Original Research Article

Consumption Pattern and Heavy Metals Content of Commonly Consumed Fish in Benghazi

Abstract

Fish consumption has become an essential phenomenon due to the increasing appreciation of its health and economic benefits. The current study aims to identify the pattern of fish consumption and knowledge regarding the nutritive values of fish in Benghazi City. As well, it aims to analyse the heavy metals lead, cadmium and mercury in the top five most consumed fish's spices in Benghazi. A cross-sectional study was carried out on December 29, 2022, and extended to June 30, 2023. A total of 300 Subjects were randomly approached to participate in the study, giving a response rate of 85.5%. Fresh fish's samples were collected from Bankina and analysed the mentioned heavy metals using an Atomic Absorption Spectrophotometer**.** *Sparus aurata*, *Pegellus bogaraveo*, *Sardina pilchardus*, *Mullus barbatus*, and *Epinephelus marginatus* are the most commonly consumed fish in Benghazi. Age, female gender, and number of family members are the variables associated with the fish consumption pattern in Benghazi. Lead, cadmium and mercury are the three heavy metals analyzed in the top five most consumed fish in Benghazi. All heavy metal results are within the recommended level by the WHO. The results of the current study recommend that increasing fish consumption habits should be considered an essential fact for having healthier generations. Furthermore, fish consumption should be increased through information given by educational institutions, government agencies, and non-governmental organizations.

Keywords: Benghazi, Consumption, Pattern, Fish, Heavy Metals

Introduction

Fish approximately 34,000 species of vertebrate animals found in fresh and salt water globally. Fish species range from the primitive jawless hagfishes and lampreys through the cartilaginous skates, sharks, rays to the ample and varied bony fishes. Most fish species are cold-blooded; however, the opah (*Lampris guttatus*) is warm-blooded. Pollution of water streams may affect aquatic animals, like fish, directly or indirectly. [1, 2] Metals are a group of elements with atomic weights ranging from 63.549 to 200,590 Dalton. Metals are characterized by a similar electronic distribution in the outer shell, such as copper, cadmium, and zinc. Metals can be divided into two groups: transition metals and metal-like elements. [3] The transition metals include manganese, iron, copper, and cobalt. This group is essential for metabolism at low concentration levels. However, they can become toxic at higher concentrations. The metal-like elements include arsenic, cadmium, lead, mercury, selenium, and tin. This group is not important for metabolic function. They are toxic at low concentration levels. [4-6]

The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic at low concentrations. Heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb). Heavy metals cannot be destroyed or degraded. They enter humans' bodies via food, drinking water, and air. The presence of heavy metals in foods is a threatening issue, as it contaminates the food chain and harm public health. [7, 8] There is a wide range of foods contaminated by heavy metals. In particular, fish is one of the products most affected by heavy metal contamination; because heavy metals are bioaccumulative in the food chain. When heavy metals accumulate in waters, fish ingest them through their diet and accumulate them over the course of their lives. [9] The influence of heavy metals in fish varies between different species and different metals. Fishes accumulate heavy metals at concentrations many times higher than those present in water streams. Environmental circumstances such as water hardness, salinity, and pH can play a

significant role in heavy metal accumulation in the fish's bodies. [10, 11] Aquaculture is a recent activity in Libya, beginning with the culture of a variety of freshwater fish species in the 1970s. Success, however, was not forthcoming as a result of a lack of acceptance of farmed fish products by domestic consumers. The culture of marine fish species followed a decade later, encouraged through several government initiatives. In terms of human resources, no historical data is available. The main marine species cultured on a commercial basis in Libya are gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*), Atlantic bluefin tuna (*Thunnus thynnus thynnus*), common carp (*Cyprinus carpio*), bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idellus*) and catfish. Nile tilapia (*Oreochromis niloticus*) and red tilapia (Tilapia species) are the most important freshwater-cultured fish. Libya does not have any endemic freshwater species, and all freshwater species were introduced in the 1970s and 1990s. [12, 13] Many studies have been conducted in different regions of the world to evaluate fish consumption patterns and the parameters affecting them. It was reported that the parameters determining fish consumption include income level, education level, social status, parents influencing the pattern of fish consumption within the family, religion, and awareness of the nutritional value of fish. Benghazi is the second- biggest city in Libya. However, to the best of our knowledge, there are almost no previous studies on the consumption trend of fish in Benghazi city. According to the Food and Agriculture Organization (FAO), Libya's gross domestic product (GDP) from fisheries is 0.13%, while aagricultural GDP from fisheries is 2.69%. Furthermore, the fish available for consumption is 14.9 kg/capita. During 2019, imports of fish and fish products made up USD 236 983 550 of the Libyan eeconomy. [12-15] Fish is an important food because of its high protein, vitamins, and minerals, as well as being an important source of omega-3 fatty acids. Consuming fishes have protective role against cancer, and heart diseases. Heavy metal toxicity as a result of fish consumption can result in deterioration of central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, bones, liver and other vital organs. Long term exposure may result in Alzheimer's disease, Parkinson's disease, muscular dystrophy, multiple sclerosis, allergies, and cancer. [16, 17] Involving fish in the diet is very important because it is a source of proteins, vitamins, minerals and unsaturated essential fatty acids, especially omega-3 fatty acids. [18, 19] Several factors determine the dietary habits of people in the Arab world. Food consumption patterns have dramatically changed in some Arab countries as a result of the sudden increase in income from oil revenue. It is believed that the food subsidy policy has adversely affected food habits in the Arab states by encouraging the intake of fat, sugar, rice, wheat flour, and meat. Socio-cultural factors such as changing lifestyles, food preferences, education, and women's' employment all have a noticeable influence on food consumption patterns in this region. Comprehensive studies on social, cultural, and economic factors associated with food consumption patterns in the Arab region are highly recommended. Libya is important part of the African agri-food system. Fish provide 19% of animal protein intake to Africans. The fish consumption pattern in North Africa is 13.5 kg/person/year. Africa lags behind other regions in developing its share in global fish production, consumption, and trade, and Libya is no exception. Currently, however, Africans are in the paradoxical position of being highly dependent on fish for animal protein but ranking low in per capita fish consumption. Globally, Africans are

second only to Asians in terms of relying on fish as a major share of the total animal protein intake in their diet. Fish represent over 20% of animal protein intake in twenty African countries. No data is available about the fish consumption pattern in Libya. To the best of our knowledge, this is the first study regarding fish consumption patterns in Libya. [12, 20-22] Several techniques have been used for the determination of metal concentrations in fish species, such as flame atomic absorption spectrometry, graphite furnace atomic absorption spectrometer, electro-thermal atomic absorption spectrometry, inductive coupled plasma, and mass spectrometry. Different digestion methods were used as sample preparation methods for the determination of heavy metals in fish samples. [23- 27] In 2017, a study was carried out in Sabratha coastal sediments, Mediterranean Sea, Libya, to detect the distribution and enrichment of heavy metals. 30 sediment samples were collected for iron, copper, lead, manganese, cadmium, cobalt, Nickel, and zink analysis using atomic absorption spectrometry. The analysis indicated that the Sabratha's coastal sediments were enriched with Cd, Pb, Cu, Ni, Co, and Zn (EF = 81.48, 17.26, 12.80, 11.42, 9.85, and 8.56 respectively). The highest levels of Mn, Cu, Ni, Pb, and Co were recorded nearby the Mellitah complex oil and gas station in the western Libyan region, while the highest levels of Zn and Cd were recorded in the central part of the study area nearby the fishing port and Sabratha hospital. [25] The average values of Cd, Pb, and Co were mostly higher than the ones recorded from the Arabian and Oman gulfs, the Red Sea, the Gulf of Aqaba, the Caspian Sea, the coast of Tanzania, and the background shale and the earth's crust. The high levels of most of the studied heavy metals suggested significant anthropogenic sources along the Sabratha coast. [28] In 2010, a Libyan study determined the concentrations of Co, Cd, Pb, Fe, and Cu in different tissues (bone, skin, flesh, and tail) of fish species of the Mediterranean Sea (Libyan coastline) using flame atomic absorption spectrometry. The fish species used in this study were *Sardinella aurita, Pagellus erythrinus, Balistes capriscus, Trachurus trachurus, Synodus saurus*, and *Dactylopterus volitans*. The concentration of Co ranged from 0.570 mg/kg to 44.693 mg/kg. These concentrations of Co in all examined tissues were higher than the World Health Organization's (WHO) recommended level. The results of the analysis indicated that the concentrations of Cadmium in all examined tissues varied from 0.328 mg/kg to 2.929 mg/kg. These values were greater than the WHO-recommended level**.** The concentration level of Pb in all examined tissues ranged from 0.246 mg/kg to 2.386 mg/kg. These values were higher than the values accepted by WHO. [29] In 2008, another Libyan study was published. This study aimed to investigate the relationship between the concentration of some heavy metals (lead, cadmium, mercury, copper and zinc) in water and their bioaccumulation in the liver and muscle tissues of some marine fish species in the El Khoms area of Libya. The present work revealed a marked increase in heavy metal concentration in the muscles and liver tissues of investigated fish, and such increases were positively correlated with a corresponding increase in heavy metal concentration in water. [30] The concentration of heavy metals in two tropical fish species from the Ogba River, Nigeria, showed varying concentrations of Cu, Mn, Zn, Pb, Cr, Ni, and Cd in the fish tissues. Concentrations of Cu, Mn, Cr, and Ni in both fish were higher than the permissible reported by the WHO while those of Zn and Pb were lower than permissible concentrations. [31] Limited literature is found regarding fish consumption patterns in Benghazi as well as the heavy metal contents of Benghazi fish. The current study aims to evaluate the heavy metals contents of the most

commonly consumed fish in Benghazi. The current study seeks to study methods of fish's meal preparation, knowledge regarding the nutritive value of fish, the association between socio-economic variables, and the current fish consumption pattern in Benghazi.

Methodology

This is a cross-sectional study carried out from December 29th, 2022, and extended to June 30th, 2023. A total of 300 subjects (male and female) were randomly approached to participate in the study. The study respondents were people aged 18 years and older, who were fishers, selling, and purchasing fish from the fish local market (Bankina) in Benghazi city, giving a response rate of 85.5 %. The sample size was determined by using the Richard Jaeger equation. Informed consent was obtained from the subjects who were also assured of the confidentiality of the information collected. The research was approved by the administration of the Faculty of Public Health, University of Benghazi. The questionnaire consists of four sections: socioeconomic information, fish's consumption pattern, information regarding Nutritional value, and fish cooking methods. A qquestionnaire was developed by deep reading in similar previous studies. The questionnaire's validity was assessed via a pilot study on thirty participants. After determination of all consumed types of fish in Benghazi, the top five consumed fish were nominated to be analyse for heavy metals content. These fish include *Sparus aurata*, *Pegellus bogaraveo*, *Sardina pilchardus*, *Mullus barbatus*, and *Epinephelus marginatus*. Three fresh samples were collected from each fish type in the Bankina. A physical inspection was done on all samples. Fish samples have been collected from the Benghazi local fish market (Bankina). Collected samples are illustrated in Figure 1. Samples were analysed in the Food Chemistry Laboratory, Department of Nutrition, Faculty of Public Health, University of Benghazi. **Reagents**: Water: redistilled or deionised, nitric acid A.R. 0. 1 M, diluted 7 mL concentrated acid to 1 litre, Nitric acid concentrated (Sp. Grade 1.40), standard solutions for cadmium, mercury, and lead. Working standard solutions: for flame analysis, dilute the standard solution with 0.1 M HNO_3 to a range of standards that cover the concentration of the elements to be determined. [32] The researchers weighted accurately 1 g of each fish type assigned to be analysed. 10 ml of concentrated nitric acid has been added. The dish content is heated with a soft flame using a Bunsen burner until all the volatile or readily combustible matter has been removed. Then, the sample is left to cool. 5 mL of hydrogen peroxide is added and heated for five minutes. The solution is transferred to a volumetric flask to be filled with water. All the previous steps of sample preparation are repeated with blanks. Identical procedures are followed even in heat and time. Sample preparation is illustrated in Figure 2.

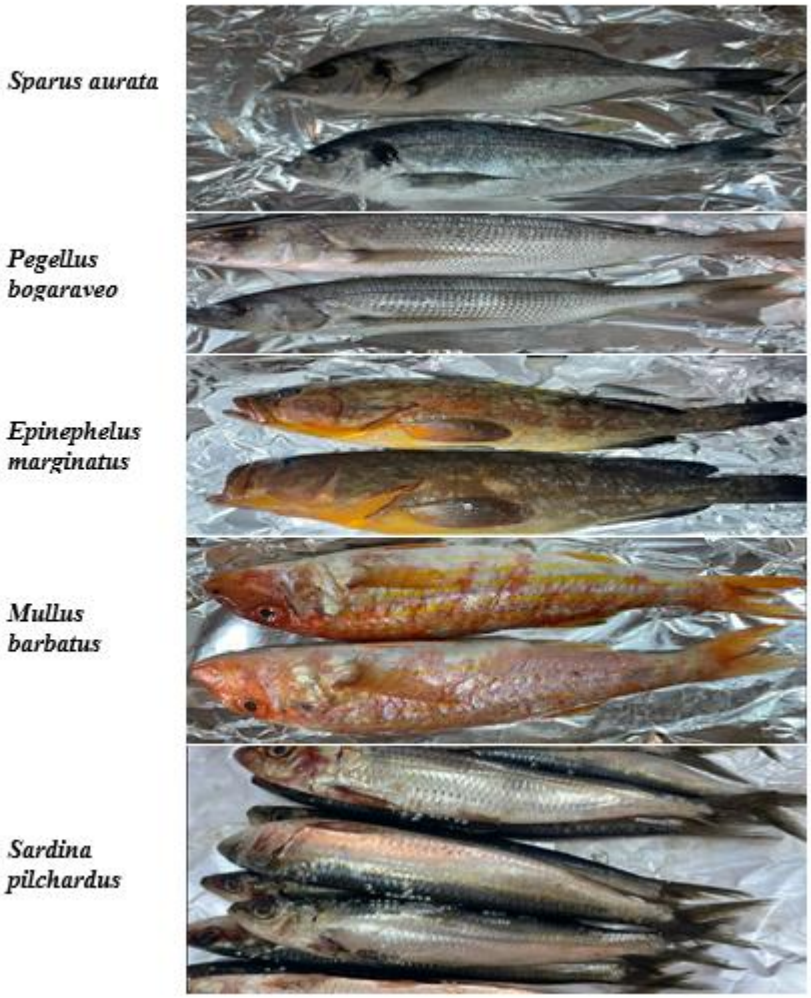

Figure 1: Samples of analysed fish species

Determination of Heavy metals

Set the instrument as per the previously established optimum conditions as per the guide lines given in the Instruction Manual (provided along with the instrument). Determine the absorbance of the sample solution(s) and blank. Calculate the heavy metal content from the standard curve.

Preparation of standard curve:

Read the absorbance of a series of standard metal solutions in the atomic absorption spectrophotometer after setting the instrument to optimum conditions. Plot absorbance is done against µg of metal/mL solution. [32] All data will be coded prior to being entered into a computer. The description and analysis of the data were done by *Statistical Package for the Social Sciences* (SPSS) version 22. The level of significance was set at a *P* value < 0.05. The researchers of the current study realize that the observational and cross-sectional design, with a single measurement in one season is a limitation of the current study. A shortage in laboratory materials limits the nominated analyzed samples to only five types and the analyzed heavy metals to only three metals.

Results

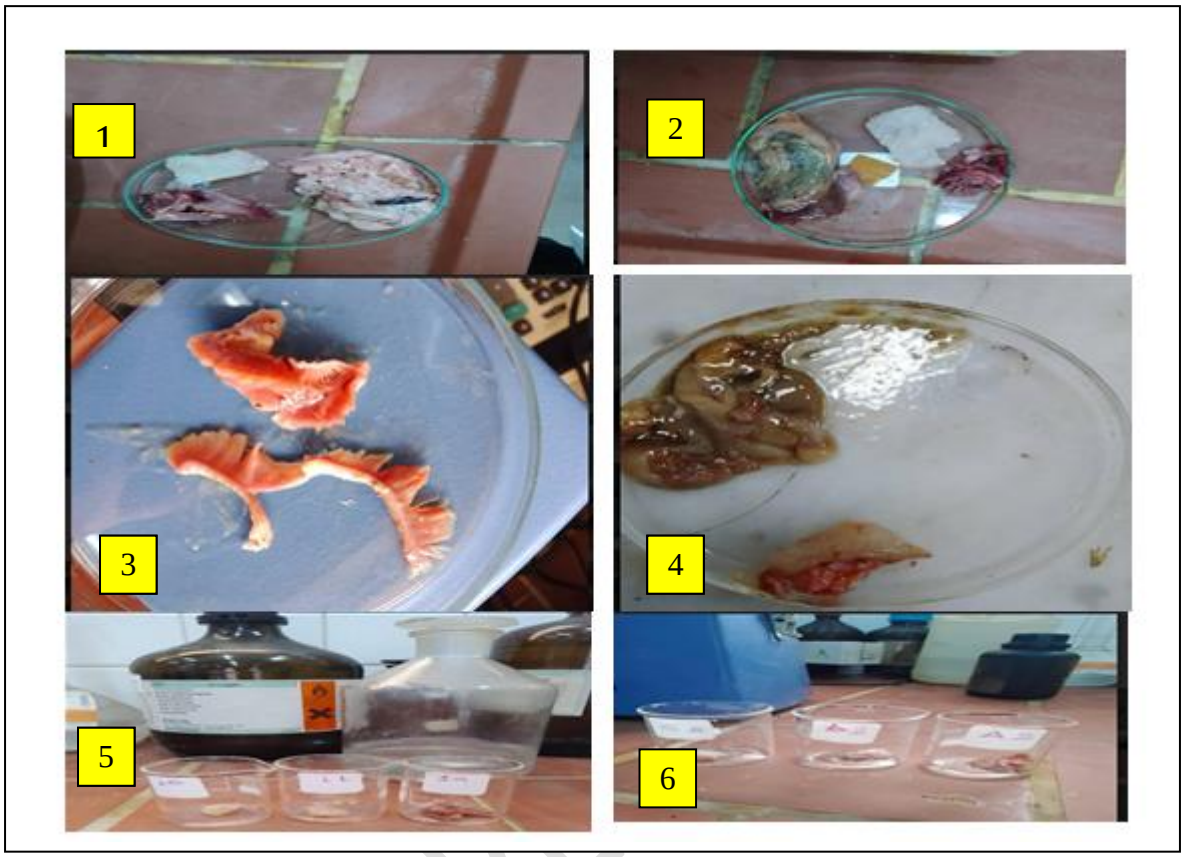

Photo 1: sample from gills, Photo 2: sample from guts, Photo 3: sample from muscles, Photo 4: samples from guts. Photo 5: Nitric acid preparation. Photo 6: samples separation.

Figure 2: Samples preparation

The percentage of subjects in the age group 18-40 years is the highest (44%). The percentage of subjects in the age group 41-60 years made up 37.67%. The males made a percentage of 59.33 and the females made a percentage of 40.67 out of the total number of subjects (300). The general average ages of males and females mean ±SD is about 34±4.6 as shown in Table 1. Socio-economic characteristics and details of the respondents were presented in Table 2. The marital status shows that50.33% are married and 49. 67% are not married. Regarding the education level of the subjects, the percentage of subjects with a basic education was 6%, and the percentage of people with a secondary education was 18%, while the highest percentage of subjects with a university level was 72.33%. Regarding occupation, 5.33% of the subjects were students, housewives, employees, freelancers were 40.33% 36%, and 3.3% respectively of the total sample. The percentage of subjects whose income was less than 500 Libyan Diner (LD) was about 3.67%, while the percentage of subjects whose average income was between 500-1000 LD was 42.33%, which is the highest percentage of earned income. The subjects whose average income was 1000-1500 LD were 23.33%. The percentage of subjects whose income was more than 1500 LD was about 30.67%.

Families with less than five members were 40%, while families with more than five members were 60% of the total sample.

Table 1: Subject characteristics

Age (Years)		Total		Total
		Male	Female	
20-40	No. (%)	82(27.33)	50(16.67)	132(44)
41-60	No. (%)	78(26)	35(11.67)	113(37.67)
61-80	No. (%)	18(6)	37(12.33)	55(18.33)
Total	No. (%)	178(59.33)	122(40.67)	300(100)
Age (Years)Mean ± SD		35±3	33±6.2	34±4.6

Table 2: Socioeconomic characteristics of the subjects

Socioeconomic Characteristics	No.	%
Marital status		
Married	151	50.33
Not Married	149	49.67
Education Level		
Basic	18	6
Secondary	54	18
University	217	72.33
Higher Education	11	3.67
Occupation		
Student	16	5.33
House wife	121	40.33
Employee	108	36
Freelance	10	3.3
Retired	45	15
Income level		
<500	11	3.67
500-1000	127	42.33
1000-1500	70	23.33
>1500	92	30.67
Family members		
<5	120	40
≥5	180	60

Fish consumption pattern

The percentage of subjects who consume fish is 88%. The reasons for not eating fish varied between tastes and smell (33.33%) and bone (30.56%). Subjects who consume fish from once to twice a week make about 42.33%. It is has the highest percentage. 8.67% of subjects consume fish three to four times a week. 33% of subjects do not eat fish on a weekly basis. 42.67% of the subjects consume once to twice a month which is the highest percentage. 25.33% of the subjects consume fish three to four times a month. Furthermore, subjects who consumed fresh fish made 72% of the total sample;, which is the highest percentage. 7.3% of subjects preferred canned fish. frozen fish , salted fish, and smoked fish were preferred by 10%, 6.7%, and 4% of the subjects, respectively. Figure 3 shows the frequency of the most consumed fishes in Benghazi. The top five consumed fish were *Sparus aurata* (45.33%), *Pegellus bogaraveo* (36.67%), *Sardine pilchardus* (34.67%), *Mullus barbatus* (33.33%), and *Epinephelus marginatus* (29.67%).

Table 3: Fish consumption pattern

Socioeconomic Characteristics	No.	%
Fish Consumption		
Yes	264	88
No	36	12
Reasons for Not eating fishes		
Taste and Smell	12	33.33
bones	11	30.56
Taste, Smell and Bones	13	36.11
Weekly fish consumption		
No	99	33
1-2	127	42.33
3-4	26	8.67
5-6	4	1.33
≥ 7	8	2.67
Monthly fish consumption		
No	20	6.67
1-2	128	42.67
3-4	76	25.33
5-6	26	8.67
≥ 7	14	4.67
Types of preferred Fishes		
Fresh	216	72
Canned	22	22
Frozen	30	30
Salted	20	20
Smoked	12	12

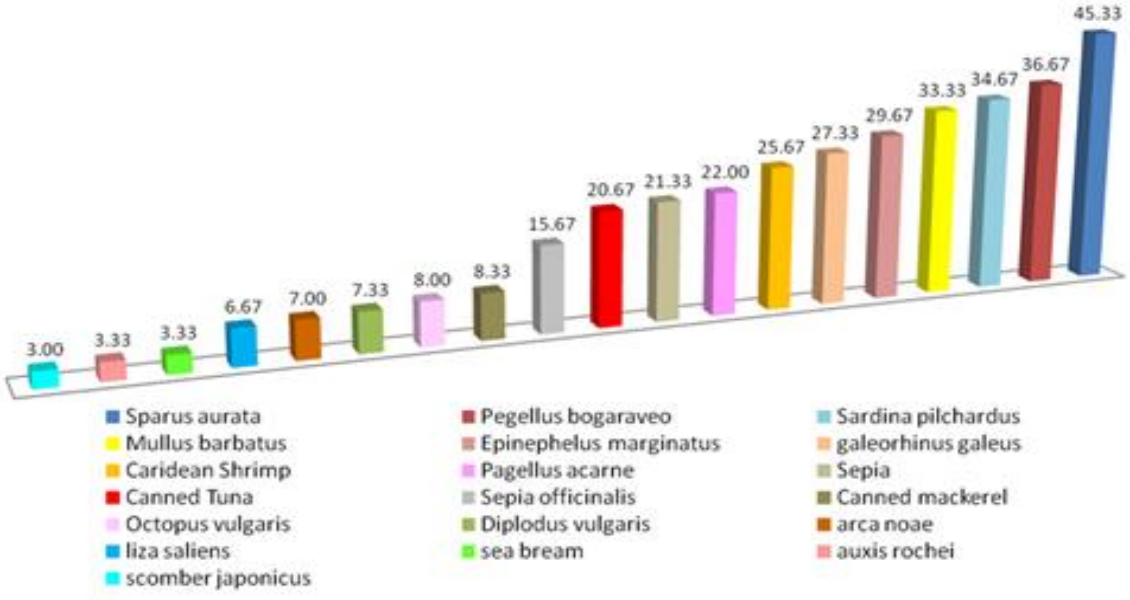

Figure 3: Frequency of different fishes consumption in Benghazi

Figure 4 presents the reasons for selected the preferred fish. The fish quality was 9%; it is the lowest percentage. The price of the fish was 16%, the taste was 39%; it is the highest percentage, and the nutritive value was 30%. Figure 5 shows the sources of consumed fish. The highest percentage comes from the local market "Bankina" with 46%. Supermarkets, fish restaurants, fishermen, and fishing make 24%, 11%, 12%, and 7%, respectively. Figure 6 shows the reasons for selecting fish's sources. The highest percentage (51%) was for available fish types, 30% for place close to home and 19% for price. Figure 7 presents factors affecting fish selection. The highest percentage was for there is no special reason (44.3%), 14.7% for gill color, and 12% for eye status. The lowest percentages were 10.3%, 10%, and 8.7% for tenderness, smell, and color, respectively. Figure 8 shows the most preferred cooking methods for fish in Benghazi. Grilling on charcoal is the preferred preparation method for fish in Benghazi (35.2%). 20.9% of the subjects prefer eating fried fish. Libyan traditional Tagin and oven roasting are coming after that with a percentage of 12.36% and 11.1%1, respectively.

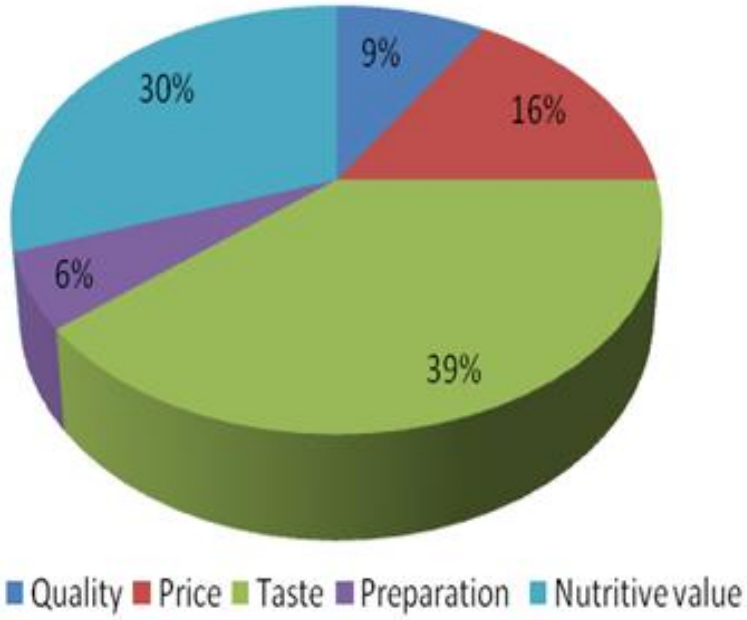

Figure 4: Reasons for selecting the preferred fish

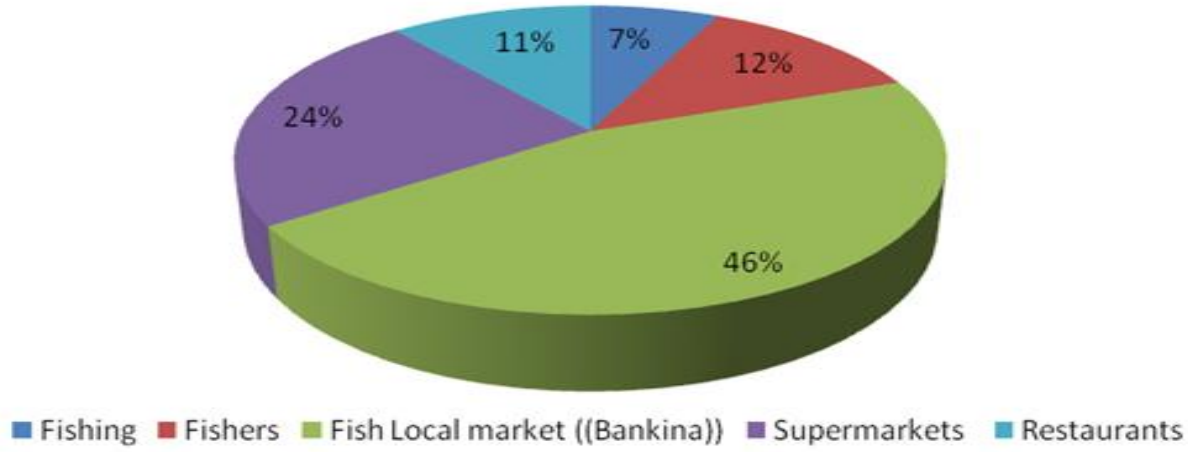

Figure 5: Sources of consumed fish

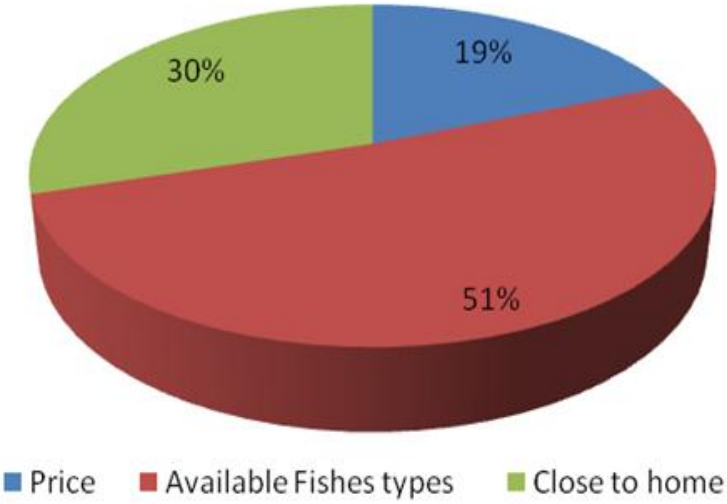

Figure 6: Reasons for selecting fish sources

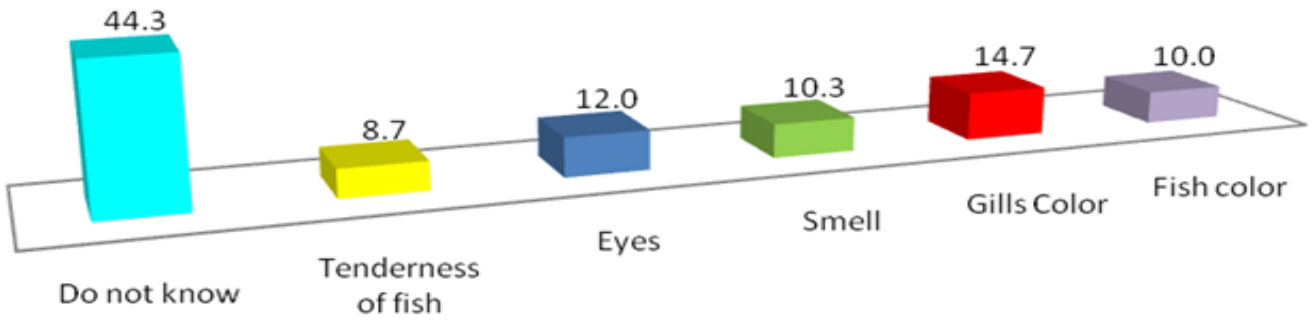

Figure 7: Factors affecting fish Selection

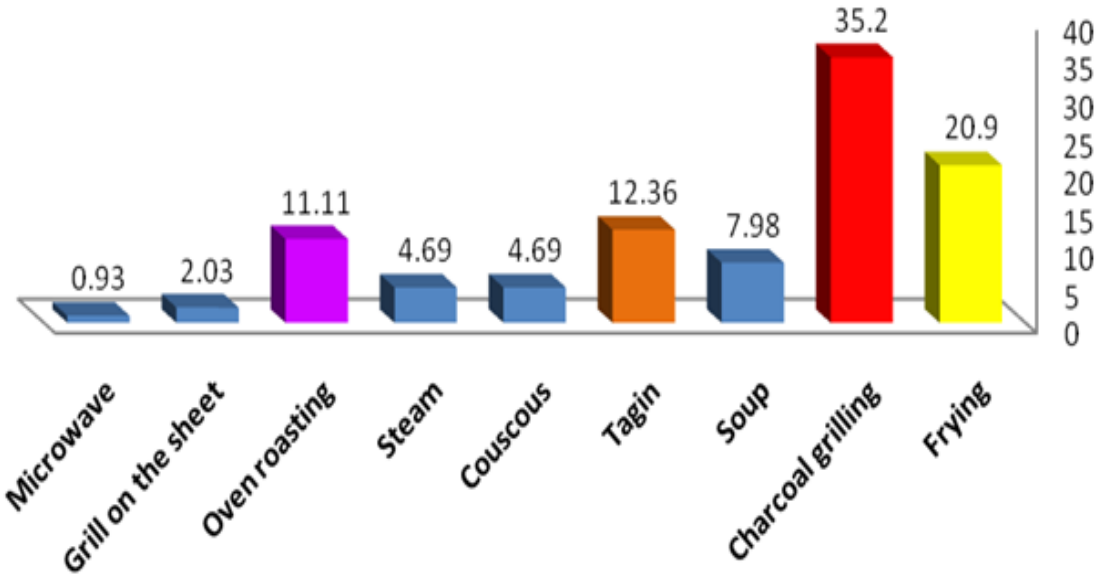

Figure 8: Fish prefering cooking methods

Figure 9 shows the subject knowledge of the nutritional value of fish. The highest percentage of the subjects 45% know that fish are good sources of omega 3. Only 19% of the subjects know that fish are good sources of protein. Furthermore, only 9% of the subjects know that fish are good sources of healthy types of fat. 10% and 5% of the subjects know that fish are good sources of vitamin D and carbohydrate, respectively. 12% of the subjects state that they do not have any information regarding the nutritional value of the fish. Figure 10 shows the subject knowledge of the adult health benefits of fish. 9.33% of the subjects know that fish are significant for bone health. Prevention of chronic diseases and brain health as benefits of fish has response by the subjects 25.33% and 25.67%, respectively. Only 19.67% of the subject think that fish are important for general health. Figure 11 shows the sources of information regarding fish. The internet was the biggest source of information with a percentage of 42%. The radio was the second source of information, with a percentage of 26.7%. Television and health education programs have similar effects, with a percentage of 15.7% and 15%, respectively.

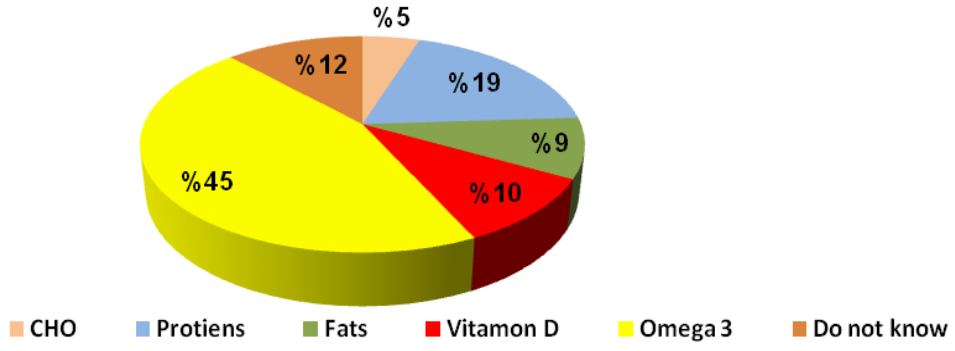

Figure 9: Subject knowledge of the adult health benefits of fish

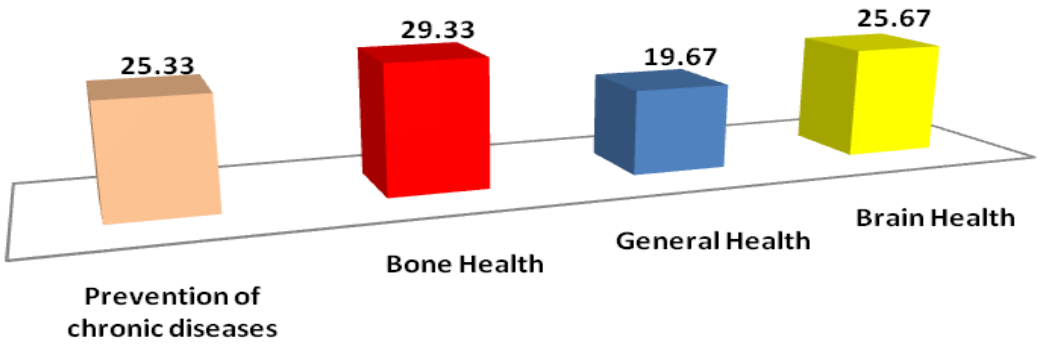

Figure 10: Subject knowledge of the nutritional value of fish

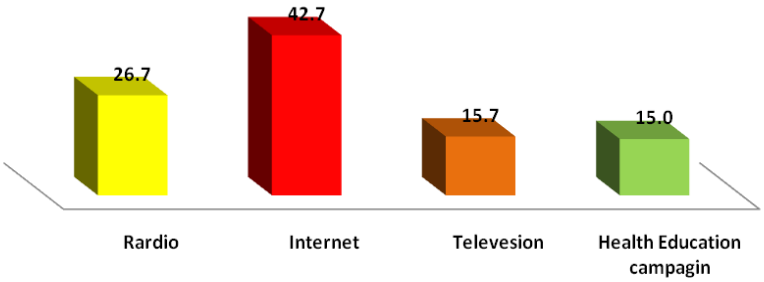

Figure 11: Sources of Information regarding Fish

In *Sparus aurata* and *Epinephelus marginatus*, lead is higher in muscles than guts and grills respectively. *Pegellus bogaraveo*, *Sardina pilchardus*, and Mullus barbatus lead (Pb) are higher in guts than muscles and grills. Regarding, cadmium (Cd), it is higher in gills than muscles and guts in all samples of the five fish. Looking at mercury, all samples provide less than 0.01 ppm except in *Epinephelus marginatus*. *Epinephelus marginatus* contains 0.03 ppm of mercury in the gut, which is the highest compared to gills and muscles. Muscles and gills of *Epinephelus marginatus* contain 0.027 and 0.016 ppm of mercury, respectively as illustrated in Table 4 .

Table 4: Heavy metal contents in the most consumed fish in Benghazi

Fish Samples	Gills			Guts			Muscles		
	Lead	Cadmium	Mercury	Lead	Cadmium	Mercury	Lead	Cadmium	Mercury
Sparus aurata	0.010	0.012	<0.01	0.015	<0.005	<0.01	0.018	<0.005	<0.01
Pegellus bogaraveo	0.014	0.010	<0.01	0.024	<0.005	0.013	0.020	<0.005	0.011
Sardina pilchardus	<0.005	0.007	<0.01	0.008	<0.005	<0.01	<0.005	<0.005	<0.01
Mullus barbatus	0.008	0.017	<0.01	0.011	0.006	<0.01	0.010	<0.005	<0.01
Epinephelus marginatus	0.019	0.025	0.016	0.027	0.009	0.030	0.032	0.006	0.027

The results of the Logit model are shown in Table 5. The age variable has been found significant at the 5% level statistically. The probability of consuming fish increases by 1.643 for every unit increase in age. In this study, females

consume more fish at 0.489 rates than males. Also, as family members increase, the probability of consumers' consumption increases to 1.40.

Table 5: Association of socioeconomic variables with fish consumption

Variables	B (Coefficient of explanatory variables)	Standard Error	Z-statistics	Severity Rating	Betting odds
Age	0.497	0.193	2.568	0.010	1.643
Gender	-0.715	0.357	-2.003	0.045	0.489
family members	0.337	0.139	2.425	0.015	1.401

Discussion

Worldwide, fish consumption and marketing have become an essential phenomenon due to the increasing appreciation of their health and economic benefits. Given this, the current study sought to identify the pattern of fish consumption and knowledge regarding the nutritive values of fish in Benghazi City. Consequently. The top five most consumed fish's spices in Benghazi have been analyzed in terms of the heavy metal content of lead, cadmium, and mercury. Data obtained have been analyzed using the Statistical Package for Social Sciences (SPSS). *Sparus aurata, Pegellus bogaraveo, Sardina pilchardus, Mullus barbatus,* and *Epinephelus marginatus* are the most commonly consumed fish in Benghazi. [1, 17] Fish consumption preferences are affected by individuals' socioeconomic characteristics. The percentage of subjects in the age group of 20-40 years is the highest percentage, and they constituted about 44%. It is followed by subjects from the age group 41-60 years 37.67%). The mean ages of male's ±SD were about 35±3, and the mean ±SD for females was about 33±6.2. The general average ages of males and females mean ±SD about 34±4.6. This mean is almost close to the mean age of a similar study 31 years done by Rhoda Foil's 2020. [33]In a similar study in Tripoli, the age category (36-45) had the highest age (34%) among the study sample. The age variable has been found significant at the 5% level statistically. [34] The coefficient of the age variable took **a** positive value. The probability of consuming fish increases by 1.643 for every unit increase in age. This result is similar to previous studies by Ahmad (2016) and Burger (2002). [35, 36] The males made a percentage of 59.33% and the females made a percentage of 40.67% of the total number of the subjects (300). This result is opposite to the Tripoli study of fish consumption patterns. In Tripoli, nearly 60% of respondents were females, while 40% were males. The coefficient of the gender variable takes a negative value. In this case, it has been determined that females consume fish more than males. Females consume more fish at 0.489 rates than males. The findings of this study are similar to those of a Turkish study that was carried out in 2013. [34, 37] The marital status shows that 50.33% are married. In the current study as well as in previous studies, statistical tests did not show significant differences relating to the fish consumption and marital status of respondents. [34] Regarding the education level of the subjects, the percentage of subjects with a basic education was 6%, and the percentage of people with a secondary education was 18%, with the highest percentage of subjects with a university level (72.33%). Comparing to the literature, most of the respondents (36%) indicated that the terminal educational level was junior high school, while a minority (8%) indicated primary as their last level of education. Only 8% of the respondents reported not having a formal education. Statistical tests did not show a

significant difference relating to fish consumption and the level of education. [34, 37] Regarding occupation 5.33% of the subjects were students, the housewives (40.33%), employee(36%), and freelance (3.3%), respectively, of the total sample. In the previous study, 17.4% of them were civil servants, 20.3% were workers, 23.2% were homemakers, 19.2% were other, 10.7% were self-employed, and 9.2% were unemployed. Statistical tests did not show a significant difference relating to fish consumption and occupation. [33-37] The percentage of subjects whose income was less than 500 Libyan dinars (LD) is about 3.67%, and the percentage of subjects whose average income was between 500 and 1000 is 42.33%, which is the highest percentage of earned income. When considering the exchange rate, the results of this study are similar to those of the Turkish study. [37] Families with less than five members make (40%)40% up to the total sample, while families with more than five members make 60%. In this study, the variable of the individual number in the family takes on a positive value. A unit increase in the number of family members increases the probability of consumers' consumption at by 1.401. This result is similar to the results of a previous study done by Onurlubas in 2013. [37] The current study reveals that the percentage of subjects who consume fish was 88%. Accordingly, 12% of the subjects do not consume fish. The consumption rate in Benghazi is higher than the previous rate in sub-Saharan African, where the majority of the respondents (72%) consumed fish, while 28% indicated that they do not consume fish. The consumption rate in Benghazi is lower than in Tripoli. Tripoli results showed that 98% of the respondents consume fish. [33, 34] The reasons for not eating fish in the current study vary between tastes and smell (33.33%) and bone content (30.56%). In a previous study, subjects did not like fish, and being very expensive was one of the main reasons for non-consumption of fish, with a percentage of 16.7% and 16.7%, respectively. It is noteworthy that 44.4% of the respondents did not give a reason for not consuming fish. [34] Subjects who consume fish once to twice a week make up about 42.33% of the total sample. It is the highest percentage (8.67%) of subjects who consume fish three to four times a week. 33% of subjects who do not eat fish on a weekly basis. Regarding monthly fish consumption, 6.67% of the subjects don`t consume, and 42.67% of the subjects consume once to twice a month, which is the highest percentage. 25.33% of the subjects consume fish three to four times a month. The results of the Tripoli study show that the largest percentage of respondents (66%) consume fresh fish one to two times per month, 27% consume fish once to twice a week, and 5% consume fresh fish daily. Furthermore, subjects who consumed fresh fish made up 72% of the total sample, which is the highest percentage. 7.3% of subjects preferred canned fish. and frozen fish (10%) , salted fish (6.7%), and smoked fish (4%) were preferred, respectively. In the previous study, the categories of fish consumed were, in descending order, fresh, canned, frozen, salted, and smoked with percentages of 96.7, 94.7, 21.8 and 0.98%, respectively. [33-37] Nine teen Nineteen fish types are consumed in Benghazi. The top five consumed fish were *Sparus aurata* (45.33%), *Pegellus bogaraveo* (36.67%), *Sardine pilchardus* (34.67%), *Mullus barbatus* (33.33%), and *Epinephelus marginatus* (29.67%). In previous Libyan date, more than one-third of the respondents frequently buy and consume sardine, sea bream, and mackerel with a percentage of 57.6, 47.0 and 37.2%, respectively. The reasons for the selection of these types include fish quality (9%);, price (16%), taste (39%), and nutritive value (30%), respectively. In previous study, the reasons behind respondents' choices towards a certain fish included that 61% of the respondents buy certain types

of fish because of their taste, while 38% of them make their choice based on their belief that this type of fish is good for their health. Meanwhile, 22, 21, and 8% of the respondents buy certain kinds of fish because their prices are affordable, fit within budget, high quality, and easy to prepare, respectively. [34] The highest percentage of consumed fish (46%) comes from the local market "Bankina". Supermarket, fishers, fish restaurants, and fishing make 24%, 11%, 12%, and 7%, respectively. Literature showed the that fish market at the seaport is the most popular market for respondents (75%) to buy fish from, followed by the fish store (13.3%), directly from fishermen (11%), the fish and meat market (6%), the supermarket (5%), and vehicles for selling fish (3%). [33-37] The reasons behind the selection of these places vary in the current study. The highest percentage (51%) was for available fish types, 30% for places close to home, and 19% for price. In a previous study, the reasons behind the choice of a certain place for buying fish by respondents were varied. The majority of the respondents (82.2%) chose a place to buy fish because of the availability of fresh fish in the chosen place, followed by the reasons of being near their house, and cheap, with a percentage of 23.6% and 14.3%, respectively. [34] Grilling on charcoal is the preferred preparation method for fish in Benghazi (35.2%). 20.9% of the subjects prefer eating fried fish. Libyan traditional tagine (mixed fish and different types of vegetables such as potato, zucchini, carrot, eggplant, and garlic) and oven roasting are coming after that with a percentage of 12.36% and 11.11%, respectively. The most popular methods of fish cooking include frying, grilling, soup, tagine, and couscous. The results from the Tripoli Study revealed that frying is the most frequent method of cooking fish (71.1%) among the respondents in this study, followed by grilling (61.7%). [34] The highest percentage of the subjects (45%) know that fish are good sources of omega 3. Only 19% of the subjects know that fish are good sources of protein. Furthermore, only 9% of the subjects know that fish are good sources of healthy types of fat. 10% and 5% of the subjects know that fish are good sources of vitamin D and protein, respectively. 12% of the subjects state that they do not have any information regarding the nutritive value of the fish. In the previous study, the subjects had better knowledge than Benghazi subjects regarding the fish content of omega 3. In a previous study, a lower percentage of the subjects (32%) of the participants were able to identify omega 3 fatty acids as essential fats. [36, 37] In the current study, 29.33% of the subjects know that fish are significant for bone health. Prevention of chronic diseases and brain health as a benefits of fish have received from the subjects 25.33% and 25.67%, respectively. Only 19.67% of the subjects think that fish are important for general health. In the previous study, the majority of the respondents (85.6%) agreed that eating fish is good for health. Again, literature indicates that knowledge is much lower in Benghazi regarding the health benefits of fish compared to other regions. [34] The internet was the biggest source of information, with a percentage of 42%. The radio was the second source of information, with a percentage of 26.7%. Television and health education programs have similar effects, with a percentage of 15.7% and 15%, respectively. In a previous study, the majority of the respondents (83%) chose television as the most effective medium for getting information about the benefits and use of fish. While 12%, 4%, and 1% of the respondents chose radio, the internet, and newspapers as effective mediums for obtaining information about the benefits and use of fish. Different sources of information justify the differences in knowledge levels compared to other regions. [34, 35] Lead (Pb), cadmium (Cd), and mercury (Hg) are the heavy metal

analysed in the top five most consumed fish in Benghazi part per million (ppm) in the current study using atomic absorption spectrophotometer inside the Food Chemistry and Analysis Laboratory of the Department of Nutrition, Faculty of Public Health, University of Benghazi. In *Sparus aurata* and *Epinephelus marginatus* lead is higher in muscles than guts and grills, respectively. ~~Pegellus bogaraveo~~, *Sardina pilchardus*, and *Mullus barbatus* lead are higher in guts than muscles and grills. All these values are higher than previous Libyan studies published by researchers from Tripoli, Alkhomse, and Sebha. However, all these levels are still within the recommended levels by the WHO. Regarding cadmium it is higher in gills than muscles and guts in all samples of the five fish. Moreover, these results for cadmium are still within the recommended levels by the WHO. Looking at mercury, all samples provide < 0.01 ppm except in *Epinephelus marginatus*. *Epinephelus marginatus* contains 0.03 ppm of mercury in guts, which is the highest compared to gills and muscles. Muscles and gills of *Epinephelus marginatus* contain 0.027 and 0.016 ppm of mercury, respectively. All these results are within the recommended level by the WHO. [34, 37, 38)

Conclusion

Sparus aurata, *Pegellus bogaraveo*, *Sardina pilchardus*, *Mullus barbatus*, and *Epinephelus marginatus* are the most commonly consumed fish in Benghazi. Age, female gender, and number of family members are the variables associated with fish the consumption pattern in Benghazi. The current study reveals that the percentage of subjects who consume fish in Benghazi is 88%. Accordingly, 12% of the subjects do not consume fish. Lead (Pb), cadmium (Cd), and mercury (Hg) are the heavy metals analyzed in the top five most consumed fishin Benghazi. All these results are within the recommended level by the WHO.

Consent

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

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