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Utilization of Fayoum Fisheries by Products in the Production of Fish Meal High Nutritional Quality and Microbiological Safety

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Abstract: This study was carried out to utilize of fish by products from different Fayoum fisheries to produce of Fayoum fisheries waste meal (FFWM). As well as planning for the production of this fish meal on the large-scale from fish wastes and large & small fish untapped in human consumption. This fish meal can be use for feed animals, poultry and fish in Fayoum governorate instead of imported fish meal, in addition to reducing environmental pollution. The produced FFWM was high-quality low-cost and high microbiological safety as confirmed by the chemical analysis (chemical composition, amino acids, fatty acids and minerals) and microbiological aspects (total bacterial count, thermophilic bacteria, salmonella and yeast &mould) that carried out. The obtained results indicated that the produced fish meal was represented about 20.5% from fish by products used in processing. FFWM contains a high level of protein (67.90%) and moderate quantity of fat (8.70%) and minerals (15.30 %), low number of total bacterial count (0.45×10^3) and thermophilic bacteria (0.013×10^3). Pathogenic bacteria (salmonella) and yeast & mould not detected. FFWM have better protein quality as indicated by the increase of essential amino acids (EAA); lysine (8.32 g/100g protein), leucine (6.20 g/100g protein), methionine (4.85 g/100g protein) and valine (4.20 g/100g protein), EAAI essential amino acids index (76.71 g/100g protein) and (B.V. %) biological value (71.88%). Fatty acid compositions of FFWM; (26.68%) saturated fatty acids (SFA), (34.00%) monounsaturated (MUFAs), (37.07%) polyunsaturated fatty acids (PUFAs); oleic acid was the highest value (22.30) of all detected fatty acids. The predominant omega-3 fatty acids are (DHA) docosahexaenoic acid (19.60 % of total fatty acids)and (EPA) eicosapentaenoic acid (12.28 % of total fatty acids), ω3/ ω6 and PUFA/SFA ratios were high in FFWM indicated to the high of nutritional quality. Moreover, FFWM contains the moderate quantity of essential macro and micro minerals as recorded by many researchers; Macro minerals quantity was calcium (26.50 g/kg), phosphorus (23.85 g/kg), magnesium (2.20 g/kg), potassium (8.45 g/kg) and sodium (11.20 g/kg), the micro minerals quantity were iron (218.60 mg/kg), manganese (5.50 mg/kg), copper (5.35 mg/kg), zinc (82.50 mg/kg) and selenium (3.15 mg/kg). Therefore, the produced FFWM provides a balanced amount of all essential nutrients including amino acids, fatty acids and mineral contents as well as free of salmonella and yeast & mould. Thus, the current study recommended to produce of fish meal on a commercial scale from fish wastes not be neglected that can collect from fish markets (as a result of cleaning and manufacturing of fish), from fish restaurants in addition to small and large fish that are not used in human consumption as instead of imported fish meal as well as reducing environmental pollution.

Keywords: FFWM, Composition, Microbial, Amino Acids, Fatty Acids, Minerals.

Introduction

Every year, millions tons of high nutrient fish by-products are discarded by fish processing plants throughout the world. Discarding these by-products caused two major problems. First, is not benefiting of a large amount of nutrients such as protein, oil, minerals and vitamins. Second, disposal of such large quantities that contains polluting organic matter cause many of the major environmental and economic problems[1].The world catch of fish is about 154 million metric tons annually[2] and one-third of the world catch is not utilized for human consumption and considered as fishery by-products[3]. The processing of fish for filleting, canning, and processed fish products result in an immense quantity of by-products that include belly, heads, frames, fins, skins, and viscera[1]. The discards fish wastes from the processing plants was about 20 million tones which is equivalent to 25% of the world's total production from marine capture fisheries[4].

The quantities of these inedible portions depend on many factors such as fish type, size, sex, maturity as well as catching season and place. For example,[5]showed that the percent of fish bolti wastes collected from Aswan, Qarun, Wadi El-Rayan Lakes and Nile were 42.1%, 52.3-59.9%, 53.7-62.6% and 53-58% respectively, whereas of bolti obtained from Fayoum fish farms ranged between 57.1-68%. Shrimp wastes that collected from Qaroun Lake represented about 49% [6].

In many countries, environmental pollution from fish wastes and inadequate animal protein supply are considered health and nutritional problems, so the use of fishery by-products is becoming increasingly important[7]. Fish meal is the predominant product; probably about 95% of all raw material that not used for direct human consumption is processed into fish meal because it is easy to produce, stable, high protein and transported around the world without deterioration, whereas fish itself is highly perishable[8]. Fish meal is a ground solid product that obtained by removing most of the water and some of the oil from fish and fish waste[9]. About 25% of fish meal comes from the usage of waste from the fish processing sectors[10]. Also, the same result was found by[11] evident that 25% (1.23 million tons in 2008) of the total fishmeal produced from fish by-products.

Fish meal is a high in biological value; it contains all the essential amino acids in adequate quantities such as lysine which is often deficient in grain products that are the typical base for most animal feeds and high levels of methionine and cysteine contents. It also contains vitamins such as B12, choline, niacin, pantothenic acid and is a good source of calcium (Ca), copper (Cu), iron (Fe), phosphorous (P) and other trace minerals[12, 13]. Moreover, it is an excellent source of the essential polyunsaturated fatty acids (PUFA) in both the omega-3 and omega-6 of fatty acids. Fish meal's fats are highly digestible by all species of animals and are exactly between 6-10% and high-quality fish meal normally contains between 60-72 % crude proteins[14]. Thus, fish meal is a good source of energy[15]. The demand for fish meal is increasing, as it is used to feed aquaculture, poultry, pigs, etc. as a good source of protein[16].

Therefore, many researchers studied fish meal processing from fish by-products, [17]studied the processing of fish meal from bolti wastes obtained from Nasser's Lake and found that it contains 5.5% moisture, 36.2% crude protein, 6.5% fat and 51.8% ash in addition to, the yield of fish meal was 17% of the total wastes. And also,[6]studied the chemical composition of fish meal made from Fayoum shrimp shells plus appendages and reported that the yield of shrimp meal was 18% of raw material and was complete source of amino acids then a good of nutritional quality, this indicated by the high of essential amino acid index, biological value and protein efficiency ratio. While[18] reported the chemical composition of catfish offal meal were 6.4% moisture, 60.4% crude protein, 8.2 ether extract, 24.1% ash and 0.5% crude fiber. Moreover, the balanced amino acid profile and high palatability of fish meal provides synergistic effects with vegetable proteins in the other animal diet to promote fast growth and reduce feeding cost[19]. It has been reported by[20] that fish by-products are a valuable protein source in animal feeds, including fish, and should not be neglected.

Therefore, the aim of the present work to study the utilize of fish by-products from Fayoum Fisheries for produce low cost fish meal and evaluate its nutritional quality and microbiological safety by determination of chemical composition, amino acids, fatty acids and minerals as well as microbiological aspects. Also, this work is plan to produce this fish meal in large scale for commercial purposes instead of high-priced imported fish meal and can be use for feed animals, poultry and fish in Fayoum Governorate.

Material and methods

Material

A total 70 kg of dominant fish species in Fayoum Fisheries: They were bolti *(Tilapia zillii*), bouri (*Mugil cephalus*), shrimp *(Metapenaeus stebbing)* caught from Qaun Lake and bolti (*Oreochromis niloticus)*,bouri (*Mugil cephalus)* caught from Wadi El-Rayan Lake and fish Farms (10 kg from every species) as illustrated in Table 1 were purchased from fish local market center in Shakshouk village on the shore of Lake Qaroun, El Fayoum Governorate, Egypt in February, 2017. The fish samples were quickly washed with tap water and immediately each type of fish has been outfitted separately to separate the edible portion (fillets) from by-products (all residue of fish parts, heads, skins, viscera, scales, shells, fins, tails, bones and blood, etc...) to estimate the percentage of by-product for each species. The total fish by-products from various fish species were collected in icebox and cooled by quantities of ice then transported directly within about 10 min. to the Laboratory of Fish Processing Technology in Shakshouk Fish Research Station, National Institute of Oceanography and Fisheries (NIOF) to use in the manufacturing and producing fish by-products meal high quality and low price. Note, when the fish meal is produced on a commercial scale, fish wastes are collected from fish markets (as a result of cleaning and processing of fish), from fish restaurants in addition to small and large fish that are not used in human food.

Technological method for manufacturing of fish meal

The total fish by-products from investigated various fish species were mixed and rinsed in clean water and the quantity of by-products (wastes) was added to equal its weight of water and cooked (95-100°C) for 20 minutes in order to prevent contamination by disease pathogens. The cooked-fish by-products were drained and pressed manually in cheese cloth to reduce the water quantity and oil (stick water) from the pressed cake. All pressed cake were exposed to sunlight in order to be dried[21] which was directly spread well on clean concrete platform and sun-dried for[2] days and then complete the drying in electric oven at70-80°C for 2 hr. (the same work in a period of April to October do not need the drying in an electric oven, where high in atmospheric temperature), however for a large scale production of fish meal, it is desirable to use a regular fish meal plant consisting of a rotary steam drier and a screw press. The dried fish meal was grinded with an electric grinding machine and sieved to obtain brownish yellow Fayoum fish waste meal (FFWM) which packed in polyethylene bags and kept at low temperature until analysis of chemical composition, amino acids, fatty acids, minerals and microbiological aspects.

Analytical methods

Chemical composition

Moisture, crude protein (N×6.25), crude fat and ash contents were determined according to the standard methods recommended by[22]. Carbohydrate was calculated using the standard equation 100% - (% protein + % fat + % ash + % moisture).

Microbiological counts

Total bacterial count (TBC) determined using nutrient agar medium according to[23]. Thermophilic bacteria count was determined after heating the original sample solution at 80 °C for 15 minutes and their plating with above media by the same method used for the total bacterial count[24]. Salmonella, an important measure of quality in fish meal as regards organism of public health was also investigated as reported by[25]. Yeast and mould count was determined using potato dextrose agar[26]. The results were expressed as cfu/g of sample.

Amino Acids:

Amino acids were determined by using HPLC & Amino acid analyzer LC3000 Eppendr of Germany in National Research Center according to the method described by[27]. Tryptophan was not determined. The evaluation of nutritional protein was carried out by determined essential amino acids index (EAAI) calculated according to[28] and biological value (B.V. %) calculated as recorded by[29] as follows: $(\mathrm{B.V.} = 1.09 \times \mathrm{EAAI} - 11.73)$.

Fatty Acids

Total lipids in fish meal were extracted using a chloroform-methanol solution (1:1, v/v) as recorded by[30]. Fatty acids composition were determined by preparing methyl esters and analyzing them by gas chromatography in Faculty of Agriculture Research Park (FARP), Cairo Univ. Fatty acids were identified by comparison of retention times with a mixture of fatty acid standards. Each fatty acid was quantified by calculating its peak area relative to the total peak area.

Minerals

Major elements (g/kg); phosphorus (P), calcium (Ca), potassium (K), sodium (Na), and magnesium (Mg) and trace elements (mg/kg); iron (Fe), copper (Cu), manganese (Mn), zinc (Zn) and selenium (Se) were determined as described by[22] in the Chemistry Laboratory, Fresh Water and Lakes Division, National Institute of Oceanography and Fisheries.

Statistical analysis

Values of chemical composition and minerals were analyzed statistically using the Standard Deviation (Mean ± SD).

Results and discussion

1- Fish meal quantity can be produced annually from Fayoum fisheries by products

In Fayoum, fish are produced from Qarun and Wadi El-Rayan Lakes and fish farms; these fisheries considered the main sources of Fayoum fisheries. There are different fish species in Fayoum Fisheries according to water salinity, therefore Qarun Lake high salinity contains common marine fish (bouri, bolti zilli and shrimp) while, the common fish in Wadi El-Rayan Lake and fish farms were Nile bolti and bouri where fresh water or brackish water were found. These dominant fishes in Fayoum Fisheries were used to determination the proportion of by-products for each species, thus determination the percentage of fish meal produced from fish by-product as shown in Table 1. Data presented in Table 1 evidenced that the mean weight of fish by-products were estimated by 39.9 kg produced from filleting 70 kg as total weight of investigated fish species, represented 57%. Also, from the same Table, fish meal produced from processing this quantity of fish by products was 8.18 kg, represented 20.5% from processed fish by products.

Furthermore, to estimate the annually production of fish meal from all fish by products in Fayoum Fisheries, the total amounts of fish, fish by-products and fish meal in Fayoum Fisheries are shown in Table 2 during the period of 2004-2013. The observed results in Table 2 indicated that the production of fish, fish by-products and fish meal were gradually increased annually. The quantity of fish meal produced from fish by-products in Fayoum Fisheries were estimated by thousands metric tons annually as shown in Table 2. For example in 2013, from the same Table, it could be found that the total production of fish from all Fayoum Fisheries was 1.105.380 metric tons as reported by (General Authority for Fish Resources, Ministry of Agriculture and Land Reclamation) can be produce 630.067 metric tons of fish by-products that can be used in manufacture of 129.164 metric tons fish meal in addition to other species of uncommon fish and whole fish are not suitable for human consumption. These results indicated that can be producing high quantity of fish meal from Fayoum Fisheries by-products that decrease the imported fish meal. Fish meal was use as 63% by the aquaculture industry, 25% by the pigs, 8% by the poultry and 4% by other animals[31]**.**

Table 1 Experimentally production of fish meal from fish by-products of common fish in Fayoum Fisheries

Fish species	Fish weight (kg)	Edible parts (kg)	By-products (kg)
Qarun Lake:			
Bolti	10.00	3.70	6.30
Bouri	10.00	4.50	5.50
Shrimp	10.00	4.90	5.10
Wadi El-Rayan Lake:			
Bolti	10.00	3.90	6.10
Bouri	10.00	4.30	5.70
fish farms:			
Bolti	10.00	4.10	5.90
Bouri	10.00	4.70	5.30
Total weight	70.00	30.10	39.90 (57%)
Fish meal represented 20.5% from processed fish by products			8.18

Table 2 Total fish meal can be produced annually from Fayoum Fisheries during the period of 2004-2013 (tons).

Fishing area / Year	Qarun @ Lake	Wadi @ El-Rayan Lake	Fish @ farms	Total catch	Total by-products*	Total fish meal**
2004	2682	1271	471535	475488	271028	55561
2005	3037	1992	539747	544776	310522	63657
2006	1672	1691	595029	598392	341083	69922
2007	3072	2126	635517	640715	365207	74867
2008	3184	2055	693815	699054	398461	81685
2009	3400	2624	705490	711514	405562	83140
2010	3903	2494	919585	925982	527810	108201
2011	4364	3053	986820	994237	566715	116177
2012	4410	3451	1.017738	1.025600	584592	119841
2013	4420	3416	1.097544	1.105380	630067	129164

@: Ministry of Agriculture and Land Reclamation, General Authority for Fish Resources Development, Books of Statistics Fish.

*: A counted total by-product represents 57 % of total catch.

**: A counted total fish meal represents 20.5 % from total fish by- products.

2- Chemical composition and microbiology assessment of fish meal produced from Fayoum fisheries by-products

The obtained fish meal is brownish yellow fish waste meal which normally contains a high level of protein and moderate quantity of fat and minerals. Chemical composition in produced Fayoum Fisheries waste meal (FFWM) is shown in Table 3.The obtained data revealed that the contents of moisture, protein, fat, minerals and carbohydrates in produced FFWM were 7.65%, 67.90%, 8.70%, 15.30% and 0.45% (on wet basis), respectively. The moisture content of obtained FFWM in this study was agrees with reported by ISO 9001 and ISO 14001 (999, 2012) for analysis of fish meal that determined the moisture by average (7.3%). However, it was higher than found by[15] for tilapia by-product meal that estimated by (5.40%), and that reported by[32], average moisture of six fish meal samples was 4.55%. While, it was lower than that reported by[21], evident the moisture content of fish wastes meal (FWM) was 9.60%.

With regard to crude protein content, from the same Table 3, it could be found that the crude protein of produced FFWM was 67.9% and higher than those reported by[33] of kilka fish meal samples (59.1%) and that by[34] of fish meal prepared by method of raw fish waste (65.4%), by direct stream method (51.3%) and by Bligh & Dyer method (47.3%). Moreover, the obtained FFWM protein was higher than that from tilapia by-product (63.50%) as reported by[15]. On the contrary, it was lower than that found of herring meal ranged from 70.5-73.1%, in blue whiting meal 68.0-70.8% and in capelin meal 69.6-72.7% [35].

As for the crude fat content in investigated FFWM, it was represent a moderate value (8.70%) and was lower than the average of kilka fish meal samples (22.9%) prepared by[33], indicated the stability of our produced fish meal, where although the presence of high fat content in fish meal can be beneficial in providing energy for animal, however it may facilitate the deterioration of product and reduce its nutritional value. On the other hand, FFWM was higher than reported by[15] who found that the value of crude fat content of tilapia by-product meal was 0.58%.

Ash content of obtained FFWM sample was 15.3% as shown in Table 3, this value was higher than reported by[32] of six fish meal samples that have average ash (12.5%) and that found by[33], evident the average ash content of kilka fish meal samples was 13.2%. On the contrary, it was lower than found by[21] that pointed to the ash content of fish wastes meal (FWM) was 22.20%. Concerning the carbohydrate content in prepared FFWM, it can be noted that the value of carbohydrates is very low (0.45%), and this is consistent with reported by[36] for fish meal does not contain carbohydrates, so it should be provided by grains.

From these results of chemical composition, the produced fish meal was considered agree with that found in Denmark, Norway, and Iceland that have specifications (fish meal typically comprises 60-72% protein, 10-20% ash, and 5-12% fat). Also, these results are in agreement with the given by[37] reported that fish meal is considered to be a high values source of quality protein, fat and minerals where the protein content ranged 62-72%, the fat content ranged 8-10 % and ash content ranged 12-20%. [38] recorded that the chemical composition of imported fish meal (IFM) and smoked fish waste meal (SFWM) were 92.50 and 93.91% dry matter, 72.26 and 68.07% crude proteins, 14.18 and 9.57% total lipids and 11.05 and 16.85% ash content, respectively. While in Pakistan, [39] report the chemical composition of 18 fish meal collected from various plants of fish meal processing in Pakistan were 87.43-93.13% dry mater, 50.51-61.26% protein contents, 15.29-26.23% fat and 12.32-18.32% ash content.

Regarding to microbiological assessment and safety of Fayoum Fisheries waste meal FFWM, from obtained data in Table 3, it could be noticed that the low number of total bacterial count (0.45×10^3cfu/g) and thermophilic bacteria (0.013×10^3 cfu/g) in prepared fish meal might be due to that many of microorganisms were removed with the separated stick water and the effect of heat during cooking and drying. Moreover, pathogenic bacteria (salmonella) and yeast &mould not detected. It must be borne in mind that if the fish meal under dried, the bacteria, mould and yeast may be able to grow, while if it is over dried the nutritional value of the fish meal will be reduced. The typical water of fish meal is 6% and maximum 10%, the fish meal has 10% moisture corresponding to an Aw (water activity) of approximately 0.60. Most bacterial require Aw above 0.95corresponding to 30-35% water in order to grow, mould and yeast Aw was 0.85-0.90 as recorded in specification of fish meal according to ISO 9001-9002. These results were agreement with reported by[40] that evident the optimum temperature for growth pathogens bacteria such salmonella and E. coli is approximately 40°C and maximum temperature 45°C, the bacteria are killed at temperature above maximum temperature of growth and the killing rate increases with increasing temperature. Therefore, fish meal obtained from Fayoum Fisheries waste (FFWM) was high safety and agree with reported by.[6, 41]

Table 3 Proximate composition and microbial counts (Mean ± SD) of fish meal prepared from Fayoum Fisheries by-products (on wet basis)

Proximate composition (%)		microbial counts (cfu/g)	
Moisture	7.65 ± 0.26	Total bacterial count	$0.45 \times 10^3 \pm 1.07$
Crude protein	67.90 ± 1.27	Thermophilic bacteria	$0.013 \times 10^3 \pm 0.08$
Crude fat	8.70 ± 0.02	Sallmonella	ND
Ash	15.30 ± 0.61	Yeast & Mold counts	ND
Carbohydrates	0.45 ± 0.01		

ND: Not detected

3- Amino acids composition and nutritional quality of fish meal produced from Fayoum fisheries by-products

Fish meal is one of the best high quality animal protein sources, where; high-quality fish meal normally contains between 60-72% crude proteins and provides a balanced amount of all essential amino acids. Amino acids compositions as (g/100g protein) of investigated Fayoum fisheries waste (FFWM) are shown in Table 4. It could be found that, seventeen amino acids were found by total amount (TAA) 79.74g/100g protein and total essential amino acids (TEAA) recorded 35.36g/100g protein. It's rich in some EAA such as lysine (8.32g/100g protein), leucine (6.20g/100g protein), methionine (4.85g/100g protein) and valine (4.20g/100g protein), whereas the high values of non essential amino acids (NEAA) were found in glutamic acid (11.14g/100g protein) and aspartic acid (9.25g/100g protein). Thus, it is fairly rich in all essential amino acids that are balanced and unaffected by the cooking and drying processes used in fish meal preparation. Also, in this study tryptophan was not determined.

Moreover, the results showed clearly that the prepared FFWM have better protein quality as indicated through the increase of (TEAA) total essential amino acids (35.36 g/100g protein), EAAI essential amino acids index(76.71g/100g protein) and (B.V.%) biological value (71.88%). On the other hand, the balanced amino acids composition of prepared fish meal complements and provides synergistic effects with other animal and vegetable proteins in the diet to promote fast growth and reduce feeding costs.

Therefore, prepared fish meal in this study was high protein content and high in amino acids composition especially essential amino acids, thus the presence of a complete amino acids of fish meal is makes this feed ingredient was attractive as a protein supplement, whereas, proteins in cereal grains and other plant do not contain a complete amino acids and usually are deficient in the essential amino acids especially lysine and methionine. These results are in agreement with reported by[3, 18, 6, 42, 14].

Table 4 Amino acids composition and nutritional quality of fish meal prepared from Fayoum Fisheries by-products

Amino acids	**g/100g protein**
Isoleucine*	3.15
Leucine*	6.20
Lysine *	8.32
Methionine *	4.85
Cystine	1.86
Threonine *	3.71
Histidine*	2. 05
Phenylalanine *	2.88
Tyrosine	2.35
Valine*	4.20
Aspartic acid	9.25
Serine	3.22
Glutamic acid	11.14
Proline	3.86
Glycine	4.50
Alanine	4.30
Arginine	3.10
Total amino acid [TAA]	79.74
Total essential amino acids [TEAA]	35.36
Total essential amino acids index [TEAAI]	76.71
Biological value (%)	71.88

*: Essential amino acids. Tryptophan not determined.

4- Fatty acids composition and nutritional quality of fish meal produced from Fayoum fisheries by-products

Fatty acids composition of prepared fish meal from Fayoum Fisheries waste (FFWM) is shown in Table 5. It was found that oleic acid (C18: 1 ω-9) was the highest value of all detected fatty acids, it recorded 22.30 % of total fatty acids, this agreement with found by[18] of catfish meal. Saturated fatty acids (SFA), mono unsaturated fatty acids (MUFA) and poly unsaturated fatty acids (PUFA) were recorded 26.68% of total fatty acids, 34.00% and 37.07% respectively, while; 2.25% of total fatty acids represented unidentified fatty acids. Thus, PUFA represent the most important fatty acids in investigated fish meal with its high content of ω-3.

Palmitic acid(C16:0) was the prominent SFA in prepared FFWM and oleic acid (C18: 1 ω-9) was the prominent in (MUFA), while in PUFA; the predominant omega-3 fatty acids are docosahexaenoic acid (DHA) 19.60% and eicosapentaenoic acid (EPA) 12.28% of total fatty acids,where, both DHA and EPA fatty acids are produced in fish through the consumption of these fish for small algae and zooplankton. Therefore, fish meal contains more omega-3 than omega-6 fatty acids; in contrast, most plant lipids contain higher concentrations of omega-6 fatty acids[14]. Hence, essential fatty acids in fish meal are necessary for normal larval development, fish growth, and reproduction.

Also, the obtained results revealed that ω-3 series of investigated FFWM are good source of (EPA) eicosapentaenoic acid, (DHA) docosahexaenoic acid and (ALA) linolenic acid which is important to chick growth, reproduction, and egg production[3]. While, ω-6 series are good source of linoleic acid (LA).

Regarding to ω3/ω6 and PUFA/SFA ratios, it was considered the main factors for assessing the nutritional value of fish meal[43], where increasing these ratios caused an increase in fatty acids containing ω-3. The family (ω-3) has the functions of essential fatty acids as a catalyst in chick growth and egg production as well as the growth and natural development of the fish, in addition to assist the immune system in defense of disease agents and reduces the stress response. Therefore, the obtained results clearly indicate an increase in the

nutritional value of fish meal (FFWM) prepared from Fayoum fisheries by products. Also, these results are in agreement with reported by [44].

Table 5 Fatty acids composition and nutritional value of fish meal prepared from Fayoum Fisheries by-products

Fatty acids % (g / 100 g of total fatty acids)	
Saturated Fatty Acids (SFA)	
C 14:0 Miristic acid	4.15
C 15:0 Pentadecanoic acid	0.80
C 16:0 Palmitic acid	17.25
C 18:0 Stearic acid	4.20
C 20:0 Arachidic acid	0.28
Total SFA	26.68
Monounsaturated Fatty Acids (MUFA)	
C16:1 ω-7 Palmitoleic acid	2.45
C18:1 ω-9cis Oleic acid	22.30
C20:1ω-9 Eicosenoic acid	3.50
C22:1 ω-9 Erucic acid	3.25
C24:1 ω-9 Nervonic acid	0.50
Total MUFA	32.00
Polyunsaturated Fatty Acids (PUFA)	
C18:2 ω-6 Linoleic acid (LA)	2.00
C18:3 ω-3 linolenic acid (ALA)	3.24
C20:4 ω-6 Arachidonic acid (AA)	1.20
C20:5 ω-3 Eicosapentaenoic acid (EPA)	12.28
C22:5 ω-3 Docosapentaenoic acid (DPA)	0.75
C22:6 ω-3 Decosahexaenoic acid (DHA)	19.60
Total PUFA	39.07
Unidentified	2.25
Omega-3 series (ω-3)	35.87
Omega-6 series (ω-6)	3.20
ω-3/ω-6	11.21
PUFA/ SFA	1.49

5- Minerals contents of fish meal produced from Fayoum fisheries by-products

The ash (minerals) content of fish meal can range from 10 to 25%. It is an excellent source of calcium, phosphorus and copper for animal feeding; a mineral content of fish meal produced by whole fish is less than produced from by products and crustacean[45]. The macro and micro elements contents of prepared fish meal from Fayoum fisheries by products(FFWM) are shown in Table 6. It was found that the major elements quantity; calcium (Ca), phosphorus (p), magnesium (Mg), potassium (K) and sodium (Na) were 26.50, 23.85, 2.20, 8.45 and 11.20 g/kg, respectively. While, micro element contents; Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn) and Selenium (Se) were 218.60, 5.50, 5.35, 82.50 and 1.35 mg/kg, respectively. From data, it could be noticed that the prepared fish meal is a good source of minerals especially of calcium and phosphorus and agreement with reported by[46] for farmed fish meal.

Ca content of investigated FFWM sample (26.50 g/kg) was higher than that reported by[47] for Herring fish meal (2.29%), but lower than that of Anchovy (3.73%) and Menhaden (5.11%) fish meal. But lower than reported by [33] that the average calcium content of kilka fish meal samples was (3.97%). P is the most essential mineral that must be supplied in the diet because it is an important component for animal body[48]. P content of investigated FFWM sample (23.85g/kg) was higher than those reported by[39] of 18 fish meal collected from various fish meal processing plants of Pakistan (0.21- 0.83%) and reported by[47] for herring fish meal (1.7%) but was lower than that of kilka fish meal samples (2.61%). Mg content of FFWM sample was (2.20 g/kg), not different from that reported by[32] for six fish meal samples (0.23%) but was higher than of Herring fish meals (0.15%). K content of our study FFWM (8.45g/kg) was lower than that reported of herring fish meal value

(1.09%) whereas, higher than that of kilka fish meal (0.52%). Na content in present study FFWM (11.20 g/kg) was higher than those reported by [47] for anchovy (0.65%), herring (0.61%) and menhaden (0.65%) fish meals.

Micro minerals; iron, and manganese, copper, zinc and selenium are essential and play important roles in biological systems of animal body. In the current study, from the same Table 6, Fe content of our sample FFWM (218.60 mg/kg) was higher than those of [32] for six fish meal samples (164.5 mg/kg) and herring fish meal (140 mg/kg) but was lower than that of menhaden (440 mg/kg) fish meals. Mn content of this study sample FFWM (5.50 mg/kg) was higher than those of herring (5 mg/kg) and kilka (3.7 mg/kg) fish meals, while was lower than reported by[47] for anchovy (10 mg/kg) and menhaden (33 mg/kg) fish meals. Cu content of FFWM (5.85 mg/kg) was not much different from those of herring (6 mg/kg) and kilka (6.2 mg/kg) fish meals, but lower than that of menhaden fish meals (11 mg/kg). Zn content of produced FFWM was (82.50 mg/kg) and higher than that found of kilka fish meals (74.5 mg/kg) but was lower than found of herring (132 mg/kg) and menhaden (147 mg/kg) fish meals. Finally concerning to the Se content of FFWM was (1.35 mg/kg), it was agreed with reported by[33] for kilka fish meals (1.58 mg/kg) and with reported by[47] for anchovy (1.36 mg/kg) fish meal, but it was lower than that for herring (1, 93 mg/kg) and menhaden (2.1 mg/kg) fish meals. The latter authors suggested that micro-minerals as Fe, Cu, Mn, Se and Zn are important to be supplemented in fish feeds due to the low levels in practical feed ingredients and interactions with other dietary components.

These results are in agreement with the finding of ISO 14001 and ISO 900 of Mineral Analyses 999 Fish Meal in Denmark, 2012 that reported that the average of macro minerals were 27.9, 22.1, 2.1, 16.4 and 9.6 g/kg sample for Ca, p, Mg, K and Na, respectively, whereas micro minerals were 208.1, 12.6, 4.2, 107.7 and 2.5 mg/kg for Fe, Mn, Cu, Zn and Se, respectively. Finally, the above results showed that the produced fish meal FFWM contains a moderate percentage of the major and trace essential metals of high importance when mixed in feeds of animals, poultry and fish.

Table 6 Minerals composition (mean ± S.D) of fish meal prepared from Fayoum Fisheries by-products

Macro elements (g/ kg)		**Micro elements (mg/ kg)**	
Calcium (Ca)	26.50 ± 1.04	Iron (Fe)	218.60 ± 2.22
Phosphorus (p)	23.85 ± 0.24	Manganese (Mn)	5.50 ± 0.16
Magnesium (Mg)	2.20 ± 0.11	Copper (Cu)	5.35 ± 0.50
Potassium(K)	8.45 ± 119	Zinc (Zn)	82.50 ± 1.90
Sodium (Na)	11.20 ± 0.05	Selenium (Se)	1.35 ± 0.06

Conclusion

In the present study, it was benefit from fish wastes of Fayoum fisheries in the production of high-quality low-cost fish meal contains essential amino acids, essential fatty acids, basic minerals, microbiological safety as reported by chemical and microbiological analysis that carried out. As well as planning for the production of fish meal on the large-scale from fish wastes and large & small fish untapped in human consumption, this produced fish meal can be used for feed animals, poultry and fish in Fayoum governorate instead of imported fish meal, in addition to reducing environmental pollution.

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