www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 17: 935-943 (2017) DOI: 10.4194/1303-2712-v17_5_09

RESEARCH PAPER

Influence of Superheated Steam Cooking on Proximate, Fatty Acid Profile, and Amino Acid Composition of Catfish (Clarias batrachus) Fillets

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Received 30 November 2016
Accepted 20 February 2017

Abstract

Influence of convection oven cooking and superheated steam oven cooking on proximate, fatty acid profile, and amino acid composition of catfish (*Clarias batrachus*) fillets were evaluated. Purchased quantities of catfish were filleted and divided into three parts: one part was cooked using the superheated steam oven for 5 min with grilling mode (no temperature setting); another part was cooked using the convection oven at 200 ℃ for 8 min and the remaining was used as a control (raw catfish). The cooking treatments reduced moisture and increased protein, lipid, and ash content significantly ($P<0.05$). The most abundant fatty acids found in raw catfish fillets were palmitic acid (C16:0, 24.51% of total fatty acids), oleic acid (C18:1 n-9c, 29.57% of total fatty acids), and linoleic acid (C18:2 n-6c, 19.07% of total fatty acids). Superheated steam oven cooked fillets had higher n-3 fatty acids, EPA, and DHA content. The PUFA/SFA ratio was significantly reduced ($P<0.05$) after convection oven cooking as compared to superheated steam oven cooked fillets. There was no significant difference in amino acid contents among the raw and cooked samples. In summary, superheated steam is recommended for fish cooking as far as healthy eating is concerned.

Keywords: Catfish (*Clarias batrachus*), superheated steam, fatty acid profile, amino acid.

Introduction

Fish is globally consumed by people all over the world. Fish has long been recognized as an important source of high-quality protein, polyunsaturated fatty acid (PUFA), minerals and vitamins in the diets of human.. The American Heart Association (AHA) suggests consumption of no less than two 3 oz servings of fish every week (Kris-Etherto et al., 2002). However, pregnant or breastfeeding women should avoid eating fish that are high in methylmercury, including tilefish, shark, swordfish, and king mackerel and eat less than 6 oz of tuna per week. Seventeen percent (17%) of the total animal protein and 6% of all protein consumed by humans are coming from fish (Domingo et al., 2007). Fatty acids from fish were found to have higher in the proportion of polyunsaturated omega-3 fatty acids (n-3 PUFAs) compared to terrestrial animals. The major n-3 PUFAs in fish are eicosapentaenoic acid (EPA; 20:5 n-3) and docosahexaenoic acid (DHA; 22:6n-3) (Mahaffey, 2004; Domingo et al., 2007). There have been studies showing these fatty acids having beneficial effects on diseases such as coronary heart diseases, human breast cancer, inflammatory and autoimmune diseases (Kris-Etherton et al., 2002; Simopoulos, 2002; Jimoh and Aroyehun, 2011).

Aquaculture production in Malaysia has grown rapidly and predominated by freshwater tilapia and catfish. Catfish is a promising aquaculture in Asia and Africa due to its high production, fast growth rate, good taste, source of protein, high market demand and has tremendous popularity among consumers (House et al., 2003;Shourbela et al., 2016). Catfish is widely consumed by Malaysian and it is easy to farm in a warm climate and leading to inexpensive and abundance food at the freshest market or grocers. In Malaysia, catfish is commonly known as “ikan keli” or “ikan lele” (House et al., 2003; Sahoo et al., 2010; Singh et al., 2013).

Fish is often treated by various cooking methods before consumption. Typically the objective of a cooking process is to produce fish with desirable sensory qualities (color, texture, flavor and aroma), while also minimizing nutrient loss and ensuring the destruction of microbial pathogens. During cooking, heat treatment and the evaporation of water affect the physical and chemical changes in fish, and therefore

digestibility is increased due to protein denaturation but PUFA is often reduced (Raj et al., 2008; Asmah et al., 2014). Previous research suggests that cooking process could affect the amino acid content of fish. Nurhan (2007) reported that both essential (EAA) and non-essential amino acids (NEAA) in rainbow trout increased significantly after oven and microwave cooking. The effects of different cooking methods on the fatty acid profiles of various fish also have been studied extensively (Nurhan, 2007; Weber et al., 2008; Larsen et al., 2010; Koubaa et al., 2012; Şengör et al., 2013; Asmah et al., 2014; Neff et al., 2014). However, despite the literature being rich with frying, boiling, steaming, grilling, baking, oven and microwave cooking on various fish species, currently there is no published literature detailing the effect of superheated steam cooking on amino acid and fatty acid profiles of catfish.

Superheated steam (SHS) is a clear, colorless steam generated by instantaneously reheating 100 ℃ steam, thus the steam produced at a higher temperature than its saturation or vaporization (boiling) point and normally working in the absence of oxygen (Ezhil, 2010). A Recent study has shown that superheated steam can reduce lipid oxidation, retain vitamin C, and preserve color and texture of various foods (Idrus and Yang, 2012; Zzaman and Yang, 2013; Abdulhameed et al., 2014). These criteria make it an attractive alternative to cooking fish with minimal amino acid and PUFA destruction. This study was, therefore, conducted to determine the influence of superheated steam oven cooking on the proximate composition (moisture, fat, protein, and ash), fatty acid profile and amino acid composition of catfish (*Clarias batrachus*) fillets. The superheated steam oven cooking was compared with the convection oven cooking.

Materials and Methods

Freshwater Catfish

Samples of freshly harvested catfish (*Clarias batrachus*) with the mean weight and length of 190.25 ± 4.96 g and 29.67 ± 0.58 cm, were obtained from a local fish farm (Bukit Mertajam, Penang) during the spring (March) of 2015 shown in **Figure 1.** The samples were kept in plastic bags and transported in an insulated icebox to the laboratory within 1 h. The catfish were filleted and yielding two separate fillets (19.70 ± 2.41 g each one). The fillets from each side of the catfish were divided into 3 portions of ~40 g each, which were assigned to the three repetitions for the convection oven cooking; the fillets from the other side of the same catfish used for convection oven cooking were divided into another 3 portions and used for superheated steam oven cooking. Other fillets were then divided into another 3 portions for the raw group that was used as a reference. A sample size of 6 catfish was used for each cooking method as well as the raw group.

Sample Preparation

All fillets were grilled with skin-side down and patted dry with a paper towel prior grilling. Each fillet was cooked separately. No salt, oil or additional ingredients were added to the fillets. To prepare convection oven grilled fillets, the convection oven (Bakbar, Turbofan Moffat E32, Victoria, Australia) was set at 200 ℃ for 15 min (pre-heating), then the fillets were grilled for 8 min. The mean core temperature immediately after grilling was 79 ± 1.17 ℃. Superheated steam grilled catfish fillets were prepared in a superheated steam oven (SHARP, Healsio AV-1500V, Japan) that was preheated for 10 min. The fillets were grilled for 5 min with grilling mode (no temperature setting). The mean core temperature immediately after grilling was 80 ± 0.58 ℃. Raw and cooked samples were ground in a food blender equipped with the stainless steel blade to ensure homogeneity. Each sample was wrapped in an aluminum foil and frozen at –20 ℃ for subsequent proximate, fatty acid, and amino acid analysis.

Proximate Composition

All proximate analysis were done according to International Official Methods of Analysis (AOAC, 2012). The moisture content of cooked and uncooked catfish fillets was dehydrated by an oven (Memment, UL 40, Schwabach, Germany) at 105℃ until a constant weight was obtained (AOAC method 926.08). Ash content was determined by incineration in a muffle furnace (Thermo-Thermolyne, F6000, Waltham, USA) at 550 ℃ for at least 2 h (AOAC method 923.03). The crude protein (N x 6.25) content was determined by the micro-Kjeldahl procedure with a distillation unit system (VELP Scientifica, UDK 127, Milano, Italy) (AOAC method 960.52). Fat content was determined according to the Soxhlet method (AOAC method 920.39) by using petroleum ether (b.p. 40 – 60 ℃) as an extraction solvent.

Fatty Acid Profile

Fatty Acid Methyl Esters (FAME) are non-polar and more volatile than their corresponding fatty acids; therefore they are much more amenable to analysis by gas chromatography than free fatty acids. All samples were prepared on a “just in time” basis to ensure all samples would be treated in the same fashion. FAMEs were prepared by following Mondello et al. (2006) method with some modification. Crude catfish oil (0.1 g) were trans-esterified in a Pyrex glass test tube with screw cap by using 2 ml of boron trifluoride-methanol (20% BF3) reagent and heated at 100 ℃ for 30 min. After the solution was cooled down to room temperature, 2 ml of n-hexane and 8 ml of distilled water were added and the mixture was agitated

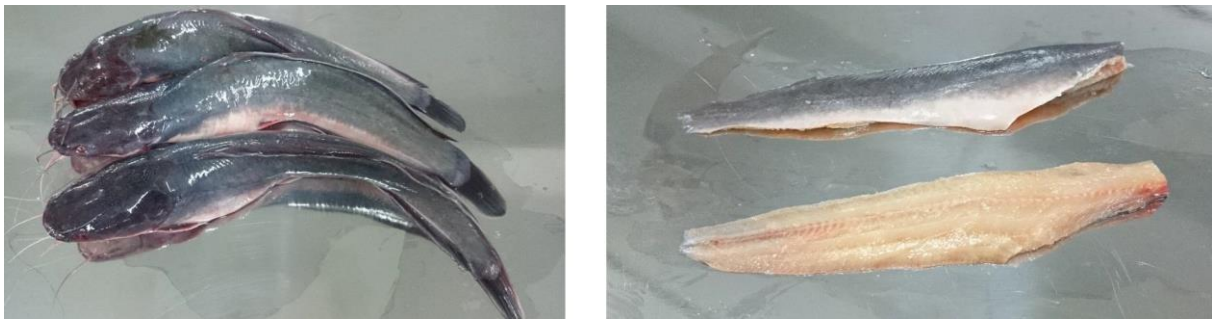

Figure 1. Photograph of Fresh Catfish (Left side) and Catfish fillets (Right side).

vigorously for 1 min. Separation of the hexane soluble and insoluble layer was done using centrifugation at 3500 rpm for 2 min. The upper hexane soluble layer was then collected and transferred into a 2 ml glass vial used for chromatographic analysis. The preparation of FAMEs was done in triplicate. The gas chromatography analysis of methylated fatty acid was performed on a gas chromatography mass spectrometer (Shimadzu, QP-2010 Ultra, Kyoto, Japan) (Agilent 7890A/5975C GCMS System) with an autosampler (Shimadzu, AOC 5000, Kyoto, Japan). The GCMS was equipped with a polar (70% Cyanopropyl Polyphenylene-siloxane, 0.32 mm ID x 0.25 m x 30 m) GC capillary column (SGE Analytical Science Pty Ltd, BPX70, Victoria, Australia). Gas chromatography condition was initial temperature of 155 ℃ , and increased to 180 ℃ with a rate of 2 ℃/min and further increased to 220 ℃ with a rate of 4 ℃/min. Holding time was 5 min. Injector and detector temperature was both at 250 ℃ and split ratio used was 80:1. Fatty acid methyl ester sample was injected in the volume of 1 l. Carrier gas used was Helium with a flow rate of 1.29 ml/min.The mass spectrum from the chromatogram was compared with WILEY (399, 383 spectra; Ver. 8) Mass Spectra Library. The library search function compared the unknown spectrum to reference spectra registered in a library one by one. A total ion chromatogram was obtained with its similarity index. Each fatty acid detected was expressed as a percentage of fatty acid over the sum of all fatty acid detected.

Amino Acid Composition

Amino acid composition was determined according to the method described by Abedin et al. (2014). The catfish samples were freeze-dried and crushed into powder form. 0.1017 g of samples were digested with 5 ml of 6 N HCl in sealed glass test tubes for 24 h at 110 ℃ in an oven. The aliquot of the hydrolysate was taken and 0.4 ml of 50 mol ml-1 alpha-aminobutyric acid (AABA) was added as an internal standard. Deionized water (100 ml) was then added to the aliquot. This aliquot was filtered using Whatman filter paper no.1 followed by a syringe filter with 0.45 µm pore size. Heating block was preheated to 55 ℃. Vial 2A (AccQ·Fluor Reagent Powder) was tapped lightly to ensure all AQC powder was at the bottom of the vial. One ml of AccQ·Fluor Reagent Diluent (acetonitrile, CH3CN) from vial 2B was added to vial 2A. Vial 2A was cap quickly and vortexed for 10 s. Vial 2A was heated on the heating block for less than 10 min and vortexed occasionally until the powder was completely dissolved. A liquid chromatograph with a multi λ fluorescence detector (Waters, 2475, Milford, Massachusetts USA) was used for the Waters AccQ·Tag amino analysis method. The liquid chromatograph was equipped with a binary HPLC pump (Waters, 1525, Milford, Massachusetts USA) and an autosampler (Waters, 717 plus, Milford, Massachusetts USA). The excitation wavelength was 285 nm, the emission wavelength was 354 nm. Filter and gain sets were 1.5 s and 10, respectively. The mobile phase of the HPLC system consisted of AccQ·Tag concentrate (Eluent A) and 60% acetonitrile: water (Eluent B). A reversed-phase C18 (3.9 x 150 mm, 4m) HPLC column was used (Waters, AccQ·Tag, Milford, Massachusetts USA). The column temperature was set at 36 ℃. The column was first conditioned with Eluent B at 1 ml/min flow rate for 5 min and followed by equilibrating the column in 100% AccQ·Tag Eluent A concentrate at 1 ml/min flow rate for 9 min. Consistent period of the equilibration was kept for all analysis and a blank was carried out before each analysis to determine the baseline performance.

Sensory Evaluation

Sensory evaluation of this experiment was evaluated by 30 panelists (15 Male, 15 Female, 25-40 years). Sensory evaluation was performed at sensory room at the Food Technology division, School of Industrial Technology, USM. Panelists were asked to evaluate taste, color, texture and overall acceptability cooked by two methods of superheated steam and conventional at 200 ℃ for 15 min and the mean core temperature of the samples after cooking was 78 ± 0.53 ℃. Panelists were asked to score all the attributes by using 7-point Hedonic scale as 1= dislike very much, 2= dislike moderately, 3= dislike slightly, 4= neither like nor dislike, 5= like slightly, 6= like

moderately and like very much. (Meilgaard et al., 2007).

Statistical Analysis

All data were expressed as a mean ± standard deviation. Data generated were analyzed using SPSS software, version 22 for windows. The one-way ANOVA, Duncan post-hoc test ($P<0.05$) and the mean standard deviation (SD) were conducted. Data generated from sensory evaluation were presented as mean ± standard deviation and were used t-test to compare the treatment mean scores of significantly different ($P<0.05$).

Results and Discussion

Proximate Composition

The changes in moisture, protein, lipid, and ash content of catfish (*Clarias batrachus*) fillets after cooking processes (convection oven cooking and superheated steam cooking) are given in **Table 1**. The proximate composition of raw catfish fillets is similar to that reported by Chukwu and Shaba (2009) for catfish (*Clarias gariepinus*). The proximate composition of the cooked fillets compared to raw fillet were significantly affected ($P<0.05$) by all the cooking methods. The moisture content of all cooked samples decreased significantly ($P<0.05$) after cooking; whereas the protein, lipid, and ash wet basis percentages increased significantly ($P<0.05$) after the cooking. These trends are in accordance with the findings of Gokoglu et al. (2004); Nurhan (2007); Weber et al. (2008); Chukwu and Shaba (2009); Ersoy and Özeren (2009); Şengör et al. (2013). The increase in protein, lipid, and ash content in cooked fillets is explained by the water loss occurring during cooking. However, when the data were expressed on a dry basis percentage, the protein content is reduced after cooking process. This indicates that the decrease in protein content of cooked catfish fillets is also related to protein denaturation during the cooking process, thus decreasing the solubility of the protein molecules. Raw catfish fillet was found to have high fat content (16.92%), which was similar to the high fat content (>8%) reported by Zzaman et al. (2014). The moisture content of raw catfish fillet was 61.38%, higher than the cooked samples. Generally, the moisture content of catfish fillet was found to be inversely related to the total extractable lipid content. This is in agreement with the findings of other researchers (Larsen et al., 2010). It was also observed that lipids were more easily extracted from cooked samples compared to raw samples. During the cooking process, bound lipids were released as free lipids, making them easier to extract; whereas lipids were bound in the tissue matrix of raw catfish, therefore making them harder to extract.

The difference in ash, moisture and lipid contents between different cooking processes were significant ($P<0.05$) for all cooked samples; however the difference in protein composition between different cooking methods was not significant ($P>0.05$). Ash levels of the raw fillet were within the published literature reviews (Puwastien et al., 1999; Gokoglu et al., 2004; Nurhan, 2007; Weber et al., 2008). The ash level in superheated steam oven cooked fillet was significantly lower ($P<0.05$) than that found in convection oven cooked fillet. The superheated steam oven cooked fillet had the lowest moisture loss compared to convection oven cooking. These results indicated that the moisture content in raw catfish fillet is retained better upon superheated steam cooking. This finding indicated superheated steam cooking can reduce significantly fat content due to the quick temperature rise and outflow of fat.

Changes in Fatty Acid Profile

The fatty acids profile of catfish (*Clarias batrachus*) fillets is presented in Table 2. Twenty-one fatty acids (from C12:0 to C24:1) were determined from raw and cooked catfish fillets. The fatty acids pattern in raw catfish followed the order: SFA>MUFA>PUFA. This trend was also apparent in the cooked catfish fillets. The most abundant fatty acids found in raw catfish fillets were palmitic acid (C16:0, 24.51% of total fatty acids), oleic acid (C18:1 n-9c, 29.57% of total fatty acids), and linoleic acid (C18:2 n-6c, 19.07% of total fatty acids). These findings are in agreement with those obtained by Weber et al. (2008) for silver catfish. Raw catfish fillets also showed considerable amounts of stearic acid (C18:0), palmitoleic acid (C16:1 n-7c), and arachidonic acid (C20:4 n-6). However, raw catfish had low levels of the n-3 PUFA linolenic acid (C18:3 n-3), EPA (C20:5 n-3), DPA (C22:5 n-3), and DHA

Table 1. Proximate composition of raw and cooked catfish fillets

Parameters	Raw	Conventional oven	Superheated steam oven
Moisture (%)	61.38 ± 0.07^{a}	49.87 ± 0.61^{c}	53.16 ± 0.54^{b}
Protein (%)	16.75 ± 0.03^{b}	19.61 ± 0.25^{a}	19.26 ± 0.12^{a}
Lipid (%)	16.92 ± 0.21^{c}	25.75 ± 0.64^{a}	21.21 ± 0.59^{b}
Ash (%)	1.01 ± 0.02^{c}	1.43 ± 0.06^{a}	1.22 ± 0.002^{b}

-Values are expressed as mean ± standard deviation (n= 3) on dry and wet basis.

[a-c] Means within the same row with different superscripts are significantly different between the raw and cooked samples ($P< 0.05$).

Table 2. Fatty acid profile (% of total fatty acids) of raw and cooked catfish fillets

Fatty Acid	Raw	Convection Oven	Superheated Steam
C12:0	0.21± 0.008	0.27± 0.03	0.32± 0.03
C14:0	0.55± 0.03	0.73± 0.07	0.60± 0.10
C16:0	24.51± 0.19	24.36± 0.03	24.51± 0.10
C17:0	0.25± 0.04	0.28± 0.02	0.32± 0.003
C18:0	8.26± 0.09	9.17± 0.41	8.26± 0.52
C20:0	0.34± 0.04	0.25± 0.01	0.30± 0.003
C22:0	0.38± 0.04	0.37± 0.005	0.35± 0.007
C24:0	0.27± 0.03	0.27± 0.01	0.29± 0.01
ΣSFA	34.77± 0.09	35.70± 0.35	35.11± 0.48
C16:1 n-7c	2.76± 0.30	2.56± 0.09	2.74± 0.14
C18:1 n-9c	29.57± 0.90	30.82± 0.10	29.82± 0.21
C20:1 n-9	0.49± 0.08^{a}	0.46± 0.01^{ab}	0.35± 0.004^{b}
C22:1 n-9	0.50± 0.08	0.46± 0.01	0.53± 0.02
C24:1 n-9	0.36± 0.05	0.33± 0.006	0.39± 0.005
ΣMUFA	33.69± 1.41	34.63± 0.02	33.83± 0.32
C18:2 n-6c	19.07± 2.03	19.61± 0.68	20.28± 0.90
C18:3 n-6	1.44± 0.28	1.32± 0.15	1.34± 0.24
C18:3 n-3	0.65± 0.08	0.67± 0.06	0.72± 0.05
C20:3 n-6	2.00± 0.23	1.86± 0.27	2.15± 0.15
C20:4 n-6	5.59± 0.09	4.55± 0.37	4.66± 0.51
C20:5 n-3 (EPA)	0.36± 0.004^{a}	0.16± 0.004^{c}	0.26 ± 0.02^{b}
C22:5 n-3 (DPA)	0.82± 0.004^{a}	0.75± 0.03^{b}	0.77 ± 0.03^{ab}
C22:6 n-3 (DHA)	1.62± 0.05^{a}	0.75± 0.03^{c}	0.90 ± 0.03^{b}
ΣPUFA	31.54± 1.47	29.67± 0.23	31.07± 0.02
Σn-3	3.45± 0.13^{a}	2.33± 0.12^{c}	2.64± 0.03^{b}
Σn-6	28.09± 1.61	27.34± 0.11	28.43± 0.006
n-3/n-6	0.12± 0.01^{a}	0.09± 0.004^{b}	0.09± 0.001^{b}
EPA+DHA	1.98± 0.05^{a}	0.91 ± 0.03^{c}	1.16± 0.05^{b}
PUFA/SFA	0.91± 0.04^{a}	0.83 ± 0.01^{b}	0.88± 0.009^{ab}

$^{a-c}$ Means within the same row with different superscripts indicate significant differences
Values without superscripts are not significantly different (P>0.05)

(C22:6 n-3). These results were similar to those found by Zzaman et al. (2014) in Clarias catfish. There were no significant differences in the total amounts of SFA, MUFA, and PUFA between raw catfish fillets and cooked catfish fillets. This reported finding also further supports the study finding that lipid content increased after cooking was due to water loss. Fatty acids are affected by different heat treatments. The saturated fatty acids (SFA) were dominated by palmitic acid (C16:0) and stearic acid (C18:0). The difference in SFA profile between raw catfish fillet and cooked catfish fillets were not significant. Many studies on different species of fish also found no significant decrease in SFA during heat treatment (Weber et al., 2008; Larsen et al., 2010). This results indicated SFA are fairly heat stable in temperature encountered during cooking methods. Changes in monounsaturated fatty acids (MUFA) were not significantly different between raw catfish fillet and cooked catfish fillets. This was also observed by Larsen et al. (2010) in cooked King Salmon. Oleic acid (C18:1 n-9c) was the predominant fatty acid in raw catfish fillets, within the class of MUFA. These findings are in accordance with those obtained by Weber et al. (2008) for silver catfish.

The polyunsaturated fatty acids (PUFA) are dominated by linoleic acid (C18:2 n-6c) as the most abundant n-6 fatty acid and DHA (C22:6 n-3) as the most abundant n-3 fatty acids. Raw and cooked catfish fillets showed no significant differences in total PUFA. However, LCPUFA such as EPA and DHA showed a significant decrease (P<0.05) after convection oven and superheated steam oven cooking. The rationale for this may be due to the higher degree of unsaturation in LCPUFA, making them the most unstable fatty acids and more vulnerable to oxidation. EPA and DHA, which is the most important n-3 PUFAs in fatty fish, were significantly higher (P< 0.05) in superheated steam oven cooked fillet compared to convection oven cooked fillet. In the current study, superheated steam oven cooked fillet has been shown to reduce the susceptibility of EPA and DHA towards oxidation. Likewise, DPA was the lowest in convection oven cooked catfish fillets and no significant loss was observed in the superheated steam oven cooked catfish fillets. The stability of superheated steam cooking towards lipid oxidation is in agreement with the findings of Abdulhameed et al. (2014). Oxygen is purged as the oven's cavity is filled with superheated steam, thus providing a low oxygen cooking condition. There have been several studies showing n-3 PUFAs intake can decrease the risk of coronary heart disease (Siscovick, 1995; Kris-Etherton et al., 2002) suppress the growth of human breast cancer cells, useful in the management of inflammatory and autoimmune diseases (Simopoulos,

2002) and decreases the risk of poor visual and neural development in infants and children (Innis, 2008). The total n-3 fatty acids were taken into account the LCPUFA and minor n-3 PUFA linolenic acid (C18:3 n-3). There were significant differences ($P<0.05$) between the raw, convection oven cooked, and superheated steam oven cooked catfish fillets. The total n-3 fatty acids in superheated steam oven cooked sample was significantly higher ($P<0.05$) than that of convention oven cooked fillets. Therefore, superheated steam oven cooking is recommended for the preparation of catfish because it resulted in better retention of n-3 fatty acids compared to convection oven cooking.

The n-3/n-6 ratio in cooked fillets was significantly lower ($P<0.05$) than that of the raw fillet. The difference in n-3/n-6 ratio between a convection oven and superheated steam oven cooking were not significant. The PUFA/SFA ratio was significantly reduced ($P<0.05$) after convection oven cooking. There was no significant decrease in PUFA/SFA ratio in superheated steam oven cooked fillet when compared with raw fillet. In this study, the PUFA/SFA ratio in raw catfish fillet was 0.91; convection oven cooked fillet was 0.83 and a ratio of 0.88 was determined in the superheated steam fillet. Although results revealed that all cooking methods do not induce a reduction of PUFA/SFA ratio below 0.45, but superheated steam oven cooked fillet is still more preferred without significant reduction of PUFA/SFA ratio when compared with raw fillet (Siscovick, 1995; Kris-Etherton et al., 2002).

Amino Acid Composition

The method used in this research only allowed analysis of 17 amino acids, including essential amino acids (histidine, threonine, valine, methionine, lysine, isoleucine, leucine and phenylalanine) and non-essential amino acids (aspartic acid, serine, glutamic acid, glycine, arginine, alanine, proline, cysteine and tyrosine). During the acid hydrolysis, glutamine and asparagines were hydrolysed to glutamic acid and aspartic acid, respectively, hence the glutamic acid detected includes the total content of glutamine and glutamic acid, and the same applies to aspartic acid. Tryptophan was not measured in this research because it is degraded by acid hydrolysis.

Amino acid composition of raw catfish fillets was similar to the composition reported for other fish species (Ismail et al., 2004; Maruf et al., 2007). The amino acid composition of raw and cooked catfish are presented in Table 3 and Table 4 as g amino acid/ 100 g sample. The major components of amino acid in

Table 3. Essential amino acid composition of raw and cooked catfish fillets (% amino acid or g amino acid/ 100 g dried sample)

Amino acids	Raw	Conventional oven	Superheated steam
Histidine	0.796± 0.05	0.867± 0.12	0.900± 0.17
Threonine	1.708± 0.08	1.953± 0.36	2.041± 0.49
Valine	1.719± 0.05	1.968± 0.23	1.602± 0.39
Methionine	1.205± 0.08	1.315± 0.20	1.286± 0.26
Lysine	2.613 ± 0.09[ab]	3.032 ± 0.33[a]	1.981 ± 0.43[b]
Isoleucine	1.601± 0.05	1.858± 0.21	1.526± 0.38
Leucine	2.631± 0.09	3.062± 0.36	2.503± 0.62
Phenylalanine	1.545± 0.06	1.731± 0.26	1.854± 0.41
Total	13.818± 0.63	15.786± 0.76	13.693± 0.49

Values are expressed as mean ± standard deviation (n= 3).
[a-b] Means within the same row with different superscripts indicate significant differences ($P< 0.05$).
Values without superscripts are not significantly different ($P>0.05$)

Table 4. Non-essential amino acid composition of raw and cooked catfish fillets (% amino acid or g amino acid/ 100 g dried sample)

Aspartic acid	2.386± 0.13	2.871	± 0.43	1.943	± 0.62
Serine	1.491± 0.04	1.589	± 0.22	1.436	± 0.32
Glutamic acid	4.024± 0.15	4.695	± 0.59	3.260	± 0.87
Glycine	2.747± 0.31[a]		2.118 ± 0.16[ab]	1.746 ± 0.36[b]	
Arginine	2.713± 0.09	2.734	± 0.39	2.712	± 0.57
Alanine	1.823± 0.03	1.864	± 0.23	1.373	± 0.32
Proline	1.524± 0.07	1.358	± 0.19	1.094	± 0.29
Cysteine	0.230± 0.03	0.270	± 0.03	0.264	± 0.04
Tyrosine	0.992± 0.37	1.317	± 0.41	1.541	± 0.36
Total	17.930± 1.12	18.816	± 1.25	15.369	± 0.88

Values are expressed as mean ± standard deviation (n= 3).
[a-b] Means within the same row with different superscripts indicate significant differences ($P< 0.05$).
Values without superscripts are not significantly different ($P>0.05$)

raw catfish were glutamic acid, which was in agreement with Tenyang et al. (2014), followed by glycine, arginine, leucine, lysine and aspartic acid.

The results indicated no significant effect of a convection oven and superheated steam oven cooking on the amino acid content, except for glycine. Glycine content was significantly reduced ($P<0.05$) after superheated steam cooking. A study on the amino acid contents of raw, boiled and fried fish was carried out by Ismail et al. (2004). They found that these cooking practices did not significantly increase nor decrease the individual amino acid contents. This similar finding indicated that heat treatment did not significantly alter the amino acid composition. The total and individual amino acid contents of raw and cooked catfish in this study were higher than those reported by Tenyang et al. (2014) and nutrient database provided by United States Department of Agriculture, Agricultural Research Service. The rationale for this may be due to different species of catfish, growing environment and fish diets (Gómez-Requeni et al., 2004). This composition is also evidence of the fact that the catfish studied is a good source of amino acids. On the other hand, it is noted that the essential amino acid comprised more than 40% of the total amino acid content of raw or cooked catfish (Table 3).

With regards the uses of amino acid, non-essential amino acids such as arginine and glycine have shown in the enhancement of wound healing after trauma. Moreover, arginine can improve the insulin sensitivity and secretion, thereby it has beneficial therapeutic effect in patients with type 2 diabetes (Menge et al., 2010). Some studies also reported amino acid can improve immune function and gastrointestinal health, this is specifically important for active lifestyle people like athletes. The essential amino acids, especially the branched-chain amino acids (BCAAs), isoleucine, leucine, and valine, are unique in that they are principally metabolized extra-hepatically in the skeletal muscle, and it led to the improvement of nitrogen retention as well as protein synthesis for liver failure patients (Charlton, 2006). It was found that both the essential and non-essential amino acid in catfish treated by either oven cooking or superheated steam oven cooking matched the amino acids requirements recommended by Holecek (2010).

Sensory Evaluation

Sensory assessment is the most accepted way of measuring fish quality. It is quick, easy, and gives direct quality information. Sensory features of the samples are clearly perceptible to the consumer and are necessary for customer satisfaction. Sensory quality of a food product relates directly to product quality as it is important aspects of the total quality perceived by human sense of sight, taste, smell and touch. Sensory evaluation for this study is conducted to know the acceptance of consumer toward superheated steam cooking method. The result of the sensory analysis is presented in Table 5. From the results, the taste, color, texture and overall acceptability were significantly ($P<0.05$) higher preference in superheated steam roasted as compared to conventional samples. The overall acceptability of the superheated steam sample was higher significantly (5.8 ± 0.20) than samples cooked by using conventional method (4.7 ± 0.35)

Prachayawarakorn et al. (2002) showed that textural properties of shrimp were improved and presented a lower degree of shrinkage using superheated steam treatment as compared to conventional hot air oven. The overall acceptability of panellists was higher in the sample of superheated steam white shrimp (6.80 ± 1.58) than conventional treated sample (5.30 ± 1.95) at the same temperature and time. Latip et al. (2013) stated that the sensory quality of fish depends on the not only the composition of the fish but also microbial load history and cultivated environment of the fishes. Oxidative reactions do not occur due to lack of oxygen around the product that improved product quality during superheated steam processing. It was also reported that food products cooked partially and brought beneficial change in texture, color and overall acceptability using by superheated steam (Pronyk et al., 2004; Head et al., 2011).

Conclusions

Both convection oven cooking and superheated steam oven cooking have little influence on the total SFA, MUFA, and PUFA content of catfish fillets. Changes in LCPUFA, such as EPA and DHA were more prominent in the cooked fillets. EPA, DHA, and total n-3 fatty acids were significantly higher ($P< 0.05$) in superheated steam oven cooked fillets than convection oven cooked fillets. Additionally, there was no significant decrease in PUFA/SFA ratio in superheated steam oven cooked fillet when compared with raw fillet. Superheated steam oven cooking is overall healthier than convection oven cooking

Table 5. Sensory evaluation of cooked catfish fillets using superheated steam and conventional oven

Treatment	Taste	Color	Texture	Overall acceptability
Superheated Steam	5.65 ± 0.17^{a}	5.93 ± 0.31^{a}	5.4 ± 0.20^{a}	5.8 ± 0.20^{a}
Conventional	4.53 ± 0.12^{b}	4.73 ± 0.21^{b}	4.3 ± 0.53^{b}	4.7 ± 0.35^{b}

[a–c] Means within the same column with different letters are significantly different ($P<0.05$)

[-] Means value ± standard deviation of three replications

because catfish cooked by this method was generally higher in the amounts of EPA, DHA, and total n-3 fatty acids. In summary, it can be concluded that superheated steam oven cooking is more appropriate for fish cooking as far as healthy eating is concerned. The content of fat soluble vitamins should be studied to obtain more valid data that can be used to evaluate the relationship between antioxidant properties of alpha-tocopherol (vitamin E) and the oxidative stability of PUFA. Liquid-holding capacity and texture of cooked catfish fillets also should be studied that can be used to evaluate the liquid losses during and after cooking and the contribution of water content to its overall flesh quality.

Acknowledgement

Great appreciation goes to the Fellowship Scheme of the Institute of Postgraduate Studies, Universiti Sains Malaysia and Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia.

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