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ORIGINAL ARTICLE

Effect of six different cooking techniques in the nutritional composition of two fish species previously selected as optimal for renal patient's diet

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Abstract Benefits of fish consumption are widely known, but there is little information about nutrient values of raw and cooked fish. The aim was to study the impact that six cooking techniques have on the nutritional composition of two fish species with low content of adverse nutrients in renal diet. Raw and steamed, foiled with aluminum, foiled with banana leaf, gas oven-baked, microwave oven-coked and fried lightly samples were chemically analyzed to determine their protein, phosphorus and lipid content. Crevalle jack: all methods increased lipid and protein content and fatty acids (FA) varied in all cooking methods. Phosphorus decreased in the steamed and microwave oven-cooked samples. Red drum: foiled and fried lightly increased lipid content compared to the raw sample. FA concentration changed in all cooking methods. Protein increased with every technique and phosphorus decreased in the steamed and gas oven-baked samples. Renal patients should preferably consume crevalle jack steamed or microwave oven-cooked and red drum steamed or gas oven-baked.

Keywords Crevalle jack · Red drum · Nutritional composition · Cooking methods · Renal diet

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Introduction

It has been well established that fish consumption has beneficial effects on human health, particularly associated with the prevention of cardiovascular disease (CVD) (Mozaffarian et al. 2003); moreover, some studies support the hypothesis that a diet rich in n-3 polyunsaturated fatty acids (n-3 PUFA) may protect against renal deterioration (Friedman et al. 2008; Friedman 2010; Lauretani et al. 2008; Lauretani et al. 2009; Fassett et al. 2010), and a regular consumption of fish may reduce Chronic Kidney Disease (CKD) prevalence (Gopinath et al. 2011). All those advantages have been related to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), of which fish is the major source in human nutrition (Agren and Hänninnen 1993; Al-Saghir 2004).

Current dietetic recommendations promote fish consumption (Ansorena et al. 2012): the American Heart Association (AHA) advices that oily fish should be eaten at least twice per week, preferably grilled, baked or broiled; and that the methods used to prepare fish should minimize the addition of saturated and *trans* fatty acids, as occurs with the use of cream sauces or hydrogenated fat during frying (Lichtenstain et al. 2006). However, recent studies have stated that n-3 PUFA content may vary significantly comparing different fish species according to the preparation method used (Mozaffarian 2003; Al-Saghir 2004; Izquierdo et al. 2001; Gokoglu 2004; Bakar et al. 2008; Kaya 2008), and therefore it is not enough to promote fish consumption in a general way, but rather to enrich the current recommendations with practical information that allows consumers to make an informed decision about the best way to eat fish.

Consumers have minimal knowledge about nutritive values of raw and cooked fish (Gokoglu 2004; Mnari-Bhouri et al. 2010), and most information about nutrition content is available for raw fish (Mnari-Bhouri 2010). For populations

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with a higher CVD risk (Svensson 2004), nutritional therapy must include prescriptions of cooking techniques that enhance the beneficial components (n-3 PUFA), and in the case of renal patients, diminish harmful nutrients (phosphorus) of consumed fish species.

Many authors have previously examined the effect that different cooking methods have on nutritional composition of fish; nonetheless they have mainly studied fatty components (total lipids, fatty acids and cholesterol) and only in a few species, being the most common: salmon, trout, tuna, cod and mackerel, among others (Agren 1993; Al-Saghir 2004; Ansorena 2012; Izquierdo et al. 2001; Gokoglu 2004; Bakar 2008; Mnari-Bhouri 2010; Echarte et al. 2001; Candela 1998; Elmadfa 2006; Moradi 2009). There are only a few studies that have analyzed other nutrients as well (Izquierdo et al. 2001; Gokoglu 2004; Kaya 2008; Elmadfa 2006; Kocatepe et al. 2011). None of the above evaluated nutritional changes with the purpose of improving renal patients' diets.

Previous studies have identified fish species that could be administered to renal patients because of their low phosphorus and high n-3 PUFA content (Castro-González 2009; Castro-González and Miranda-Becerra 2010). However, the analyses of those studies were conducted in raw samples; therefore it is necessary to evaluate the impact that cooking techniques have on the nutritional components of those species in order to provide more accurate information to renal patients.

The aim was to study the impact that six cooking techniques have on the nutritional composition of two fish species with low content of adverse nutrients in renal diet (Castro-González et al. 2010; Castro-González 2012).

Materials and methods

Sampling

The fish, crevalle jack (*Caranx hippos*) and red drum (*Sciaenops ocellatus*), were obtained from the largest fish distribution center in Latin America: the La Nueva Viga Market in Mexico City. Several fillets of fresh fish were obtained from different vendors in order to get six samples per specie.

Cooking techniques

Fillets from one fish of both species were prepared by six different cooking methods:

Steamed (ST): Fillets were placed on a steamer with boiled water until they were cooked. This technique took from 5–9 min, and the fish reached a temperature of 76–80 °C.

Foiled (with aluminum) (FO): The fish fillet was completely wrapped in aluminum foil, allowing the fish to be steamed in its own juices. The wrapped fish was placed in a "comal" (a Mexican flat sauce pan) and cooked for 6–10 min. The fillet reached a temperature of 82–93 °C.

Foiled with banana leaf (BL): This procedure was similar to the foiled method, except that the fish was wrapped in banana leaf, a common Mexican cooking technique. This method took from 5–8 min and the fillet reached a temperature of 78–92 °C.

Gas oven-baked (GO): The fish was placed in a gas oven and baked for 7–10 min, until it reached 73–78 °C.

Microwave oven-cooked (MO): The fish fillet was placed in the microwave and cooked for 2–3 min at regular power. The fillet reached a temperature of 75–82 °C.

Fried Lightly (FL): The fish was placed on a frying pan with only 5 ml of Oleic Oil™. After 3 min, the fillet was turned to cook both sides of the fish. The food was cooked for 4–7 min and it reached a temperature of 82–93 °C.

Chemical analyses

After the cooking processes, the raw (RA) and cooked samples were milled and homogenized for chemical analyses. The chemical analyses were carried out in the Food Sciences and Technology Department laboratories in the Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán in Mexico City. This laboratory is certified by the Mexican Accreditation Entity (EMA). All analyses were performed in triplicate.

Protein content was determined according to Mexican standard test methods (Norma Oficial Mexicana 2002), using automatic protein equipment (Kjeltec 1035, Tecator, Höganaäs, Sweden); this standard method is in accordance with ISO 8968, based on the Association of Official Analytical Chemists method 991.20 (2010). Phosphorus (P) content was determined using AOAC methods (Association of Official Analytical Chemists 1990), with a Beckman spectrophotometer (DU70, Fullerton, San Diego, CA, USA).

Total fat content was calculated gravimetrically (Castro-González 2007). The fatty acids were analyzed using solvent extraction and gas chromatography (Varian 3400 CX) with a flame ionization detector.

The index of peroxidisability was calculated for each specie.

The mean of three repetitions are presented here. The results were grouped in descriptive tables.

Statistical analyses

A One Way Analysis of Variance test (Kruskal-Wallis One Way Analysis of Variance on Ranks) was performed to determine the difference among nutrient content of raw and cooked samples of both species separately. To find means that were significantly different from each other a Tukey test or Holm-Sidak method was performed. For all statistical tests the probability level was 0.05. SigmaPlot (2008) for Windows statistical software was used.

Results and discussion

The nutritional composition of raw and fish cooked by six different methods is presented in Table 1, as well as significant differences in the nutritional composition of different cooking methods. Considering their lipid content, both species are low-fat fish, with a total fat percentage 2–4 % (Nurnadia et al. 2011).

For crevalle jack the total lipid content increased in all cooking techniques except in the FO sample compared to the raw fish, and the highest value was found in MO, with a 134.5 % increase. In the case of red drum, lipid content increased in FO, BL and FL samples (125.5, 112.9 and 149.3 %, respectively), the lowest lipid content was found in the GO sample with a 42.3 % reduction. These alterations in lipid level could be explained by the reduction in water content after cooking and to the lipid content of each specie (Ferreira de Castro 2007, Hosseini 2014,).

During the cooking process fatty acids undergo reactions as hydrolysis and oxidation, which not only affect the FA concentration but also the fish flavor, scent, color and texture (Ferreira de Castro 2007). The index of peroxidiability of crevalle jack is 194.32 and 155.44 for red drum, which indicates high oxidative instability of its fatty acids when heated and therefore could also explain the changes in the FA profile of both species (Testi et al. 2006, Veselý 2009).

Saturated fatty acids (SFA) in crevalle jack decreased in all cooking techniques except in ST and BL, which increased in 110.3 and 114.4 %, respectively. The lowest value was found in the FL sample, with a 39.3 % reduction. The concentration of SFA in red drum only decreased in the ST sample (with a 20 % reduction) when compared to the raw sample. BL and FL presented more than 300 % increase in SFA content. Frying results can mainly be attributed to the fatty acid composition of the frying oil and oxidation of the fish fatty acids (Hosseini 2014, Domínguez et al. 2014).

Table 1 Nutritional composition of raw and cooked crevalle jack and red drum

	Raw (RA)	Steamed (ST)	Foiled (FO)	Foiled with banana leaf (BL)	Gas oven-baked (GO)	Microwave oven-cooked (MO)	Fried lightly (FL)
Crevalle jack							
Total lipids (g/100 g)	3.76^{a}	4.22^{b}	3.51^{ab}	4.10^{b}	3.96^{ab}	5.06^{b}	3.98^{ab}
SFA (mg/100 g)	434.89^{ab}	479.96^{ab}	420.33^{ab}	497.62^{a}	393.33^{b}	403.01^{ab}	263.98^{b}
MUFA (mg/100 g)	275.10^{ab}	287.83^{a}	250.81^{ab}	278.24^{ab}	223.62^{b}	239.30^{ab}	275.72^{ab}
PUFA (mg/100 g)	295.10^{b}	374.24^{ab}	379.49^{ab}	500.25^{a}	341.60^{ab}	325.59^{ab}	260.38^{b}
PUFA n-3 (mg/100 g)	232.35^{b}	310.55^{ab}	310.78^{ab}	417.87^{a}	280.75^{ab}	271.48^{ab}	195.23^{b}
PUFA n-6 (mg/100 g)	49.77^{ab}	49.57^{ab}	55.15^{ab}	64.12^{a}	47.85^{ab}	42.39^{b}	33.60^{ab}
EPA+DHA (mg/100 g)	226.60^{b}	305.23^{ab}	304.06^{ab}	410.27^{a}	276.39^{ab}	265.89^{ab}	192.06^{b}
n-6/n-3	0.21	0.15	0.17	0.15	0.17	0.15	0.17
Protein (g/100 g)	19.02^{a}	23.01^{b}	22.63^{b}	24.50^{b}	22.37^{b}	23.81^{b}	23.03^{b}
Phosphorus (mg/100 g)	177.43^{a}	151.14^{b}	204.23^{b}	184.89^{b}	232.44^{b}	172.22^{b}	240.31^{b}
Red drum							
Total lipids (g/100 g)	2.39^{a}	1.67^{b}	3.00^{b}	2.70^{b}	1.38^{b}	2.33^{a}	3.57^{b}
SFA (mg/100 g)	328.17^{ab}	262.78^{a}	482.69^{ab}	1150.03^{b}	348.19^{ab}	399.27^{ab}	1076.22^{ab}
MUFA (mg/100 g)	202.95^{ab}	179.79^{a}	342.10^{ab}	732.27^{ab}	207.19^{ab}	377.66^{ab}	1204.73^{b}
PUFA (mg/100 g)	208.69^{a}	348.92^{ab}	460.11^{ab}	712.25^{b}	273.78^{ab}	461.46^{ab}	950.11^{b}
PUFA n-3 (mg/100 g)	189.41^{a}	256.15^{ab}	340.66^{ab}	519.66^{b}	196.91^{ab}	309.53^{ab}	638.70^{ab}
PUFA n-6 (mg/100 g)	19.28^{b}	84.38^{ab}	101.58^{ab}	167.98^{a}	69.77^{b}	151.93^{ab}	206.64^{a}
EPA+DHA (mg/100 g)	189.41^{a}	255.70^{ab}	333.24^{ab}	483.19^{b}	194.01^{ab}	309.53^{ab}	614.97^{ab}
n-6/n-3	0.10	0.32	0.29	0.32	0.35	0.49	0.32
Protein (g/100 g)	23.89^{a}	26.36^{b}	25.91^{b}	27.59^{b}	24.98^{b}	27.29^{b}	27.99^{b}
Phosphorus (mg/100 g)	173.69^{a}	171.40^{a}	180.86^{a}	175.25^{a}	171.01^{a}	202.22^{b}	226.46^{b}

SFA: Saturated fatty acids; *MUFA*: Monounsaturated fatty acids; *PUFA*: Polyunsaturated fatty acids; *EPA*: Eicosapentaenoic acid; *DHA*: Docosahexaenoic acid

Values are shown as mean. Different letters indicate significant differences in the nutritional composition of different cooking methods when compared to each other (*$p<0.05$)

Crevalle jacks' monounsaturated fatty acids (MUFA) decreased in the FO, GO and MO samples, while the samples cooked by the other three techniques presented an increase in their MUFA content. The lowest value was found in GO sample with a 15.1 % decrease in its content, while the highest concentration was presented in the ST sample, with a 104.6 % increase. For red drum all cooking techniques except ST, produced an important increase in MUFA content, ranging from 207.19 mg/100 g (only 102.0 % above the raw concentration) to 1,204.73 mg/100 g in the fried lightly sample (with an increase of more than 590.0 %).

For crevalle jack polyunsaturated fatty acids (PUFA) and n-3 PUFA increased in all cooking methods except FL. The most important factor reducing the total n-3 PUFA content during frying is oil absorption by the fish (Hossesini 2014). PUFA increased from 110.3 to 169.5 % in MO and BL, respectively; while the n-3 PUFA content increased from 116.8 to 179.8 %. n-6 PUFA content decreased in all cooking methods except in the foiled and foiled with banana leaf samples. The lowest concentration was found in the fried lightly sample, with a 32.5 % reduction.

As for red drum, all cooked samples presented a higher PUFA content compared to the raw sample, due to moisture losses that occur during cooking (Ersoy 2006). The highest increase was found in BL and FL samples, with an increase of 341.2 and 455.2 %, respectively. Both n-3 and n-6 PUFA increased in all cooking techniques compared to raw red drum. The lowest increase was found in the GO samples, while the highest concentration of both n-3 and n-6 PUFA was found in FL, with a 337.2 and 1071.7 % increase, respectively.

When compared to raw crevalle jack, eicosanoic and docosahexaenoic acids (EPA+DHA) content increased in all cooking techniques, except in FL. The highest content was found in the BL sample, with an increase of 181.0 %. For red drum the sum of those fatty acids also increased in all cooking methods, from 102.4 % in GO to 324.6 % in the FL sample.

Protein content increased in all cooking techniques in both species; BL presented the highest protein concentration (128.8 %) in crevalle jack, while FL increased the protein content of red drum up to 117.1 %. These increases occur because cooking produces important losses of water, which concentrates the protein content (Ayala et al. 2005).

Phosphorus varied greatly among the different cooking methods, crevalle jack presented slight decreases in ST and MO, and a maximum value of 240.31 mg/100 g in FL, which represents an increase of 135.4 %. For red drum, ST and GO samples presented a slight decrease (1.4 and 1.6 %, respectively), while the rest of the cooking methods had a higher content. The maximum value was observed in the FL sample, with a 130.3 % increase. Results could be related to water loss during different cooking methods (Ersoy 2009).

Table 1 presents the n-6/n-3 relation of both fish species in raw and cooked samples. Crevalle jack's n-6/n-3 relation decreased in all cooking techniques when compared to the raw sample. The lowest relation was found in ST, BL and MO samples (0.15). The n-6/n-3 relation of red drum increased in all cooking methods. The lowest relation was found in the FO sample (0.29) and the highest in the MO sample (0.49).

The fatty acid composition of raw and cooked fish is presented for crevalle jack in Table 2 and for red drum in Table 3. Table 2 also contains the fatty acid composition of the Oleic Oil™ used for the FL technique. C16:0 (palmitic acid) was the main fatty acid in raw, ST, MO and GO crevalle jack samples; as well as in raw, FO and BL samples of red drum. In crevalle jack, C22:6 n-3 (DHA) was the highest fatty acid in FO and BL; and in the ST and MO samples of red drum. C18:1 n-9 (oleic acid) was the main fatty acid in the FL samples of both species.

Cooking techniques

Cooking techniques that require heat can affect the nutritional composition of fish species depending on the temperature reached, the amount of time the food is exposed to the heat and the methods used to cook it (Agren 1993; Ansorena 2012; Puwastein 1999; Tur Marí 2004). In the present study all cooking techniques produced important changes in the nutritional composition of crevalle jack and red drum. However, the species behaved very differently when submitted to the same cooking techniques. These differences could be explained by raw composition, temperature, size, exposed surface and degree of postmortem ageing prior to cooking (Ayala 2005, Ferreira 2007, Gladyshev 2007).

Figure 1a and b presents the perceptual content of beneficial (EPA+DHA) and adverse (protein, phosphorus) nutrients in crevalle jack and red drum. Crevalle jack (Fig. 1a) presents a slight increase in its perceptual content of EPA+DHA in ST, FO, BL and MO samples. The protein perceptual content remains stable in all samples; while the phosphorus also presented variations: a higher perceptual content is found in the FL sample, while the rest of the cooking techniques present a slight decrease in their perceptual phosphorus content. In red drum's case (Fig. 1b), BL presents the highest perceptual concentration of EPA+DHA, although all cooking methods present an increase in these nutrients. Protein perceptual content presents a slight decrease in the BL and FL samples; and phosphorus perceptual content diminishes among the different techniques, being BL the one with the lowest content. Red drum (Fig. 1b), in general, presents more variations in its perceptual content of beneficial and adverse nutrients than crevalle jack (Fig. 1a).

Steam

Steaming had opposite effects in crevalle jack and red drum regarding total lipids, SFA, MUFA and n-6 PUFA. It was the

Table 2 Fatty acid content (mg/100 g) in raw crevalle jack and after different methods of cooking, and fatty acids of Oleic Oil™

	Raw	Steamed	Foiled	Foiled w/banana leaf	Gas oven-baked	Microwave oven-cooked	Fried lightly	Oleic Oil™
C6:0	1.53	1.80	0.08	0.01	1.54	1.81	0.19	1.01
C8:0	0.16	0.87	ND	0.07	0.30	0.25	ND	0.02
C10:0	0.11	0.32	ND	0.01	0.20	0.04	ND	0.02
C11:0	0.04	0.33	ND	0.05	0.05	0.21	ND	0.23
C12:0	0.21	1.25	0.16	0.01	0.13	0.33	0.09	0.16
C13:0	0.22	0.10	ND	0.06	0.03	0.07	ND	0.12
C14:0	39.27	47.79	29.68	37.02	35.86	39.07	18.79	0.48
C14:1	ND	ND	ND	ND	ND	ND	ND	ND
C15:0	6.91	7.24	5.58	6.85	5.87	6.10	3.54	0.10
C15:1	2.63	3.97	1.98	2.29	3.69	0.87	2.26	ND
C16:0	260.47	283.03	247.81	282.06	233.26	235.10	154.26	25.97
C16:1	78.61	82.43	64.24	71.64	65.11	70.78	37.52	0.76
C17:0	12.57	12.45	10.82	14.09	10.74	12.10	6.58	0.15
C17:1	5.45	5.36	4.64	5.52	4.42	4.70	2.67	0.18
C18:0	104.66	116.18	116.76	145.34	98.68	98.75	74.13	12.19
C18:1n-9 trans	1.58	0.26	1.06	1.37	0.25	1.19	0.74	ND
C18:1n-9 cis	181.27	189.56	172.97	189.96	144.36	156.15	228.76	419.29
C18:2n-6 trans	1.27	0.52	0.05	0.45	0.48	0.48	0.22	0.84
C18:2n-6cis	9.20	11.88	10.60	14.24	9.66	8.96	29.91	80.58
C18:3n-6	2.67	1.01	1.77	2.08	2.16	1.78	1.03	0.16
C18:3n-3	4.39	4.37	3.76	5.62	3.72	4.31	2.41	0.22
C20:0	5.01	5.44	4.92	5.88	4.25	5.05	3.41	2.27
C20:1	4.38	4.89	4.65	5.81	4.70	4.36	3.09	1.33
C20:2	2.15	1.53	2.45	3.54	2.74	2.12	1.42	0.01
C20:3n-3	1.35	0.94	1.42	1.98	0.62	1.26	0.76	0.03
C20:3n-6	2.80	1.96	3.21	4.19	1.99	2.78	1.85	0.01
C20:4n-6	44.29	46.58	50.17	57.84	43.67	37.81	30.71	ND
C21:0	5.34	0.43	0.72	1.02	0.33	0.76	0.44	0.05
C22:0	0.06	0.20	ND	0.05	0.37	ND	ND	0.06
C20:5n-3	44.49	59.19	56.49	67.61	48.35	50.48	34.00	2.38
C22:1n-9	1.11	0.65	1.26	1.59	1.06	1.24	0.66	0.07
C22:2	0.34	0.19	ND	0.02	0.12	0.14	ND	0.15
C23:0	0.94	0.37	0.81	0.60	0.39	1.18	0.47	0.45
C24:0	2.12	2.10	2.95	4.34	1.32	2.14	2.06	0.88
C24:1	0.04	0.68	ND	0.05	ND	ND	ND	ND
C22:6n-3	182.10	246.03	249.10	342.66	228.04	215.40	158.06	0.41

ND: not detected. Values are shown as mean of three repetitions

only cooking technique that decreased phosphorus content in both species and increased EPA + DHA concentration, nutritional qualities appropriate for renal patients. Mnari-Bhouri (2010) found that steaming lightly increased the total lipid content of both wild and farmed sea bream, and decreased the MUFA concentration in the wild fish. In the present study similar results were only observed in crevalle jack's lipid content and red drum's MUFA concentration. The same study by Mnari-Bhouri found that oleic acid (C18:1 n-9c) decreased in sea bream after steaming; n-3 PUFA decreased, and n-6 PUFA content remained stable. In the present study oleic acid and n-3 PUFA increased in both species after steaming, and n-6 PUFA decreased in crevalle jack but increased in red drum. Phosphorus decrease is consistent with the study of Hosseini (2014), who found that boiling decreased phosphorus content in fish, while Ersoy (2009) reported that minerals usually increase after cooking. The factors responsible for these results are not known.

Table 3 Fatty acid content (mg/100 g) in raw red drum and after different methods of cooking

	Raw	Steamed	Foiled	Foiled w/banana leaf	Gas oven-baked	Microwave oven-cooked	Fried lightly
C6:0	10.75	6.31	9.01	134.99	3.63	112.08	59.83
C8:0	ND	ND	3.51	0.57	1.68	ND	ND
C10:0	ND	ND	ND	ND	0.74	ND	ND
C11:0	ND	ND	1.26	26.31	0.24	ND	ND
C12:0	ND	ND	0.05	ND	0.59	ND	0.92
C13:0	ND	ND	0.15	ND	0.62	ND	ND
C14:0	9.17	3.80	25.27	31.18	18.52	ND	50.85
C14:1	ND	ND	ND	ND	ND	ND	ND
C15:0	ND	2.88	7.04	14.87	6.52	ND	18.6
C15:1	ND	ND	2.40	5.99	1.14	ND	0.18
C16:0	202.48	157.37	312.96	604.45	192.09	208.88	677.32
C16:1	80.69	55.25	125.52	240.99	51.38	63.36	262.54
C17:0	7.75	7.74	12.09	28.19	10.74	ND	35.09
C17:1	5.16	7.61	7.95	15.52	13.88	ND	10.58
C18:0	74.71	80.38	100.71	192.97	102.72	78.31	206.82
C18:1n-9 trans	ND	1.65	2.55	ND	12.94	157.20	5.43
C18:1n-9 cis	87.28	110.44	187.95	439.30	117.82	157.11	879.24
C18:2n-6 trans	ND	ND	1.48	ND	0.31	ND	1.16
C18:2n-6cis	ND	4.93	12.88	24.62	4.55	ND	98.75
C18:3n-6	ND	ND	1.45	ND	2.04	ND	6.64
C18:3n-3	ND	0.35	6.19	36.46	2.71	ND	18.93
C20:0	ND	4.30	5.37	19.32	7.45	ND	17.85
C20:1	7.96	4.85	14.20	30.46	9.38	ND	39.00
C20:2	ND	3.46	3.52	ND	0.79	ND	4.86
C20:3n-3	ND	ND	1.23	ND	0.19	ND	4.80
C20:3n-6	ND	2.16	3.76	ND	0.51	ND	3.40
C20:4n-6	19.28	82.22	96.37	167.98	67.21	151.93	196.60
C21:0	ND	ND	3.80	ND	0.55	ND	2.48
C22:0	ND	ND	ND	ND	0.19	ND	ND
C20:5n-3	21.49	40.47	86.45	130.99	37.73	81.79	190.17
C22:1n-9	21.87	ND	1.53	ND	0.65	ND	7.76
C22:2	ND	ND	ND	ND	1.46	ND	ND
C23:0	23.31	ND	ND	ND	0.60	ND	1.16
C24:0	ND	ND	1.47	97.16	1.31	ND	5.29
C24:1	ND	ND	ND	ND	ND	ND	ND
C22:6n-3	167.91	215.32	246.80	352.20	156.28	227.74	424.80

ND: not detected. Values are shown as mean of three repetitions

Foil and foil with banana leaf

There are few studies that present the effect of foiled with aluminum or banana leaf techniques on fish. In the present study, when foiled, the nutritional components of crevalle jack decreased, except for PUFA, protein and phosphorus. Opposite effects were observed in red drum, were all elements increased. As for the foiled with banana leaf technique; all components of both species increased. Banana leaf has an elevated content of PUFA, which could explain the results found in the present study (Rosas and Díaz 1983).

Gas oven

Nutritional components of GO samples presented variations among the two analyzed species. While total lipids and phosphorus content decreased in red drum, their concentration increased in crevalle jack. No other component increased in red drum, although PUFA, n-3 PUFA, EPA+DHA and protein

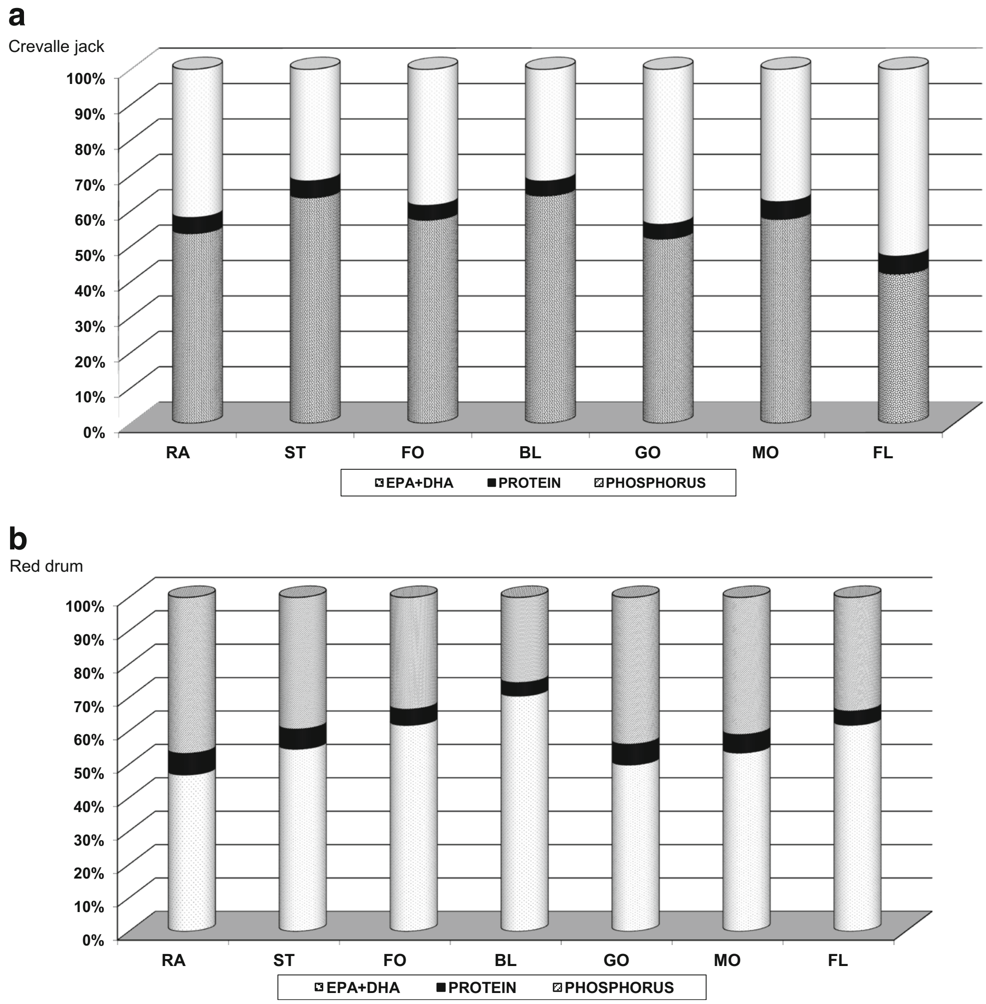

Fig. 1 Perceptual content of beneficial (Eicosanoic and docosahexaenoic acids (EPA + DHA)) and adverse (protein, phosphorus) nutrients in **a**) crevalle jack fillets under different cooking techniques and **b**) red drum fillets under different cooking techniques. *RA*: raw, *ST*: steamed, *FO*: foiled, *BL*: foiled with banana leaf, *GO*: gas oven-baked; *MO*: microwave oven-cooked and *FL*: fried lightly

content increased in crevalle jack. Kocatepe (2011) found that black sea anchovy fat content significantly increased after baking, and protein concentration slightly decreased. Agren and Hänninen (1993) found that baking in the oven decreased the fat content of rainbow trout, but increased it in vendace and pike. The results of the present study revealed that though gas oven increased the lipid content of crevalle jack, it decreased it in red drum. The nutritional increases found in these cooking technique can be explained by the exposure to heat and loss of moisture, because baking is one of the cooking methods with the greatest water loss (Ersoy 2009, Hosseini 2014).

Microwave oven

The MO technique increased total lipid content, PUFA, n-3 PUFA, EPA + DHA and protein in crevalle jack but decreased phosphorus content. In red drum's case, all components except total lipids increased with this cooking method. Gokoglu and others (2004) found that protein and fat content of rainbow trout significantly increased when cooked in the microwave; and Izquierdo et al. (2001) reported similar results in the case of tuna (*Thunnus thynnus*), where protein and lipid content also increased in the cooked samples. Results of the present study are similar, except for lipid content of red drum, which presented a small decrease after microwave cooking. The study by Gokoglu (2004) revealed a slight increase in the phosphorus content of rainbow trout, effect that was also found in red drum during the present study, however, it is noteworthy that crevalle jack's phosphorus content decreased when subjected to this cooking technique. The previously mentioned study by Izquierdo et al. (2001) reported a significant decrease in the content of C20:5 n-3 (EPA) and C22:6 n-3 (DHA) after microwave cooking. In the present study, both species increased their concentration of EPA and DHA. Higher cooking losses after microwaving are a combination of liquid and soluble matter lost during cooking, especially water since heat induced protein denaturation causes less water to be trapped within protein structures (Domínguez 2014).

Fried lightly

When fish is fried there is a fat exchange between the oil and the fish and oil absorption by fish resulting in modification of the fatty acid profile (Ansorena 2012, Hosseini 2014). Frying

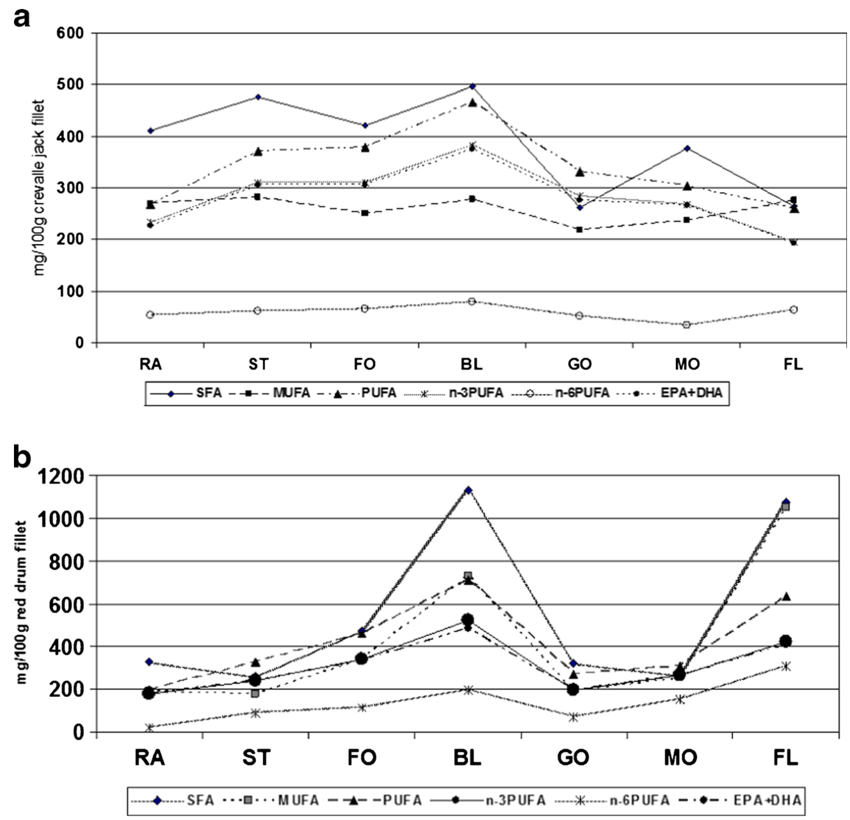

Fig. 2 Saturated fatty acids (SFA), Monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 PUFA, n-6 PUFA and eicosanoic + docosahexanoic acid (EPA+ DHA) in raw and cooked **a**) crevalle jack and b) red drum. *RA*: raw, *ST*: steamed, *FO*: foiled, *BL*: foiled with banana leaf, *GO*: gas oven-baked; *MO*: microwave oven-cooked and *FL*: fried lightly

could also cause oxidation of PUFA in the oil and reaction of the lipid oxidation compounds generated, with molecules that could appear due to proteolytic reactions (Domínguez 2014). In the present study, the FL technique included the use of Oleic Oil™, a commercial oil brand made from safflower seed and available in most supermarkets in Mexico. It has a low content of SFA and PUFA, but considerable amounts of MUFA. Previous studies have found that frying increases the fat content of fish (Agren 1993; Ansorena 2012; Izquierdo et al. 2001; Gokoglu 2004; Bakar 2008; Mnari-Bhouri 2010; Kocatepe 2011; Puwastein et al. 1999). In our study, the frying technique decreased the fatty acid content of crevalle jack, but not the total lipid content. Similarly, protein and phosphorus concentration increased in this technique, because of water loss by heating. For the case of red drum, the results are similar to those previously reported and all nutritional components increased with the frying technique.

n-6/n-3 relation

The n-6/n-3 relation indicates the proportion and balance between n-6 and n-3 PUFA. Some studies suggest that a combination of n-3 and n-6 PUFA is associated with lower levels of inflammation (Deckelbaum 2010); however, a high n-6/n-3 ratio promotes the pathogenesis of many diseases, including cardiovascular disease, cancer, and inflammatory diseases, whereas increased levels of n-3 PUFA (a lower omega-6/omega-3 ratio) exert suppressive effects (Simopoulos 2006). Modern Western diet has a typical n-6/n-3 ratio of 15.0 (Kiecolt-Glaser 2007; Simopoulos 2008), and the current recommendation for the prevention of cardiovascular disease and other chronic diseases is around 2.0-5.0 (Simopoulos 2008). In the present study, the n-6/n-3 ratios ranged from 0.15 to 0.21 in crevalle jack, and from 0.10 to 0.49 in red drum, which indicate that in all cooking techniques of both species the n-3 PUFA content was considerably higher than the n-6 PUFA. The regular consumption of fish with these characteristics would contribute to the adequate intake of a low n-6/n-3 ratio, recommended for the risk reduction of some chronic diseases (Simopoulos 2008). The best way to improve the n-6/n-3 ratio is by increasing the n-3 PUFA intake and not by decreases in n-6 PUFA (Deckelbaum 2010); therefore the consumption of fish with high n-3 PUFA, particularly EPA and DHA, is recommended for the prevention of the previously mentioned pathologies.

Figure 2a and b presents the fatty acid composition (SFA, MUFA, PUFA, n-3 PUFA, n-6 PUFA and EPA + DHA) of both fish species. In crevalle jack's case (Fig. 2a) fatty acid components present a similar trend in each cooking technique. In red drum's case (Fig. 2b), SFA present a notably high concentration in BL and FL samples; however, the rest of the fatty acid components behave similarly in each cooking method. When comparing Fig. 2a and b, different behavior is observed in both species when submitted to the same cooking techniques.

The most recommended cooking techniques for renal patients are those that diminish or maintain stable potentially adverse components (phosphorus and protein), and that increase the concentration of beneficial nutrients (EPA+DHA). Considering this, crevalle jack should be preferably consumed ST or MO; and red drum should be ST or GO. Nonetheless, all cooking techniques in both fish species produced a protein increase lower than 30 g/100 g of fillet, and a phosphorus concentration lower than 241 mg/100 g, which gives room to include them all in individualized recommendations.

Conclusion

Crevalle jack and red drum behaved different, and sometimes even in an opposite way, when cooking methods were applied to them. Therefore, it is important to further evaluate the impact that cooking techniques have on different fish species in order to give specific recommendations that provide more benefits to renal patients.

This article contributes with relevant results regarding nutritional composition of different fish species appropriate to renal patients' diets, after being submitted to cooking techniques. This information is necessary to provide more variability to their diets and to improve intake monitoring of several key nutrients in their nutritional management.

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