Food Chemistry 115 (2009) 419–422

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

The effect of cooking methods on mineral and vitamin contents of African catfish

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ARTICLE INFO

Article history:
Received 20 March 2008
Received in revised form 3 December 2008
Accepted 4 December 2008

Keywords:
African catfish
Cooking methods
Vitamins
Minerals
Proximate composition

ABSTRACT

Proximate composition, mineral and vitamin contents (A, E, B_1, B_2, niacin and B_6) were investigated in cooked African catfish. Different cooking treatments were used (baking, grilling, microwaving and frying). The protein and ash contents increased in all cooked fish. The fat content increased only in fried fillets. The moisture content of cooked fish decreased. Mineral levels were affected by cooking methods, except for Cu Although the vitamin A content significantly increased in grilled and fried fish, vitamin E increased in all cooked fish. Vitamin B_1 content of cooked fish significantly decreased. Vitamin B_2 and niacin contents of grilled fish increased significantly. B_6 content of cooked fish significantly decreased but this did not occur for the grilled fish. High levels of vitamin and mineral contents were found in grilled catfish.

1. Introduction

African catfish *Clarias gariepinus* is an extensive freshwater fish, found in the southern region of Turkey. It is a lean and highly nutritious fish that is rich in vitamins, proteins and minerals, has little or no saturated fat and is low in carbohydrates (Ersoy & Yılmaz, 2003). Catfish is generally consumed fresh and is relatively cheap in Turkey. It is an important source of cheap, high-quality protein in developing countries such as Turkey.

Fish is sometimes eaten raw, but it is usually treated by various processes, such as boiling, grilling, baking, and frying, before consumption. Heating (boiling, grilling, baking, frying) is applied to food to enhance its flavour and taste, inactivate pathogenic microorganisms and increase shelf life (Bognar, 1998). On the other hand, the use of the microwave oven for cooking has increased greatly during recent decades (Arias, Pontes, Fernandez, & Muniz, 2003). The fish obtained from sea and freshwaters are nutritionally important. A great deal of seafood is a perfect vitamin and mineral source. The high protein levels, with good digestibility and also low fat content, are advantages of seafood (Pigott & Tucker, 1990). The nutritive value of fish can be affected by cooking methods. The effects of different cooking methods on proximate and mineral composition of fish have been previously studied (Ersoy, Yanar, Küçükgülmez, & Çelik, 2006; Gokoglu, Yerlikaya, & Cengiz, 2004; Hoffman, Prinsloo, Casey, & Theron, 1994; Küçükgülmez, Çelik, Yanar, Ersoy, & Çıkrıkçı, 2006; Rosa, Bandarra, & Nunes, 2007; Weber, Bochi, Ribeiro, Victorio, & Emanuelli, 2008; Wu & Lillard, 1998; Yanar, Küçükgülmez, Ersoy, & Çelik, 2007). Early developments in the field of nutrition disclosed that certain substances, important for the proper functioning of the human body, are lost during cooking of foods. These include vitamins (Kumar & Aalbersberg, 2006). Since then, there has been continuous research on the retention of vitamins with different types of cooking. However, there is little information on fat- and water-soluble vitamin contents of cooked fish (Dias, Sánchez, Bártolo, & Oliveira, 2003; Kumar & Aalbersberg, 2006; Mattila, Ronkainen, Lehikoinen, & Piironen, 1999; Nettleton & Exler, 1992). Conservation of nutrients is a major consumer concern related to food preparation. Therefore, it is important to determine the retention of nutrients in fish cooked using several common domestic practices, namely microwaving, baking, grilling and frying.

In the present study, proximate composition, mineral content and, fat- and water-soluble vitamins have been determined in the raw and cooked African catfish, *Clarias gariepinus.* To evaluate the possible effect of different cooking methods on the nutritive value of this species, the values obtained in the cooked samples were compared with the values found in raw fish.

2. Materials and methods

2.1. Sample preparation and cooking

African catfish (*Clarias gariepinus*), with a length and weight of 25–30 cm and 250–300 g, were obtained from the Fish Bazaar in Hatay, Turkey. They were kept on ice and transported to the laboratory within 1 h. Samples were filleted and then fish fillets were divided into three groups (eight fish each). The first group was

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0308-8146/$ - see front matter
doi:10.1016/j.foodchem.2008.12.018

uncooked. The other two groups (two replicates) were cooked in the microwave oven (2450 MHz, 4 min), baked in the oven (200°C, 15 min), in the grill oven (200°C, 10 min) or fried (200°C, 4 min). Sunflower oil was used as the medium for pan-frying. Raw and cooked samples were ground in a food blender (equipped with stainless steel blade) to ensure homogeneity for analysis and each group was analyzed in the same way.

2.2. Proximate composition analysis

Proximate composition analyses of cooked and uncooked fish fillets were done in triplicate for protein, moisture, lipid and ash contents. The crude protein was determined by the Kjeldahl procedure (AOAC, 1984). Moisture was determined by oven-drying at 105°C to constant weight (AOAC, 1990). Total lipid was extracted from the muscle tissues using the Bligh and Dyer (1959) method. The lipid content was gravimetrically determined. Ash was determined gravimetrically in a muffle furnace by heating at 550 °C to constant weight (AOAC, 1990).

2.3. Water-soluble vitamins

2.3.1. General

Vitamins B_1 (thiamin), B_2 (riboflavin), B_6 (pyridoxine) and niacin were determined. B complex vitamins, B_1, B_2, B_6 and niacin, were determined according to the Finglas and Foulks (1984) and Kamman, Wanthesen, and Labuza (1980) high pressure liquid chromatography (HPLC) methods and Dionex Vydac Application Note: 1994.

2.3.2. B complex vitamin sample preparation

The samples were weighed and put into a flask (250 ml). Then, 30 ml 0.1 of M HCl were added and the flask was closed with cotton and then with aluminium foil and put into an autoclave. After this step, the pH of each sample was adjusted to 6.5 and 4.5 with sodium acetate and HCl and the volume was made up with distilled water, and filtered with a normal filter paper. If there was turbidity, this was centrifuged for 10 min at 6000 rpm. If turbidity persisted, the sample was filtered by using a filter of a 0.45 micrometer pore size. The samples were then ready for measurement.

2.3.3. HPLC conditions

A column oven was used. This had heating and cooling. Column: C18 Omni Sphere 5, 250 4.6 mm, wavelength: 254 nm B6, B2, B1, flowing rate: 1.0 ml/min, injection volume was 20 L, mobile phase: 1000 ml phosphate solvent +360 ml methanol mixture, pressure: 150–160 bar, running time 22 min.

2.4. Fat-soluble vitamins

2.4.1. General

Fat-soluble vitamins such as A and E were determined. Vitamins were analyzed by high pressure liquid chromatography (HPLC), as described by Manz and Philipp (1981).

2.4.2. A and E vitamins sample preparation

The homogenized samples were weighed and saponified. Vitamin A was saponified using ethanolic potassium hydroxide (50%) and vitamin E was saponified using methanolic ascorbic acid (5%) and potassium hydroxide (50%). Saponified samples were then extracted with 70 ml of diethyl ether, three times, in a separating funnel. The extracts were combined and washed with distilled water before being concentrated and made to volume with ether in a 250 ml volumetric flask.

2.4.3. HPLC conditions

A silica gel package column was used for vitamins A and E. The quantification of vitamin A was done by HPLC with the following conditions:

Detection: fluorescence detector; excitation: 325 nm, emission: 480 nm.

Mobile phase: 98% n-hexane, 2% propan-2-ol.

The quantification of vitamin E was done by HPLC using 97% n-hexane (Merck no. 104391), 3% 1,4-dioxane (Merck no. 103115) as the mobile phase and a fluorescence detector with excitation and emission set at 293 and 326 nm, respectively. Flowing rate was 1.0 ml/min and injection volume 20 L for vitamins A and E.

2.5. Mineral analysis

For mineral determination, the samples were digested in concentrated HNO_3 (AOAC, 1995). The digest was quantitatively transferred to a 25 ml volumetric flask with deionized water and made up to volume with deionized water. A blank digest was carried out in the same way. All minerals were determined using inductively coupled plasma atomic emission spectrometry (ICP-AES) (Varian model- Liberty Series II) against aqueous standards. The mineral concentration was expressed as mg mineral/kg fish dry weight.

2.6. Statistical analysis

Significant differences between means were determined by one-way analysis of variance (ANOVA) and Duncan's multiple range test ($p = 0.05$) (SPSS 13.0 for windows).

3. Results and discussion

3.1. Proximate composition

The changes in protein, moisture, fat and ash contents of samples after cooking processes are shown in Table 1.

The proximate composition of raw fillets is similar to that observed by other researchers (Ersoy & Yılmaz, 2003; Hoffman et al., 1994; Rosa et al., 2007; Yanar et al., 2007) for African catfish.

The proximate composition of African catfish was significantly affected by all the cooking methods ($p < 0.05$). The protein and ash contents increased after cooking in all evaluated methods; the fat content increased only in fried fillets (Table 1). The moisture content of the fish fillets ranged from 69% to 77%, decreasing after cooking (Table 1). The increases in protein, fat and ash contents observed in cooked African catfish fillets are explained by the reduction in moisture (Table 1). However, the decrease in the moisture content has been described as the change that makes the protein, fat and ash contents increase significantly in cooked fish fillets Garcia-(Arias et al., 2003).

Fried fish had a higher level of fat than raw or other cooked fish. The increase in fat content of the fried fish fillets is also related to oil absorption during the cooking process. Fat increase can be due

Table 1
Proximate composition of raw and cooked fish fillets.[A,B]

	Protein (%)	Moisture (%)	Fat (%)	Ash (%)
Raw	16.2 ± 0.66^a	76.8 ± 0.87^d	5.02 ± 0.49^a	0.83 ± 0.10^a
Baked	21.8 ± 0.42^c	69.4 ± 0.34^a	5.85 ± 0.05^a	1.21 ± 0.03^b
Grilled	19.5 ± 1.10^b	72.7 ± 0.69^c	5.16 ± 0.12^a	1.05 ± 0.13^b
Microwaved	20.3 ± 0.75^b	72.7 ± 0.20^c	5.22 ± 0.53^a	1.09 ± 0.03^b
Fried	20.0 ± 1.01^b	70.7 ± 0.25^b	8.02 ± 1.68^b	1.15 ± 0.13^b

[A] Results are means ± standard deviation of triplicates.
[B] Means within the same column that have no common letters are significantly different ($p < 0.05$).

to the oil penetration into the food after water is partially lost by evaporation (Saguy & Dana, 2003). Similar results have been reported for African catfish fried in sunflower oil (Rosa et al., 2007).

The greatest water loss was found in baking samples. Water loss, occurring during baking, resulted in higher protein content in baked fish. After cooking, an important water loss was found by Weber et al. (2008) in silver catfish and Rosa et al. (2007) in African catfish.

3.2. Mineral contents

In Table 2, the mineral contents of raw and cooked catfish are presented.

The Na content of raw fish was found to be 308 mg/kg. Na content of baked, microwave cooked and fried samples significantly increased, while that of grilled samples decreased. It was reported that Na content of fried and grilled fish significantly increased (Rosa et al., 2007).

The K content of raw fish was found to be 1817 mg/kg. This value is lower than that reported by other researchers (Hoffman et al., 1994; Rosa et al., 2007) for African catfish. K content, in all the cooking methods, significantly ($p < 0.05$) increased. This result is similar to that of Rosa et al. (2007).

The Ca content of raw fish was found to be 40 mg/kg. This value is higher than that reported by Rosa et al. (2007) and lower than that reported by Hoffman et al. (1994). The Ca content of cooked fish increased significantly ($p < 0.05$) in all cooking methods.

The mean Mg content ranged from 184–265 mg/kg in all fish samples. The Mg content of cooked fish increased significantly ($p < 0.05$) when compared to the raw control. This result is in accordance with the reports of Rosa et al. (2007).

The Fe contents of raw and cooked fish ranged from 12.0–25.9 mg/kg. The Fe content of fried samples increased significantly but an insignificant increase was found in the baked, grilled and microwave cooked samples. This result is in accordance with the notes of other authors (Gokoglu et al., 2004; Rosa et al., 2007).

The Zn content of raw fish was found to be 3.48 mg/kg. This value is lower than that reported by other researchers (Hoffman et al., 1994; Rosa et al., 2007). The Zn content of fish significantly ($p < 0.05$) increased after baking, microwave cooking and frying (but not for the grilled fish).

The Mn content of raw and cooked fish ranged from 0.22–0.42 mg/kg. The increase in Mn content after frying and microwave cooking was found to be significant ($p < 0.05$). However, the decrease in Mn content after baking and grilling was found to be insignificant. Similarly, Rosa et al. (2007) reported that the Mn content of fried African catfish increased significantly ($p < 0.05$).

The Cu contents of all fish samples were between 0.93–2.15 mg/kg. The change in Cu content of cooked fish, for all cooking methods, was found to be insignificant. This result is in accordance with the reports of Gokoglu et al. (2004) for baked, grilled and microwave-cooked rainbow trout but not for the fried fish.

3.3. Vitamin contents

Table 3 shows vitamins A, E, B_1, B_2, niacin and B_6 profiles of raw and cooked African catfish.

Fat-soluble vitamins, which include vitamins A and E, are said to be less heat-labile than the water-soluble vitamins. They are susceptible to destruction at high temperatures in the presence of oxygen (Lund, 1973). Vitamin A content of raw fish was found to be 18.1 mg/100 g. This value is lower than that reported by Dickey (1991) who found that the vitamin A content was 8 μg/100 g in fin-fish (Pacific cod). Vitamin content can vary in different parts of the same tissues, and among animals collected at different times and locations. Indeed, geographic availability, seasonality, and physiological state/maturity are known to affect variability in nutrient composition, particularly for vitamins (Greenfield & Southgate, 2003). The differences in the content of vitamin A in all samples after different methods of cooking are statistically significant at the 95% confidence level. Although the vitamin A contents of grilled and fried fish significantly ($p < 0.05$) increased, those of baked and microwave-cooked fish decreased. Similarly, it was reported that vitamin contents of fried hake and grilled salmon were higher than those of raw fish (Dias et al., 2003).

Vitamin E content of raw fish was found to be 0.34 mg/100 g. This result is similar to vitamin E values of common sole, European dogfish and plaice noted by Dias et al. (2003) (mean values of 0.32, 0.35 and 0.35 mg/100 g, respectively). The vitamin E content of cooked fish increased significantly ($p < 0.05$) when compared to the raw control. Similar results were reported by other authors (Dias et al., 2003) for other fish species, such as Axillary bream, hake and sea bass.

Vitamin B_1 is the most heat-labile of the B vitamins, particularly under alkaline conditions (Priestley, 1979). Vitamin B_1 content of raw samples was found to be 0.07 mg/100 g. This result is similar to the B_1 contents of axillary bream and meager described by Dias et al. (2003) (a mean value of 0.07 mg/100 g). Vitamin B_1 content of fish significantly ($p < 0.05$) decreased after baking, microwave-cooking, grilling and frying. Vitamin B_1 content of grilled fish was higher than those of baked, microwave-cooked and fried fish.

Vitamin B_2, together with niacin, is a relatively stable vitamin, resistant to the effects of acid, heat and oxidation. B_2 is unstable in the presence of alkali and light (Cross & Fung, 1982). Vitamin B_2 of raw fish was found to be 0.03 mg/100 g. This value is similar to the B_2 content of other fish species noted in a previously study (Dias et al., 2003; Dickey, 1991). Although Vitamin B_2 of grilled fish significantly ($p < 0.05$) increased, that of fried fish decreased. Similarly, Dias et al. (2003) reported that vitamin B_2 content of grilled gilthead increased when compared to raw fish.

Niacin has been said to be a stable vitamin (Lang, 1970). Niacin content of raw fish was 1.13 mg/100 g. Similarly, niacin value of

Table 2
Mineral contents of raw and cooked fish fillets (mg/kg).[A,B]

	Raw	Baked	Grilled	Microwaved	Fried
Na	308 ± 0.35b	341 ± 8.05[c]	287 ± 7.40[a]	375 ± 4.30[d]	451 ± 3.86[e]
K	1817 ± 132.4[a]	2486 ± 53.4[bc]	2694 ± 60.90[cd]	2373 ± 48.11[b]	2770 ± 83.01[d]
Ca	40.1 ± 0.08[a]	111 ± 1.82[d]	83.9 ± 0.74[c]	164 ± 3.95[e]	70.9 ± 4.02[b]
Mg	184 ± 18.5[a]	265 ± 10.2[c]	247 ± 8.93[bc]	230 ± 9.64[b]	248 ± 7.21[bc]
Fe	12.0 ± 0.43[a]	12.9 ± 0.06[a]	12.8 ± 0.07[a]	12.7 ± 0.10[a]	25.9 ± 2.19[b]
Zn	3.48 ± 0.16[a]	5.08 ± 0.02[b]	3.43 ± 0.28[a]	5.40 ± 0.02[b]	5.99 ± 0.11[c]
Mn	0.29 ± 0.04[a]	0.22 ± 0.01[a]	0.25 ± 0.01[a]	0.42 ± 0.05[b]	0.40 ± 0.00[b]
Cu	2.15 ± 1.49	0.93 ± 0.36	1.07 ± 0.11	1.75 ± 1.30	2.10 ± 0.14

[A] Results are means ± standard deviation of triplicates.
[B] Means within the same column that have no common letters are significantly different ($p < 0.05$).

Table 3
Vitamin contents of raw and cooked fish fillets (mg/100g).[A,B]

Vitamins	Raw	Baked	Grilled	Microwaved	Fried
A	18.1 ± 0.05[c]	11.5 ± 0.32[a]	31.7 ± 1.37[e]	16.3 ± 0.58[b]	30.3 ± 0.46[d]
E	0.34 ± 0.01[a]	1.52 ± 0.02[d]	0.59 ± 0.01[c]	0.52 ± 0.01[b]	0.52 ± 0.01[b]
B_1	0.07 ± 0.01[c]	0.04 ± 0.00[a]	0.05 ± 0.01[b]	0.04 ± 0.00[a]	0.04 ± 0.00[a]
B_2	0.03 ± 0.01[b]	0.02 ± 0.00[b]	0.07 ± 0.01[c]	0.02 ± 0.00[b]	0.01 ± 0.00[a]
Niacin	1.13 ± 0.00[d]	0.73 ± 0.01[c]	2.03 ± 0.01[e]	0.05 ± 0.00[b]	0.04 ± 0.00[a]
B_6	0.08 ± 0.00[d]	0.06 ± 0.01[c]	0.10 ± 0.01[e]	0.05 ± 0.01[b]	0.03 ± 0.01[a]

[A] Results are means ± standard deviation of triplicates.
[B] Means within the same column that have no common letters are significantly different ($p < 0.05$).

cuttlefish, noted by Dias et al. (2003), was 1.1 mg/100g. Niacin content of grilled fish increased significantly ($p < 0.05$). Similar results for niacin were reported by Dias et al. (2003).

Vitamin B_6 of raw fish was 0.08 mg/100g. Vitamin B_6 contents of baked, microwave-cooked and fried fish significantly ($p < 0.05$) decreased (but not grilled fish). Vitamin B_6 content of grilled fish increased significantly ($p < 0.05$).

As expected, grilled samples are more concentrated in water-soluble vitamins (B_1, B_2, niacin and B_6) due to minimal loss of moisture.

4. Conclusion

Dry matter, protein and Na, K, Ca, Mg, Zn contents of baked and microwave-cooked fish increased considerably. However, vitamin contents decreased, except for vitamin E.

The fat content in fried samples significantly increased due to absorption of fat. Therefore, the frying method cannot be recommended for human consumption.

Water losses in grilled fish are lower than those in baked and fried fish. Ca, K and Mg contents of grilled fish increased. However, the changes in Fe, Zn, Mn and Cu contents were found to be insignificant. Vitamins A, E, B_2, B_6 and niacin increased significantly. However, there was a decrease in vitamin B_1 content. The grilling method is the most suitable one (with less vitamin and mineral loss) among all cooking methods.

References

AOAC (1984). *Official methods of analysis of the association of the official analysis chemists. Association of official analytical chemists* (14th ed.). Washington, DC.

AOAC (1990). *Official methods of analysis of the association of the official analysis chemists. Association of official analytical chemists* (15th ed.). Washington, DC.

AOAC (1995). *Official methods of analysis* (16th ed.). Washington, DC: AOAC International.

Arias, M. T. G., Pontes, E. A., Fernandez, M. C. G., & Muniz, F. J. S. (2003). Freezing/defrosting/frying of sardine fillets. Influence of slow and quick defrosting on protein quality. *Journal of the Science of Food and Agriculture, 83*, 602–608.

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology, 37*, 911–917.

Bognar, A. (1998). Comparative study of frying to other cooking techniques influence on the nutritive value. *Grasas Aceites, 49*, 250–260.

Cross, G. A., & Fung, D. Y. C. (1982). The effect of microwaves on nutrient value of foods. *CRC Critical Reviews in Food Science and Nutrition, 16*, 355–381.

Dias, M. G., Sánchez, M. V., Bártolo, H., & Oliveira, L. (2003). Vitamin content of fish and fish products consumed in Portugal. *Electronic Journal of Environmental, Agricultural and Food Chemistry, 2*(4), 510–513.

Dickey, L. E. (1991). *Composition of foods: Raw, processed, prepared; 1990 supplement*. Agriculture Handbook No. 8. US Department of Agriculture.

Ersoy, B., Yanar, Y., Küçükgülmez, A., & Çelik, M. (2006). Effects of four cooking methods on the heavy metal concentrations of sea bass fillets (*Dicentrarchus labrax* Linne, 1785). *Food Chemistry, 99*(4), 748–751.

Ersoy, B., & Yılmaz, A. B. (2003). Frozen storage of African catfish (*Clarias gariepinus* BURCHELL, 1822) mince balls. *Turkish Journal of Veterinary and Animal Sciences, 27*, 827–832.

Finglas, P. M., & Foulks, R. M. (1984). HPLC analysis of thiamin and riboflavin in potatoes. *Food Chemistry, 15*, 37–44.

Gokoglu, N., Yerlikaya, P., & Cengiz, E. (2004). Effects of cooking methods on the proximate composition and mineral contents of rainbow trout *(Oncorhynchus mykiss*). *Food Chemistry, 84*, 19–22.

Greenfield, H., & Southgate, D. A. T. (2003). *Food composition data: Production, management and use* (2nd ed.). Rome: FAO.

Hoffman, L. C., Prinsloo, J. F., Casey, N. H., & Theron, J. (1994). Effects of five cooking methods on the proximate, fatty acid and mineral composition of fillets of the African Sharptooth catfish. *Die SA Tydskrif vir Voedselwetenskap en Voeding, 6*(4), 146–152.

Kamman, J. F., Wanthesen, J. J., & Labuza, T. P. (1980). Technique for measuring thiamin and riboflavin in fortified foods. *Journal of Food Science, 45*, 1497–1499.

Küçükgülmez, A., Çelik, M., Yanar, Y., Ersoy, B., & Çıkrıkçı, M. (2006). Effects of different cooking methods on the proximate composition and mineral contents of sea bass (*dicentrarchus labrax*). *Advances in Food Sciences, 28*(4), 223–227.

Kumar, S., & Aalbersberg, B. (2006). Nutrient retention in foods after earth-oven cooking compared to other forms of domestic cooking 2. vitamins. *Journal of Food Composition and Analysis, 19*, 311–320.

Lang, K. (1970). Influence of cooking on foodstuffs. *World Review of Nutrition and Dietetics, 12*, 266–317.

Lund, D. B. (1973). Effects of heat processing. *Food Technology, 27*, 16–18.

Manz, U., & Philipp, K. (1981). Method for the routine determination of tochopherols in animal feed and human foodstuffs with the aid of HPLC. *International Journal for Vitamin and Nutrition Research, 51*, 342–348.

Mattila, P., Ronkainen, R., Lehikoinen, K., & Piironen, V. (1999). Effect of household cooking on the vitamin D content in fish, eggs, and wild mushrooms. *Journal of Food Composition and Analysis, 12*, 153–160.

Nettleton, J. A., & Exler, J. (1992). Nutrients in wild and farmed fish and shellfish. *Journal of Food Science, 57*, 257–260.

Pigott, G. M., & Tucker, B. W. (1990). *Seafood effects of technology on nutrition*. New York: Marcel Dekker, Inc..

Priestley, R. J. (1979). Vitamins. In R. J. Priestley (Ed.), *Effects of heating on foodstuffs* (pp. 121–156). London, UK: Applied Science.

Rosa, R., Bandarra, N. M., & Nunes, M. L. (2007). Nutritional quality of African catfish *Clarias gariepinus* (Burchell1822): A positive criterion for the future development of the European production of Siluroidei. *International Journal of Food Science and Technology, 42*, 342–351.

Saguy, I. S., & Dana, D. (2003). Integrated approach to deep fat frying: Engineering, nutrition, health and consumer aspects. *Journal of Food Engineering, 56*, 143–152.

Weber, J., Bochi, V. C., Ribeiro, C. P., Victorio, A. M., & Emanuelli, T. (2008). Effect of different cooking methods on the oxidation, proximate and fatty acid composition of silver catfish (*Rhamdia quelen*) fillets. *Food Chemistry, 106*, 140–146.

Wu, W. H., & Lillard, D. A. (1998). Cholesterol and proximate composition of changes following cooking by microwave channel catfısh (*Ictalurus Punctatus*) fillets–changes heating, deep-fat frying, and oven baking. *Journal of Food Quality, 21*, 41–51.

Yanar, Y., Küçükgülmez, A., Ersoy, B., & Çelik, M. (2007). Cooking effects on fatty acid composition of cultured sea bass (*Dicentrarchus labrax*) fillets. *Journal of Muscle Foods, 18*(1), 88–94.