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# Effect of Different Cooking Methods on Total Fat and Fatty Acid Composition of Cape Snoek (*Thyrsites atun*)

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**Abstract** Cape snoek (*Thyrsites atun*) is a valuable commercial marine fish species and an important source of protein and long chain omega-3 polyunsaturated fatty acids (LCn-3PUFA), especially among the lower-income population of South Africa. The influence of microwave cooking, oven baking and steaming on total fat and fatty acid composition of Cape snoek was investigated. All cooking methods resulted in an increase of the total fat content when compared to the raw (3.88% ± 0.73) snoek samples. Microwave cooking and steaming resulted in the total fat content of samples to increase to 5.09% ± 0.69, and 5.61% ± 0.97, respectively. Oven baking resulted in the highest increase in total fat (6.66% ± 0.41). Although steaming and oven baking resulted in a marginal reduction in ecosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and alpha-linolenic acid (ALA), respectively, none of the cooking methods had any significant ($P > 0.05$) effect on the EPA, DHA, and ALA concentrations. None of the cooking methods had any significant effect on the n-6:n-3 ratio (0.12 ± 0.01 for raw snoek samples). There was no significant change in the saturated fatty acid (SFA) concentration between raw and any of the samples from the three cooking methods. Only microwave cooking resulted in a significant increase in the monounsaturated fatty acid (MUFA) concentration, while steaming significantly reduced the PUFA concentration and the PUFA/SFA ratio. Microwave cooking, followed by oven baking, seemed to be the better of the three cooking methods for preservation of PUFA.

***Keywords:*** *ecosapentaenoic acid, microwave cooking, oven baking, omega-3 fatty acids, total fat*

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## 1. Introduction

Fish is well known for its significant contribution to dietary intake of long chain omega-3 (n-3) polyunsaturated fatty acids (LCn-3PUFA), such as ecosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3). The nutritional and health benefits of especially EPA and DHA within fish muscle has been well documented [1,2,3,4]. Dietary recommendations for the prevention of dietary deficiency symptoms have been made for LCn-3PUFA; including alpha-linolenic (ALA, C18:3n-3), EPA and DHA, to achieve nutrient adequacy and to prevent and treat certain diseases. These recommendations are based on a large number of evidence from epidemiologic and controlled clinical studies [5-11]. For health benefits, especially protection against cardiovascular disease (CVD), it is recommended to consume between 0.5 and 1.8 g/day of EPA and DHA combined, and 1.5 to 3 g/day of ALA [5,10] and for the older population at high cardiovascular risk to consume at least 500 mg/day of LCn-3PUFA for reduction in sudden cardiac death and CVD. The American Heart Association dietary guidelines recommend consumption of at least two servings of fatty fish per week as part of a healthy diet.

The health benefits associated with the consumption of LCn-3PUFA have been demonstrative in the areas of infant development [1], CVD [5,9,10,12,13], platelet aggregation [14], hypertension, cognitive health [15], cancer, dementia, Alzheimer's disease, depression [7,8,16], and inflammation [3,4,17,18].

Efficacy of omega-3 PUFA is influenced by the PUFA type; food matrix, processing and storage [13]. PUFA content in raw fish tissue may not provide explicit information on the nutritive value of the marine species after cooking. Heat processes, such as boiling, microwave cooking and oven baking, are applied to marine food to enhance its flavour and taste, inactivation of microorganisms, and to increase the shelf life thereof. Various cooking methods can give rise to major changes in proximate and fatty acid composition of fish and fishery products [19,20,21]. Boiling of fish prior to drying leads to considerable losses of vitamins and amino acids in the cooking liquid [22]. The omga-3 fatty acids ALA and EPA are particularly susceptible to oxidation during heating processing [23,24]. The oxidation of fatty acids during heat processing are often related to the cooking time and temperature [25].

Snoek (*Thyrsites atun*) is a pelagic predator occurring along southern Africa, Australia, New Zealand, the east and west coasts of southern South America, Tristan da Cunha, and the islands of Amsterdam and St. Paul [26]. South African snoek, also known as Cape snoek, occurs from northern Angola to Algoa Bay on the east coast of South Africa, but are most abundant between the Cunene River and Cape Agulhas along the western cost of South Africa, i.e. in the Benguela ecosystem [26] and has a long and widespread history in Cape Town and the Western Cape Peninsula area of South Africa [27,28]. Cape snoek is a very popular eating fish and the third most available marine fish species in supermarkets throughout South Africa [29]. This marine fish species inhabits the coastal waters of the temperate Southern Hemisphere, occurring off Southern Africa, Australia, New Zealand, the east and South America [28]. Raw Cape snoek naturally contains ALA (0.70 ± 0.09%), EPA (9.11 ± 2.06%) and DHA (19.70 ± 3.25%) fatty acids [30]. Only a few studies have examined the proximate and fatty acid [30,31] and mineral [32] composition of some South African marine fish species for human consumption.

Smoked and dried snoek is very popular in the Western Cape. Air-dried snoek is especially popular among the poor and lower-income house-holds as it is used to make a stew with onions and potatoes [27]. The higher-income consumer typically purchases fresh or frozen flecked snoek for the purpose of barbequing. Amongst the different methods of preparing Cape snoek, boiling, oven baking, barbequing, and smoking are the more popular cooking methods.

Several researchers [33-39] have investigated the effects of different cooking methods on the proximate and fatty acid composition of different freshwater and marine fish species. However, there is no documentation discussing the effects of different cooking methods on the fat and fatty acid composition of South African Cape snoek (*Thyrsites atun*). The aim of this study was to determine the total fat and fatty acid composition of Cape snoek as influenced by three different cooking methods: microwave cooking, oven baking, and steaming, with the view of making nutritional data available.

# 2. Materials and Methods

## 2.1. Samples and Sample Preparations

Twenty-four eviscerated, raw, fresh, flecked Cape snoek (*Thyrsites atun*; average weight: 1.76 ± 0.28 kg) were purchased from a local fish supplier in Bellville, Western Cape Peninsula, South Africa, and transported to the laboratories of Cape Peninsula University of Technology, Bellville campus. The snoek were transported in cooler boxed with ice. Six snoek were randomly assigned to each of the four treatments, which were; raw (no cooking as the control), microwave cooking, oven baking, and steaming. Sample portions of 250 g contained dorsal and ventral muscle from both the right and left fillets, cut from the abdominal area of each flecked snoek. The portions were skinned and deboned before cooking. After cooking, all samples were allowed to cool before individually homogenised with the use of a laboratory blender (Warning commercial, Warning lab, USA). The homogenised samples were vacuum packed and stored at -80°C until total fat and fatty acids analyses.

## 2.2. Cooking Methods

### 2.2.1. Microwave Cooking

The snoek portions were individually cooked in a domestic microwave oven (Defy, 230 V~50 Hz) at 1200 Watts (2450 MHz) for 5 minutes. After cooking, the core temperature was measured, using a thermocouple. The average core temperature after cooking was 92 ± 4°C.

### 2.2.2. Oven Baking

A domestic defy oven of 230 V~50 Hz (Model DSS427) was used for baking the snoek portions. The oven was preheated to 250°C for 30 minutes. The portions were individually wrapped in tin foil and baked for 20 minutes at 250 °C.

### 2.2.3. Steaming

The snoek portions were individually steamed in a domestic steam oven of 230 V~50 Hz (CCB0170) at 98°C for 12 minutes. The portions were individually placed on trays within the steam oven. Portion were not wrapped in tin foil.

## 2.3. Total Fat Analyses

Before analyses, samples were thawed over night at refrigerator temperatures (4-6°C) and conditioned at room temperature (21-22°C) for 10 min before analysis. All analyses were done in triplicate. Total fat was determined using the chloroform/methanol (1:2 v/v) extraction method [40]. All values were calculated as percentages (%).

## 2.4. Fatty Acid Analyses

Lipids were extracted from 2 g homogenised snoek samples with the use of a chloroform/methanol (1:2 v/v) solution according to a modified method as described by Folch *et al*. [41]. All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (WiggenHauser, D-500 Homogenizer) was used to homogenise the samples with the extraction solvent. Heptadecanoic acid (C17:0) was used as an internal standard (Sigma–Aldrich Inc., 3050 Spruce Street, St. Louis, MO 63103, USA) to quantify the individual fatty acids. A sub-sample of the extracted lipids was transmethylated for 2 hours at 70°C using a methanol/sulphuric acid (19:1 v/v) solution as transmethylating agent. After cooling to room temperature, the resulting fatty acid methyl esters (FAMEs) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. Analysis was done with the use of a Thermo Focus gas chromatograph (GC) equipped with a flame ionized detector using a BPX70 capillary column (60 m x 0.25 mm internal diameter, 0.25 µm film, SGE, Australia). The FAME mix was carefully prepared by weight. Each ampule contained 10 $mg \cdot ml^{-1}$ of the FAME reference

standard mixed in methylene chloride. Gas flow rates were 25 ml·min$^{-1}$ for hydrogen and 2–4 ml·min$^{-1}$ for the hydrogen carrier gas were used. The temperature programming was linear at 3.4°C·min$^{-1}$, with an initial temperature of 140°C, a final temperature of 240°C, an injector temperature of 225°C and a detector temperature of 300°C. The FAMEs were identified by comparing the retention times to those of a standard FAME mixture (SupelcoTM 37 Component FAME Mix, 10 mg·ml$^{-1}$ in CH2Cl2, Catalogue Number 47885-U, Supelco, North Harrison Road, Bellefonte, PA 16823-0048, USA). Fatty acid concentrations are presented at percentages (%).

### 2.5. Statistical Analyses

All generated data was statistically analysed using SAS statistical software, version 9.4 (SAS institute Inc., Cary, NC, USA). The data was subjected to one-way analysis of variance (ANOVA) and the student t-test least significant difference (LSD). Student t-test least significant differences were calculated at the 5% confidence level to compare means for significant effects and differences.

## 3. Results and Discussion

The total fat content of raw, microwave cooked, steamed, and oven baked Cape snoek samples are summarised in Table 1. The total fat content for the raw samples was similar than what was reported by Henning and Hoffman [30] for Cape snoek. However, microwave cooking, steaming and oven baking resulted in a larger increase in total fat compared to cooking in water at 80ºC, as was done by Henning and Hoffman [30]. In the present study, the raw samples had the lowest (3.88% ± 0.73) fat content while all three cooking methods resulted in a significant ($P < 0.05$) increase in the total fat content. The increase in total fat is due to loss of water during the cooking processes. Oven baked samples had the highest (6.66% ± 0.41) fat content compared to microwaved and steamed samples. The reason for this could be due to the absorption of fat by the fish muscle during the baking process since the fish was baked in a baking tray without the fat dripping away. In a study conducted by Gokoglu *et al*. [35], where rainbow trout was subjected to microware cooking (13 minutes at 2450 MHz) and oven baking (30 minutes at 180 ºC), respectively, the oven baking also resulted in a higher fat content, however, not significantly different from the microwave cooking.

**Table 1. Total fat content (%) of raw, microwaved, oven baked and steamed Cape snoek samples, respectively**

| | Raw | Microwave | Oven baked | Steamed |
|---|---|---|---|---|
| Total fat (%) | 3.88±0.73$^{c}$ | 5.09±0.69$^{b}$ | 6.66±0.41$^{a}$ | 5.61±0.97$^{b}$ |

$^{abc}$ Different superscripts within a column differs significantly at $P < 0.05$.

The profile of the most important fatty acids of raw and cooked Cape snoek are summarised in Table 2. Palmitic acid (C16:0), followed by stearic (C18:0) and myristic acid (C14:0), were the most abundant of the SFA analysed. These findings are in agreement with Pethybridge *et al*. [42], whom documented that C16:0 and C18:0 are the two most dominant SFA present in 12 fish species caught off east Tasmania. These authors also documented a high C16:0 (13.6% ± 1.2) value for raw *Thyrsites atun* muscle (off south-eastern Australia), however, lower than what was found in the current study (24.68% ± 0.22). The values for C14:0 (4.3% ± 0.6) and C18:0 (4.1% ± 0.4) documented by Pethybridge *et al*. [42] for raw *Thyrsites atun* muscle were slightly different, but in a similar range, compared to what was found in this current study (C14:0; 3.60% ± 0.53 and C18:0; 5.82% ± 0.43). These differences in SFA between South African and Australian *Thyrsites atun* may be contributed to several environmental factors, such as locality, season, diet, and sexual maturity of the fish samples analysed [43,44,45].

For this study, there was no significant ($P > 0.05$) change in the concentrations of stearic and palmitic acids between the raw and any samples from the three cooking methods. For myristic acid, steaming had a significant ($P < 0.05$) increase in the concentration of this fatty acid, while microwave cooking and oven baking had no significant effects. Microwave cooking resulted in a marginal reduction of the total SFA, while oven baking and steaming resulted in an increase in the total SFA. These changes in the total SFA were, however not significant ($P > 0.05$) for any of the three cooking methods. The higher concentration of total SFA concentration for oven baked (35.58% ± 0.60) and steamed (35.79% ± 0.94) samples were, however, significant ($P < 0.05$), when compared to microwave cooked samples (34.32% ± 0.67). This may be due to a higher moisture loss during the steaming and oven baking processes, as both these heating methods cooked the samples for a longer time (12 minutes of steaming and 20 minutes of oven baking) compared to cooking in the microwave for 5 minutes.

In terms of the MUFA, palmitoleic acid (C16:1) and oleic acid (C18:1n-9c) were present in higher concentrations compared to the other MUFA analysed. These findings are similar to a study by Henning and Hoffman [30], which indicated that raw Cape snoek is high in palmitic (24.65% ± 1.43) and oleic acid (18.21% ± 2.64). Although all three cooking methods resulted in a marginal increase in palmitoleic acid and oleic acid, the increase was not significant ($P > 0.05$). In addition, the concentrations of palmitoleic acid and oleic acid were not significantly different among the three cooking methods. Microwave cooking resulted in a significant increase in C20:1 (eicosenoic acid) and C24:1 (nervonic acid) and in the overall total MUFA.

In the raw Cape snoek samples, the most abundant LCn-3PUFA was DHA (18.98% ± 1.91), followed by docosapentaenoic acid (DPA; C22:5n-3), and ALA (4.01% ± 1.11). EPA was present at low levels of 0.11% ± 0.02. Henning and Hoffman [30] also documented a high content of DHA (19.70% ± 3.25) for raw Cape snoek, however, in contrast, their study showed a higher EPA (9.11% ± 2.06) and a lower ALA (0.70% ± 0.09) concentration. Pethybridge *et al*. [42] similarly documented a high content of DHA (16.9% ± 2.6) for raw Australian *T. atun* (also known as barracouta), followed by EPA (4.1% ± 0.5) and DPA (2.0% ± 0.3). Differences in fatty acid concentrations among independent studies using the same fish species, may be attributed to inter-muscular variations within a fish species and sub-sampling of

specific portions [32]. In addition, it is well documented that the proximate composition and fatty acid profile of fish (muscle as well as other organs, such as the gonads, ovaries, and liver) varies depending on seasonal changes, migratory behaviour, sexual maturity, and feeding and spawning cycles of the fish [43,44,45].

In terms of the LCn-3PUFA, oven baking and steaming resulted in a marginal reduction of DHA and ALA, however, the change was not significant ($P > 0.05$). None of the three cooking methods had a significant ($P > 0.05$) change in the concentrations of EPA, DHA, ALA and docosapentaenoic acid (C22:5n-3), however, microwave cooking resulted in the smallest reduction in EPA, DHA and ALA compared to oven baking and steaming.

**Table 2. Mean percentage (% of total fatty acids) values for saturated fatty acid (SFA), monounsaturated fatty acid, and polyunsaturated fatty acid composition and n-6:n-3 and PUFA/SFA ratios of raw and microwaved, oven baked and steamed Cape snoek samples**

| Fatty acids | Raw | Microwave | Oven baked | **Steamed** |
|---|---|---|---|---|
| Saturated fatty acids (SFA) expressed as % | | | | |
| C14:0 | 3.60±0.53$^{bc}$ | 3.18±1.02$^{c}$ | 4.29±0.87$^{ab}$ | 4.56±0.32$^{a}$ |
| C20:0 | 0.25±0.035$^{a}$ | 0.24±0.05$^{a}$ | 0.25±0.06$^{a}$ | 0.25±0.06$^{a}$ |
| C15:0 | 0.41±0.04$^{a}$ | 0.43±0.05$^{a}$ | 0.42±0.04$^{a}$ | 0.42±0.06$^{a}$ |
| C18:0 | 5.82±0.43$^{a}$ | 5.17±0.71$^{a}$ | 5.42±0.27$^{a}$ | 5.69±0.56$^{a}$ |
| C22:0 | 0.31±0.03$^{a}$ | 0.31±0.03$^{a}$ | 0.28±0.04$^{a}$ | 0.30±0.03$^{a}$ |
| C16:0 | 24.68±0.22$^{a}$ | 24.36±0.67$^{a}$ | 25.01±1.04$^{a}$ | 24.48±0.77$^{a}$ |
| C21:0 | 0.094±0.02$^{a}$ | 0.12±0.02$^{a}$ | 0.098±0.02$^{a}$ | 0.094±0.01$^{a}$ |
| Total SFA | 35.17±0.50$^{ab}$ | 34.32±0.67$^{b}$ | 35.58±0.60$^{a}$ | 35.79±0.94$^{a}$ |
| Monounsaturated fatty acids (MUFA) expressed as % | | | | |
| C16:1 | 6.56±0.33$^{a}$ | 6.61±1.00$^{a}$ | 6.83±0.94$^{a}$ | 7.34±0.43$^{a}$ |
| C22:1n-9 | 0.13±0.03$^{a}$ | 0.13±0.01$^{ab}$ | 0.11±0.02$^{ab}$ | 0.10±0.02$^{b}$ |
| C14:1 | 0.21±0.02$^{a}$ | 0.19±0.04$^{a}$ | 0.20±0.03$^{a}$ | 0.21±0.03$^{a}$ |
| C18:1n-9c | 17.84±2.15$^{a}$ | 18.32±3.07$^{a}$ | 19.39±3.07$^{a}$ | 18.65±3.07$^{a}$ |
| C18:1n-9t | 0.16±0.02$^{a}$ | 0.17±0.04$^{a}$ | 0.17±0.04$^{a}$ | 0.16±0.02$^{a}$ |
| C20:1 | 0.10±0.007$^{b}$ | 0.12±0.014$^{a}$ | 0.11±0.02$^{ab}$ | 0.10±0.015$^{b}$ |
| C24:1 | 1.02±0.09$^{b}$ | 1.37±0.25$^{a}$ | 1.01±0.14$^{b}$ | 1.004±0.18$^{b}$ |
| Total MUFA | 25.85±2.08$^{b}$ | 27.77±1.70$^{a}$ | 26.66±0.94$^{ab}$ | 27.40±1.03$^{ab}$ |
| Polyunsaturated fatty acids (PUFA) expressed as % | | | | |
| C20:3n-6 | 0.90±0.10$^{a}$ | 0.94±0.10$^{a}$ | 0.92±0.10$^{a}$ | 6.87± 0.06$^{a}$ |
| C20:5n-3 (EPA) | 0.11±0.02$^{a}$ | 0.11±0.01$^{a}$ | 0.11±0.007$^{a}$ | 0.10±0.01$^{a}$ |
| C22:6n-3 (DHA) | 18.98±1.91$^{a}$ | 18.25±1.33$^{a}$ | 17.00±2.35$^{a}$ | 17.31±0.91$^{a}$ |
| C18:3n-6 | 0.48±0.04$^{a}$ | 0.46±0.01$^{a}$ | 0.54±0.04$^{a}$ | 0.52±0.03$^{a}$ |
| C18:2n-6c | 1.40±0.23$^{a}$ | 1.22±0.19$^{a}$ | 1.24±0.05$^{a}$ | 1.20±0.18$^{a}$ |
| C20:2 | 0.22±0.04$^{a}$ | 0.22±0.02$^{a}$ | 0.17±0.03$^{b}$ | 0.16±0.001$^{b}$ |
| C20:3n-3 | 0.06±0.01$^{b}$ | 0.07±0.01$^{c}$ | 0.06±0.01$^{ab}$ | 0.05±0.01$^{b}$ |
| C18:3n-3 (ALA) | 4.01±1.11$^{a}$ | 4.52±1.06$^{a}$ | 3.74±0.74$^{a}$ | 3.66±0.58$^{a}$ |
| C20:4n-6 | 1.37±0.20$^{a}$ | 1.27±0.17$^{a}$ | 1.19±0.18$^{a}$ | 1.18±0.07$^{a}$ |
| C22:5n-3 | 11.31±1.19$^{a}$ | 9.98±1.24$^{a}$ | 11.12±2.56$^{a}$ | 11.65±1.63$^{a}$ |
| Total PUFA | 38.95±1.95$^{a}$ | 37.85±1.13$^{ab}$ | 37.75±0.73$^{ab}$ | 36.74±1.73$^{b}$ |
| Ratios | | | | |
| PUFA:SFA | 1.11±0.06$^{a}$ | 1.10±0.04$^{a}$ | 1.06±0.03$^{ab}$ | 1.03±0.07$^{b}$ |
| n-6:n-3 | 0.12±0.01$^{a}$ | 0.12±0.01$^{a}$ | 0.12±0.008$^{a}$ | 0.11±0.005$^{a}$ |

$^{abc}$ Different superscripts within a column differs significantly at $P < 0.05$. Values are means ± standard error (n = 6).

The only significant changes were in the concentrations of eicosadienoic acid (C20:2) and eicosatrienoic acid (C20:3n-3). Oven baking and steaming significantly reduced the concentration of eicosadienoic acid, while microwave cooking significantly increased the concentration of eicosatrienoic acid. None of the cooking methods and a significant change in the n-6:n-3 ratio. Microwaved and oven baked samples had n-6:n-3 ratios of 0.12 ± 0.01 and 0.12 ± 0.008, respectively, while steaming resulted in a ratio of 0.11 ± 0.005. The n-6:n-3 ratio for the raw Cape snoek samples is similar to what was reported by Henning and Hoffman [30] for South African Cape snoek, and Pethybridge *et al*. [42] for Australian snoek. For health considerations, a n-6:n-3 ratio of between 1 and 0.5 is recommended [4].

Of the three cooking methods investigated, steaming resulted in a significant reduction of the total PUFA (38.95% ± 1.95 for raw vs. 36.74% ± 71.73 for steamed samples). Although microwave cooking and oven baking also reduced the total PUFA, it was not of significance. Steaming also resulted in a significant reduction in the PUFA/SFA ratio. The cooking of food within a microwave oven results from waves of oscillating electromagnetic energy energising water molecules within the food product [46]. Microwave oven energy is more penetrating than heat generated within an oven or through steam. Cooking with the use of an oven or steam, heats food by the process of conduction, which are typically slower than heating with the use of microwaves. Baking or steaming of food therefore requires a longer time for the food to be cooked, thus, resulting in more degradation of PUFA due to longer exposure to heat, light and oxygen.

## 4. Conclusions

Results of the present study have shown that microwave cooking and steaming similarly increased the total fat content of Cape snoek. Oven baking resulted in the highest total fat content.

Based on the results obtained for total PUFA, microwave cooking and steaming were found to be the best among the three cooking methods for preserving the total PUFA concentration and PUFA/SFA ratio. Steaming resulted in a significant decrease and loss of total PUFA. Although the changes in EPA, DHA and ALA concentration between the three cooking methods were not significantly different, microwave cooking showed the smallest reduction in EPA, DHA and ALA. However, it is important to keep in mind that the quality, total fat content and fatty acid composition of fish muscle are influenced by season, locality, sex, diet and health of the fish.

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