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The effects of different methods of cooking on proximate, mineral and heavy metal composition of fish and shrimps consumed in the Arabian Gulf

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SUMMARY. This study analyzed eight cooked species of fish and one species of shrimps (grilled, curried, fried and cooked in rice) commonly consumed in Bahrain for their proximate, mineral and heavy metal content. The results reveled that the protein content was in the range of 22.8-29.2 g/100g, while the fat content was between 2.9-11.9 g/100g. The energy content was the highest in the fried *Scomberomorus commerson* being 894.2 KJ/100g, followed by *Scomberomorus commerson* cooked in rice (867.3 KJ/100g). The samples also had a considerable content of sodium ranging from 120-600 mg/100g, potassium (310-560 mg/100g) phosphorous (200-330 mg/100g), magnesium (26-54 mg/100g) and zinc (0.4-2.0 mg/100g), while the other minerals were present to a lower extent. Lead was present to an extent of 0.30 µg/g in the grilled *Plectorhinchus sordidus* while *Lethrinus nebulosus* cooked in rice contained 0.35 µg/g of mercury. Cadmium levels were constant at <0.02 µg/g. It can be concluded the traditional methods of cooking fish and shrimps have an effect on their nutrient composition and heavy metal content hence, it is advisable to avoid excessive frying and use minimal salt. In addition, consuming of a wide variety of species of fish and alternating between the various modes of cooking is the best approach to achieve improved dietary habits, minimizing mercury exposure and increasing omega-3 fatty acid intake.
Key words: Fish, shrimp, cooking, proximate composition, minerals, heavy metals.

RESUMEN. Efecto de diferentes métodos de cocción en la composición proximal, minerales y metales pesados de pescados y camarones consumidos en el Golfo Arabe. Se analizó la composición proximal, contenido en minerales y metales pesados de ocho especies cocidas de pescado y una de camarón (asado a la parrilla, al curry, frito y cocido en arroz), de consumo frecuente en Bahrain. El contenido de proteinas varió entre 22.8 y 29.2 g/100 g y el de lípidos entre 2.9 y 11.9 g/100 g. El valor energético mas elevado, 894.2 KJ/100 g, se encontró en el *Scomberomorus commerson* frito seguido por esta misma especie cocida con arroz. Todas las muestras presentaron el perfil de minerales siguiente (mg/100g): sodio 120-600; potasio 310-560; fósforo 200-330; magnesio 26-54 y zinc 0.4-2.0. Se encontraron cantidades menores de los otros minerales analizados. La especie *Plectorhinchus sordidus* a la parrilla, evidenció un contenido de plomo de 0,3 µg/g y el *Lethrinus nebulosus* cocido en arroz, un contenido de mercurio de 0.35 µg/g. Los niveles de cadmio se mantuvieron menores de 0.02 µg/g. Se concluye que los métodos tradicionales de cocción de los pescados y camarones, afectan su composición en cuanto al valor nutritivo y contenido en metales pesados, es aconsejable por lo tanto, evitar un tiempo prolongado de fritura y un exceso de sal. Un consumo variado de pescados y alternar los métodos de preparación y cocción, es la mejor manera de mejorar los hábitos alimentarios, disminuyendo exposición al mercurio a la vez que se asegura una elevada ingesta de ácidos grasos omega-3.
Palabras clave: Pescado, camarones, cocción, composición proximal, minerales, metales pesados.

INTRODUCTION

Fish has long been a favorite meal of people living around the Arabian Gulf, even before the discovery of oils and natural gas (1). During the past 20 years, there has been renewed interest in dietary components such as fish, which are rich sources of omega-3 fatty acids, and might favorably improve lipid profiles and reduce risk of coronary heart disease (2). Additional reported benefits of fish consumption also include their hypolipidemic and/or antiatherogenic effects (3), decreased risk of prostate cancer (4), reduced occurrence of renal cell carcinoma in women (5), reduced risk of dementia and alzheimer disease in certain conditions (6).

In the Arabian Gulf few studies have been carried out to assess the nutrient composition of fish. A study on the chemical composition of raw fish caught off the coast of Qatar indicated that fish was a good source of minerals and many trace elements (1). Many of the Arabian Gulf species of raw fish especially sardines were found to be a good source of omega-3 polyenoic fatty acids (7). Crab meat consumed in Bahrain was found to be a good source of high quality protein and minerals like calcium and phosphorous (8).

Although fish is a good source of some essential nutrients, cooking practices could cause modifications in proximate composition, fatty acids and amino acids as well as changes in solubility and nutritional quality of fish (9, 10). Another study indicated that cooking of fish consumed in Saudi Arabia leads to alteration in cholesterol, fat and protein content but the cholesterol content of raw and cooked fishes was not directly correlated to fat content (11). Recent studies showed that that mercury intake from fish could counteract the beneficial effects from this food source (12). Researchers studied the effects of commonly used cooking practices on total mercury concentration in fish and found that in some cases mercury concentrations were increased with increased cooking times due to loss of moisture and fat (13). Of the heavy metals cadmium, lead, and mercury are potentially toxic; exposure to these metals can cause renal disturbances and neurological alterations (14).

Although reports are available on the composition of fish, studies to assess the chemical composition and nutritional profile of cooked fish and shrimps in the Arab Gulf countries are at most scanty. In addition, there is no information on the role of different cooking methods on the nutrient composition. This paper is therefore, an attempt to assess the chemical and heavy metal composition of cooked fish and shrimps commonly consumed in Bahrain prepared using the traditional methods of cooking.

MATERIALS AND METHODS

All fish and shrimps were purchased from the central market in Manama city, the capital of Bahrain. Only the most commonly consumed fish and shrimps consumed in Bahrain were included in the study. Local, common and scientific names of these fishes and shrimps are presented in Table 1. The species of fish and shrimps consumed in Bahrain and the method of cooking are generally common to most of the Middle East region. The fish and shrimps were all caught off the coast of Bahrain and were landed several hours after the catch. On board they were kept covered with ice and were subsequently shipped in a refrigerated truck to the central market. About 5 kilogram of each type of whole fish and shrimps were obtained from the central market and were cleaned by scaling and gutting and removing the internal organs. They were washed with water and were subsequently cooked according to the most commonly employed practice for that particular species (15) (Table 2). These include grilling (*Liza alata, Siganus canaliculatus, Plectorhinchus sordidus, Rhabdosargus haffara)*, frying (*Seriolina nigrofasciata, Lethrinus nebulosus, Scomberomorus commerson)*, cooking in curry (*Scomberomorus commerson, Penaeus semislcatus, Lethrinus nebulosus, Siganus canaliculatus)*, and cooking in rice (*Lethrinus nebulosus, Scomberomorus commerson, Penaeus semislcatus, Epinephelus areolatus)*. The skin of the fish was removed after the cooking process and samples were prepared by grinding edible portions of the shrimps and fish (each species separately) for further analysis.

TABLE 1
Local, common and scientific names of Arabian Gulf fish species included in the study

Local name	Common name	Scientific name
Hamman	Blackbanded Trevally	*Seriolina nigrofasciata*
Safai	Pearlspotted Rabbitfish	*Siganus canaliculatus*
Qurqufan	Haffara Bream	*Rhabdosargus haffara*
Kanad	Narrow-barred panish mackerel	*Scomberomorus commerson*
Maid	Diamond Mullet	*Liza alata*
Hammour	Grouper	*Epinephelus areolatus*
Yanam	Grey Grunt	*lectorhinchus sordidus*
Shari	Spangled Emperor	*Lethrinus nebulosus*
Rubian	Tiger Shrimp	*Penaeus semislcatus*

Proximate analysis

Proximate analysis was carried out using the standard procedures (16). Briefly, for moisture content, the sample was dried in a vacuum oven at 100°C and dried to a constant weight (approximately 5 hours). Protein and other organic nitrogen in the sample were converted to ammonia by digesting the sample with sulfuric acid containing a mercury catalyst mixture. The acid digest was made alkaline, and the ammonia was distilled and titrated with standard acid. The percent nitrogen was determined and converted to protein using the factor 6.25. For fat, the sample was hydrolyzed in a water bath using 8 M hydrochloric acid after addition of ethanol to liberate fat. The fat was extracted using ether and hexane. The extract was washed with a dilute alkali solution and filtered through a sodium sulfate column. The remaining extract was evaporated, dried and weighed. Carbohydrate was calculated using the standard equation 100% - (% protein + % fat + % ash + % moisture) and the energy evaluation was done by multiplying the protein, carbohydrate and fat by the factors 4, 4 and 9 respectively. All samples were analyzed in triplicates and concentrations were reported on a wet weight basis (g/100g).

Mineral composition

The samples was weighed into a borosilicate calibrated flask to which 4ml of concentrated HNO_3 and 1ml of 30% H_2O_2 were added and microwave digested. The samples were cooled and made up to volume before analysis and the mineral elements measured using a flame system (Air acetylene flame). Pyrolytically coated graphite tubes in an inert atmosphere of argon were used in the furnace. Mineral composition was determined in triplicates by the atomic absorption spectrophotometry (AAS) and graphite furnace (GFAAS) and reported as wet weight basis (16).

TABLE 2
Ingredients and methods of preparation of fish commonly consumed in Bahrain

Local name	Common name	Ingredients	Method of preparation
Samak mashwie	Grilled fish	Fish, spices	Marinate fish in spices and grill till done
Saloonat samak/ rubian	Curried fish/shrimps	Fish/shrimps, onions, tomato, egg-plant, garlic, green coriander, tomato paste, corn oil, salt, mixed spices, ripe tamarind, Fry in hot oil. dried lemon, water	Marinate fish/shrimps in salt for 1 hour. Wash with water, Fry in hot oil. Wash with water, Brown onions and garlic in oil. Add fish/shrimps and other ingredients and cook under low heat till done.
Samak maglee	Fried fish	Fish, corn oil, salt, spices	Marinate fish in salt for 1 hour. Wash with water, fry in hot oil until brown.
Ayash bil samak/rubian	Fish/shrimps cooked in rice	Fish/shrimps, rice, onions, garlic, potato, corn oil, butter, salt, mixed spices, ground cardamom, dried lemon, chopped pepper, water	Marinate fish/shrimps in salt for 1 hour. Wash with water, fry in hot oil until brown. Brown onions and garlic add rest of ingredients and saut Boil rice. Place rice, fish/shrimps with rest of the ingredients and cook till done.

Heavy metal analysis

One fillet consisting of muscle tissue was selected for each species and macerated in a high-speed blender. Duplicate sub-samples were extracted for estimation of mercury, lead and cadmium. About 0.5g of the homogenate was digested under pressure with HNO_3. Lead and Cadmium were determined by graphite furnace AAS using Perkins Elmer ™ Zeeman 3030 spectrophotometer. For mercury, the prepared samples were analyzed using a Perkins Elmer ™ mercury analyzer system (16). All concentrations were reported on a wet weight basis (µg/g). Each analytical run was carried out in triplicates for each of the sample. The accuracy of the trace element determinations was confirmed with certified standard reference materials as per procedure.

RESULTS

Proximate content

The proximate composition of cooked fish and shrimps consumed in Bahrain is presented in Table 3. There was no considerable difference in the water content in different varieties of cooked fishes however, it was lower in the fried fish variety, and the lowest content was in the fried *Lethrinus nebulosus* (56.4 g/100g). The protein content appeared to increase as a result of cooking in rice as evident by the increased protein content in *Penaeus semislcatus* (29.2 g/100g), *Lethrinus nebulosus* (27.9 g/100g) and *Scomberomorus commerson* (24.9 g/100g) compared to their respective curried varieties. Fat content was considerable in all the varieties of *Scomberomorus commerson*, with no considerable difference between the fried (11.9 g/100g), cooked in rice (12.0 g/100g) and curried (10.g g/100g) varieties. As expected, energy content increased as a result of frying as evident by the fried *Scomberomorus commerson* (894.2 KJ/100g) compared to the curried (759.3 KJ/100g) and cooked in rice (867.3 KJ/100g) varieties.

Mineral content

The mineral content in cooked fish and shrimps is given in Table 4. There was no variation in the iron content in all the varieties of fried fish (0.6 mg/100g) while only a slight variation was seen in the grilled variety (0.4-0.6 mg/100g). The highest iron content was in the curried *Scomberomorus commerson* (1.0 mg/100g). Sodium content was generally lower in most of the fish cooked in rice but, *Penaeus semislcatus* (500 mg/100g) had higher sodium content. Sodium content for all the other varieties varied between the cooking methods and species, the highest content was in the fried *Scomberomorus commerson* (600 mg/100g). Potassium content was higher in all the fried fish (500-560 mg/100g) ranging from 500-560 mg/100g. It is also observed that *Penaeus semislcatus* had low levels of potassium compared to other varieties of fish. On the other hand calcium level was highest in the *Penaeus semislcatus* (92 mg/100g in curried and 100 mg/100g in cooked in rice) and furthermore, cooking in rice appeared to reduce the calcium content in fish. There was not much of a difference in the magnesium content in most species of fish and the highest levels were in the *Penaeus semislcatus* (49 mg/100g in curried and 54 mg/100g in cooked in rice). Of the fishes the fried *Lethrinus nebulosus* had the highest levels of magnesium (40 mg/100g). Phosphorous content was highest in the fried fish varieties (320-330 mg/100g) while the other 3 methods did not show much of a variation. Apart from frying, cooking in rice improved the phosphorous content as evident by the increase seen in *Lethrinus nebulosus* (280 mg/100g) compared to curried *Lethrinus nebulosus* (250 mg/100g). Zinc levels were also higher in *Penaeus semislcatus* (2.0 mg/100g cooked in rice and 1.8 mg/100g in curry) and among the fish the highest levels were seen in the grilled and curried *Siganus canaliculatus* (1.0 and 1.1 mg/100g respectively). On the other hand *Scomberomorus commerson* had low zinc content (0.4 mg/100g).

TABLE 3
Proximate composition of cooked fish commonly consumed in Bahrain (g/100g)

Method of cooking and type of fish used (common and scientific names)	Water	Prot -ein	Fat	Ash	Carbohy- -drate	Energy KJ	Energy Kcal
Grilled							
Liza alata (Diamond Mullet)	64.5	24.2	10.5	1.9	0.0	799.9	191.2
Siganus canaliculatus(Pearlspotted Rabbitfish)	68.0	27.3	4.3	2.5	0.0	623.2	148.9
Plectorhinchus sordidus (Grey Grunt)	68.6	25.9	5.6	1.8	0.0	647.5	154.8
Rhabdosargus haffara (Haffara Bream)	73.8	22.8	1.8	1.9	0.0	454.2	108.6
Curried							
Scomberomorus commerson (Narrow-barred Spanish mackerel)	66.1	22.9	10.0	1.9	0.0	759.3	181.5
Penaeus semislcatus (Tiger Shrimp)	70.1	24.6	1.9	2.3	1.1	507.2	121.2
Lethrinus nebulosus (Spangled Emperor)	69.0	25.4	4.9	1.9	0.0	613.1	146.5
Siganus canaliculatus (Pearlspotted Rabbitfish)	69.5	23.4	5.2	2.5	0.0	590.2	141.1
Fried							
Seriolina nigrofasciata (Blackbanded Trevally)	67.3	27.8	4.2	2.1	0.0	628.0	150.0
Lethrinus nebulosus (Spangled Emperor)	56.4	25.9	7.0	2.8	0.0	699.3	167.0
Scomberomorus commerson (Narrow-barred Spanish mackerel)	60.5	26.7	11.9	2.8	0.0	894.2	213.7
Cooked in rice							
Lethrinus nebulosus (Spangled Emperor)	67.3	27.9	4.9	2.0	0.0	655.6	156.7
Scomberomorus commerson (Narrow-barred Spanish mackerel)	63.4	24.9	12.0	1.9	0.0	867.3	207.3
Penaeus semislcatus (Tiger Shrimp)	62.7	29.2	5.6	2.4	0.1	705.3	168.6
Epinephelus areolatus (Grouper)	70.2	27.3	3.2	1.4	0.0	582.5	139.2

TABLE 4
Mineral composition of cooked fish commonly consumed Bahrain (mg/100g, wet weight)

Method of cooking and type of fish used (common and scientific names)	Fe	Na	K	Ca	Mg	P	Cu	Zn
Grilled								
Liza alata (Diamond Mullet)	0.6	400	330	33	29	210	1.3	0.8
Siganus canaliculatus (Pearlspotted Rabbitfish)	0.5	510	480	42	32	270	0.5	1.0
Plectorhinchus sordidus (Grey Grunt)	0.4	220	360	21	26	200	0.5	0.4
Rhabdosargus haffara (Haffara Bream)	0.4	320	390	23	28	240	0.4	0.6
Curried								
Scomberomorus commerson (Narrow-barred Spanish mackerel)	1.0	350	420	13	30	240	1.0	0.4
Penaeus semislcatus (Tiger Shrimp)	0.4	540	230	92	49	250	3.3	1.8
Lethrinus nebulosus (Spangled Emperor)	0.5	280	400	23	28	250	0.3	0.6
Siganus canaliculatus (Pearlspotted Rabbitfish)	0.9	530	330	64	30	220	0.5	1.1
Fried								
Seriolina nigrofasciata (Blackbanded Trevally)	0.6	320	500	61	35	320	0.5	0.7
Lethrinus nebulosus (Spangled Emperor)	0.6	590	560	52	40	320	0.4	1.0
Scomberomorus commerson (Narrow-barred Spanish mackerel)	0.6	600	530	22	37	330	0.3	0.8
Cooked in rice								
Lethrinus nebulosus (Spangled Emperor)	0.4	130	410	10	32	280	0.8	0.5
Scomberomorus commerson (Narrow-barred Spanish mackerel)	0.7	120	400	10	30	240	0.1	0.4
Penaeus semislcatus (Tiger Shrimp)	0.9	500	250	100	54	280	0.6	2.0
Epinephelus areolatus (Grouper)	0.3	190	310	16	31	220	0.4	0.6

Heavy metal content

The heavy metal content in cooked fish and shrimps is presented in Table 5. Lead content was generally low (<0.02 μg/g) in most of the species of fish. There was no difference in the lead content between curried and cooked in rice *Penaeus semislcatus* (0.04 μg/g). Lead content of curried *Lethrinus nebulosus* was higher (0.02 μg/g) than the same fried (<0.02 μg/g) and cooked in rice (<0.02 g/g) varieties. Mercury content was higher in *Lethrinus nebulosus* (0.04-0.35 μg/g) and *Scomberomorus commerson* (0.12-0.30 μg/g). Cooking in rice increased the mercury content in the fish species and also in *Penaeus semislcatus*. The cadmium levels remained steady at <0.02 g/g for all the methods of cooking employed.

TABLE 5
Heavy metal content in cooked fish commonly consumed in Bahrain (μg/g)

Method of cooking and type of fish used (common and scientific names)	Lead	Mercury	Cadmium
Grilled			
Liza alata (Diamond Mullet)	0.14	<0.02	<0.02
Plectorhinchus sordidus (Grey Grunt)	0.30	<0.02	<0.02
Siganus canaliculatus (Pearlspotted Rabbitfish)	<0.02	0.09	<0.02
Rhabdosargus haffara (Haffara Bream)	<0.02	0.05	<0.02
Curried			
Scomberomorus commerson (Narrow-barred Spanish mackerel)	<0.02	0.12	<0.02
Penaeus semislcatus (Tiger Shrimp)	0.04	<0.02	<0.02
Lethrinus nebulosus (Spangled Emperor)	0.02	0.14	<0.02
Siganus canaliculatus (Pearlspotted Rabbitfish)	0.20	<0.02	<0.02
Fried			
Seriolina nigrofasciata (Blackbanded Trevally)	<0.02	<0.02	<0.02
Lethrinus nebulosus (Spangled Emperor)	<0.02	0.04	<0.02
Scomberomorus commerson (Narrow-barred Spanish mackerel)	0.20	0.24	<0.02
Cooked in rice			
Lethrinus nebulosus (Spangled Emperor)	<0.02	0.35	<0.02
Scomberomorus commerson (Narrow-barred Spanish mackerel)	<0.02	0.30	<0.02
Penaeus semislcatus (Tiger Shrimp)	0.04	0.05	<0.02
Epinephelus areolatus (Grouper)	<0.02	0.29	<0.02

*<0.02 μg/g are instrumentally detected values

DISCUSSION

The protein content was generally high in the shrimps and all the species of fish studied, which is an expected outcome since fish and shrimps are a good source of protein (17, 18). The higher protein content observed in *Penaeus semislcatus* cooked in rice is over the curried variety is due to concentration of meat as a result of moisture loss. Further evidence of this is seen in the fact that *Penaeus semislcatus* cooked in curry had lower protein content but had higher moisture values. This can be attributed to absorption of water from the cooking medium thereby causing dilution of the muscle tissue analyzed. This higher protein content in fish and shrimps is important from a dietary point of view since; the quality of fish protein is very high because of its essential amino acid composition (19). Further, reports also indicate that fish muscle is more digestible than other animal protein due to lower level of connective tissue (20). At the same time it is important to note that depending on the food and on the temperature and duration of cooking, a food can become more, or less, digestible. Seidler (21) studied the effects of heating on the digestibility of the protein in hake, a type of fish and found fish meat heated for 10 minutes at 130°C (266°F), showed a 1.5% decrease in protein digestibility. Similar heating of hake meat in the presence of potato starch, soy oil, and salt caused a 6% decrease in amino acid content.

An important factor to be considered while cooking is its influence on the fat content of the fish and shrimps. If we compare the fat content for the *Scomberomorus commerson* that was fried, curried and cooked in rice, we see that, there is not much of a difference between frying and cooking in rice, but curried *Scomberomorus commerson* has lower fat content. The higher fat content in the fried variety is a result of uptake of oil by the fish muscles and similar findings have been previously reported (22). This logic also holds good for fish cooked in rice where the increase in fat is due to the method of preparation employed, where generally, the fish is first fried and then added to the rice. Further increase in the fat could be a result of uptake of oil added to the rice during cooking. Similarly, if we were to compare the effect of the same three modes of cooking on the fat content of the *Lethrinus nebulosus* we see that the values for the curried and cooked in rice *Lethrinus nebulosus* are similar but those for fried are higher. This variation in fat content is mainly because, though fish muscles tend to absorb fat during the frying/cooking process, some fish muscles absorb more fat than others (11). Hence, the difference in the fish muscles used for frying and cooking in rice in this study could have caused the discrepancy in oil absorption.

The lower fat content in the curried *Scomberomorus commerson* is mainly due to absorption of water used in the curry. The absorption of water is evident when we compare the fried *Lethrinus nebulosus* and *Scomberomorus commerson* with the curried *Lethrinus nebulosus* and *Scomberomorus commerson* wherein, the latter method of cooking shows higher moisture values. Though curried fish has lower fat values, if further reduction in fat content in desirable then, the most suitable method of cooking fish would be grilling. This decrease in fat is evident when we compare the fat values between the grilled and curried *Siganus canaliculatus*, wherein the former has lower fat values by up to 1.0%w/w. This decrease in fat on grilling is due to the leeching of fat in the cooking drip and is in accordance to a study on the effect of grilling on the fat content of salmon where a loss of 11.7% in fat was seen (23).

The sodium levels were considerable in shrimps and most of the fish which is mainly due to the salt added to the diet to make it more palatable than the same diets without salt (24). In addition previous reports on the chemical composition and functional properties of prawns in Nigeria (18) indicate that prawns contain a good amount of sodium. The lower levels of sodium in the rice dishes could be due to the absorption of the salt by rice. Potassium levels were generally high in all the fish but when the different methods were compared we found the levels were the highest in the fried fish. One reason for this could be due to the loss of water on frying thereby causing a concentration of meat thus reflected by increased potassium values. This concentration effect on frying of food has been attributed to loss of moisture as a result of frying (13). Similar was the case with phosphorous where the high levels in the fried fishes can be attributed to concentration of meat and use of spices in the preparation, as spices from seeds are high in phosphorus (25). The higher content of magnesium and calcium in *Penaeus semislcatus* cooked in rice is a reflection of the high content of these minerals in various prawn species (18) with probably a marginal contribution of magnesium from the rice itself (26). The lower level of calcium in the rest of the fishes is because the main reservoirs for calcium in fish are the scales as well as bone (27). In general practice of cooking, the scales are discarded during cleaning thereby limiting the contribution of calcium by fish in a diet. Iron and copper were generally low in all the varieties of cooked fish tested with not much of a variation observed between the various modes of cooking. Furthermore, decrease in the iron content in the fried fish compared to the curried variety can be attributed to the spices such as dried lemon and tamarind which contain considerable amount of iron and are used in the preparation of curry (28). Only curried *Penaeus semislcatus* showed high levels of copper which could be a result of contribution from the spices commonly used in the Arabian Gulf region.

Results for the heavy metals did not indicate much variation for lead among different modes of cooking. There was no difference in lead content in the curried *Scomberomorus commerson* and that cooked in rice but, fried *Scomberomorus commerson* showed a slight increase. The increase in the lead level is again due to loss of moisture and resultant concentration of meat (13). Comparison between different values for the *Lethrinus nebulosus* indicated an increase in lead values in the curried *Lethrinus nebulosus*, while the other two values remained comparable. This increase in lead could be due to the ingredients used in cooking, and, recent studies indicate that spices could contain high levels of lead due to contamination (29). Some varieties of fish also contained mercury though they were within the safe limits of consumption of 0.5mg/kg of fish (30). One way of reducing exposure to mercury could be by removing the skin and fat from these fish before cooking them; however, because methylmercury is distributed throughout the muscle, skinning and trimming does not significantly reduce mercury concentrations in filets (31). Mercury levels were generally higher in the fish cooked in rice which is because rice cooked in Bahrain also contains added spices, which are a source of heavy metals (32). The various modes of cooking had no effect on the cadmium content of fish and any amount of cadmium reported was from the original source which was the raw fish.

CONCLUSIONS

The different modes of cooking employed in Bahrain did have a considerable influence on the nutrient and heavy metal composition of fish and shrimps. It is found that including *Penaeus semislcatus* as a regular part of the diet would be beneficial due to its high content calcium, magnesium, phosphorus, copper, zinc and protein. The high content of zinc is important since zinc deficiency affecting the growth of the children and adolescents in the Arab Middle East countries including the Gulf States has been reported (33). Curried *Scomberomorus commerson* could be a good source of iron especially since iron deficiency anemia is quite common in the Arab Gulf region (34). However, avoidance of excessive frying, minimal use of salt and opting for grilling would be beneficial as far as controlling excessive fat and sodium is concerned. This is all the more important since obesity, coronary heart disease and hypertension are a growing menace in the Arab Middle East, the main reason being the pattern of food consumption (35). Consumption of a wide variety of species of fish and alternating between the various modes of cooking is the best approach to achieve improved dietary habits, minimizing mercury exposure and increasing omega-3 fatty acid intake.

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