Protein Concentrate. *J. Nutr Food Sci.,* 8: 744. (2018).
48. S.C. BASTOS, T. TAVARES, M.E.S.G. PIMENTA, R. LEAL , L.F. FABRI ´CIO, C.J. PIMENTA, C.A. NUNES, A.C.M. PINHEIRO. Fish filleting residues for enrichment of wheat bread: chemical and sensory characteristics. *J Food Sci Technol*. 51(9): 2240–2245. (2014).