

Effects of Different Cooking Methods on Chemical Composition and Quality Indices of Beef Steaks

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Abstract Processing methods are aimed at enhancing the quality of meat products. However, safety of heat-processed meat is an important global issue as cooking may lead to formation of toxic substances like heterocyclic aromatic amines (HAA) and polycyclic aromatic hydrocarbons (PAH). There is dearth of information on effects of different cooking methods on quality attributes of beef steaks. Thus, quality attributes of beef steaks using different cooking methods were assessed in this study. Beef steaks (n=224) of uniform size and shape were selected and assigned randomly to different cooking methods: Deep frying at 180°C (DFBS); Smoking 300°C (SBS); Microwaving 600 watt (MBS) and Roasting 200°C (RBS) to attain inner temperature of 75°C. The concentrations of benzo (a) anthracene (µg/kg) 1.85 (DFBS), 1.75 (SBS), 1.67 (MBS) and 0.83 (RBS) differed highly significantly (p<0.0001). 2-Amino-3-methyl-3H-imidazo (4, 5-F) quinoline (IQ ng/g) of 4.05 (DFBS) was significantly (p<0.0001) higher than 3.97 (SBS), 3.61 (MBS) and 2.25 (RBS). However, product yield (%) 47.81 (MBS), 46.13 (DFBS), 42.43 (RBS) and 40.13 (SBS) were significantly (p<0.0001) different. Also, the crude protein (%) of RBS (66.73) was significantly (p<0.0001) higher than DFBS (57.18), SBS (52.11) and MBS (47.75). The arachidonic acid (mg/L) 0.018 (DFBS), 0.012 (SBS), 0.012 (RBS) and 0.008 differed significantly (p<0.0001). Linoleic and oleic acids of DFBS (0.017), SBS (0.012), RBS (0.011) and 0.008 (MBS) were similar however, fatty acids of the four products were significantly different (p<0.0001). Cholesterol content (mg/100g) 959.11 (DFBS) was significantly higher (p<0.0001) than 666.23 (MBS), 505.23 (SBS) and 366.43 (RBS). Study showed that deep frying increased PAH, HAA and cholesterol content of beef steak while roasting reduced their formation.

Keywords Polycyclic aromatic amines, Heterocyclic aromatic amines, Products yield, Crude protein, Essential fatty acids, Cholesterol

1. Introduction

Cooking of meat products at high temperatures has been reported to lead to generation of mutagens or carcinogens [1]. [2] It posited that a variety of heterocyclic amines and polycyclic aromatic hydrocarbons in heat-treated meat products were formed with different cooking methods. The HAA and PAHs concentrations in meat increase with longer cooking time and higher temperature as well as the fat content [3]. [4] It showed that PAHs and HAAs that are known mutagens and carcinogens are transferred into a range of meats which therefore may make the product unsafe for consumption. These substances have been related with cardiovascular diseases, colorectal and breast cancers [5]. Studies have demonstrated that carcinogenic PAHs are

present in food, being formed through the grilling, roasting, barbecuing and smoking of foods [6-8]. [9] It labelled several heterocyclic amines as likely carcinogens.

The PAH and HAA formation during cooking have been noted to depend on type of meat, cooking temperature, degree of browning and the cooking time. More of these chemicals are formed when pan surface temperatures are higher than 220°C (428 °F) such as with most frying or grilling [9]. [10] It reported that the range of HAAs (IQ, IQx, MeIQx, DiMeIQx, and PhIP) found in the ready to eat meats (beef, pork and turkey hotdogs) was 0.05-13.07ng/g. The total HAAs in fried pork (13.91 ng/g, PhIP accounting for 9.20 ng/g) were significantly higher than those in fried beef (8.92 ng/g, PhIP accounting for 6.60 ng/g) and fried chicken (7.06 ng/g, PhIP accounting for 6.06 ng/g) at 204°C temperature [11]. [12], in charcoal grilled (well done) chicken breast found PhIP (31.1 ng/g), 4,8-DiMeIQx (4 ng/g), and MeIQx (1.2 ng/g). The lower content of total HAAs in fried chicken (1.01 ng/g), fried pork (0.5 ng/g), and fried beef (0.1 ng/g) when cooked to well-done (internal temperature 75°C for chicken, 88°C for pork, and 78°C for beef) was reported [13]. [14] It reported that Danish smoked

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meat contained a maximum of total PAH ($n = 27$) prepared by direct smoking to be 1387 mg/kg. Levels as high as 200 mg/kg in food have been found for some individual PAHs in smoked meat products [6] [15]. [16] It showed that sum of PAH was highest in barbecued beef (average 17.3 $\mu\text{g/kg}$) compared with pork (average 2.6 $\mu\text{g/kg}$) and chicken (average 1.1 $\mu\text{g/kg}$). BaP levels in beef steaks were found to be 4.9 $\mu\text{g/kg}$ [17] and barbecued pork 1.8 $\mu\text{g/kg}$ [18].

Cholesterol is an essential structural component of all animal cell membranes that is required to maintain both membrane structural integrity and fluidity. Too much cholesterol, high levels of Low density lipoprotein in particular, may cause atherosclerosis, a condition in which plaque is deposited in artery walls, blocking the blood flow to vital organs, which can result in high blood pressure or stroke [19]. Since cooking has been associated with production of toxic substances, there is therefore, the need to assess the safety of different cooking methods and their influence on beef steak quality and chemical composition.

2. Materials and Methods

Beef loin was purchased within one hour post mortem and transported in an ice pack container to the laboratory. The meat samples were trimmed off of all visible fat, ligament and bones. Each chunk was cut into steaks of about 40g each. A total of 224 steaks of uniform size and shape were selected and assigned randomly to each cooking method (deep frying at 180°C, smoking at 300°C (traditional kiln smoking using hard fire wood flame from burning *Tectona grandis*), microwaving at 600 watt and roasting at 200°C) and were replicated four times in a completely randomised design. The cooking was done until a core temperature of 75°C was attained with certified meat probe thermometer.

Each of the differently cooked steak was oven dried at 60°C and then ground into powder. Precisely, 100g of each ground samples was immersed into 500 mL distilled N-hexane and was left for 72 hours with intermittent stirring after which, the samples were drained of distilled methanol 500 mL into each samples and kept for another 72 hours with intermittent stirring. The methanol extracts from the mixture were decanted and then concentrated; thereafter the concentrated methanol extracts were subjected to gas chromatography mass spectrophotometry (GCMS).

The GCMS analysis was performed using an Agilent GC 6890 (Santa Clara, CA, USA) with automatic sample injection by a heated transfer line (300°C) interfaced to an Agilent MS 5973 (Palo Alto, CA, USA) in electron ionisation mode with an electron impact of 70 eV. The analysis was carried out according to [13] using a DB-5MS capillary column from J and W Scientific (50 m \times 0.25 mm i.d. \times 0.25 μm film thickness). The PAHs and HAAs were identified by comparing responses with those of standard mixtures. The criteria for identification was the same retention time as the standard within $\pm 2\%$, and corrected relative abundance of two characteristic ions within $\pm 15\%$ as

described [13]. External standards of all PAHs and HAAs in toluene were used for calculating the calibration curves, using ready-to-use solutions with concentrations of 0, 1, 2, 10, 30, 100 and 250 ng/mL toluene. All standard curves had correlation coefficients of >0.97 .

Determination of cholesterol composition of MSB, DFBS, RBS and SBS were carried out by adding 5 mL of chloroform into a conical flask containing 5 g of the sample and ground. Additional 5 mL of chloroform and 10 mL of distil water were added and mixed thoroughly. The mixture was poured into a separating flask and the lower layer was released into a test tube. Accurately 1 mL each of acetic anhydride and concentrated sulphuric acid were added into the separated solution. Green colour was observed at the interface. Absorbance wavelength of the solution was measured in spectrophotometer at 640 nm. Cooking loss and the product yields were determined as follows:

Product yield (%) =

$$\frac{\text{weight of product}}{\text{Initial weight of sample}} \times 100$$

Cooking loss (%) =

$$\frac{\text{weight of steaks before cooking} - \text{weight of steaks after cooking}}{\text{Weight of steaks before cooking}} \times 100$$

Statistical Analysis: Data were subjected to descriptive statistics and analysis of variance [20], while means were separated using Duncan's multiple range test of the same software at $\alpha_{0.005}$.

3. Results

Table 1. Polycyclic Aromatic Hydrocarbons Content of Beef Steak differently cooked

Parameters ($\mu\text{g/kg}$)	Products				SEM	P-value
	DFBS	SBS	MBS	RBS		
BaA	1.85 ^a	1.75 ^b	1.67 ^c	0.83 ^d	0.007	P<0.0001
BbF	0.70 ^a	0.57 ^b	0.51 ^c	0.37 ^d	0.006	P<0.0001
BaP	0.60 ^a	0.48 ^b	0.43 ^c	0.30 ^d	0.005	P<0.0001
Pyrene	1.39 ^a	1.35 ^b	1.31 ^c	1.25 ^d	0.007	P<0.0001
Chrysenes	0.66 ^a	0.55 ^b	0.47 ^c	0.35 ^d	0.006	P<0.0001
TPAH	5.20 ^a	4.70 ^b	4.38 ^c	3.11 ^d	0.026	P<0.0001

^{a,b,c} Means with different letters along the row are significantly different (P<0.05), BaA (Benzo (a) Anthracene), BbF (Benzo (b) Fluoranthene), BaP (Benzo (a) Pyrene), TPAH= Total Polycyclic Aromatic Hydrocarbons; DFBS (Deep-fried beef steak), SBS (Smoked beef steak), MBS (Microwaved beef steak), RBS (Roasted beef steak).

The PAH concentration of differently cooked beef steaks is shown in Table 1. Benzo[a]Anthracene (BaA $\mu\text{g/kg}$) of DFBS (1.85) was significantly ($p<0.0001$) higher than SBS (1.75), MBS (1.67) and RBS (0.83). The trend of Benzo [b] Fluoranthene (BbF) for the beef steak was similar to that of BaA except that they were lower. The concentration of Benzo [a] Pyrene (BaP) were significantly ($p<0.0001$)

different across the beef steaks. The DFBS had the highest value (0.60 $\mu\text{g/kg}$), followed by SBS (0.48 $\mu\text{g/kg}$), MBS (0.43 $\mu\text{g/kg}$) and (0.30 $\mu\text{g/kg}$). The pyrene level ($\mu\text{g/kg}$) 1.39 (DFBS) differed significantly ($p<0.0001$) from 1.35 (SBS), 1.31 (MBS) and 1.25 (RBS). Chrysenes were also highly significantly ($p<0.0001$) different and this followed the same trend across the products.

The level of heterocyclic aromatic amines content of differently cooked beef steaks is shown Table 2. There were highly significant differences ($p<0.0001$) in HCA concentration of the four beef steaks. The 2-amino-3-methyl-3H-imidazo [4,5-F]quinoline (IQ ng/g) of DFBS (4.05) was highly significant ($p<0.0001$) compared with SBS (3.97), MBS (3.61) and RBS (2.25). The 2-amino-3,8-dimethyl imidazo [4,5-f] quinoxaline (MeIQx) of DFBS (4.33 ng/g) was significantly higher ($p<0.0001$) than SBS (3.61 ng/g), MBS (3.48 ng/g) and RBS (3.40 ng/g). Also, the 2-amino-1-methyl-6-phenylimidazo (4,5-b) pyridine (PhIP) of DFBS (5.32 ng/g) was significantly higher than the other beef steaks namely SBS (4.28 ng/g), MBS (3.88 ng/g) and the least RBS (3.44 ng/g). The value of PhIP was the highest across the differently cooked beef steaks.

Table 2. Heterocyclic Aromatic Amines Content of Beef Steaks differently cooked

Parameters (ng/g)	Products				SEM	P-value
	DFBS	SBS	MBS	RBS		
IQ	4.05 ^a	3.97 ^b	3.61 ^c	2.25 ^d	0.005	$P<0.0001$
MeIQx	4.33 ^a	3.61 ^b	3.48 ^c	3.40 ^d	0.009	$P<0.0001$
PhIP	5.32 ^a	4.28 ^b	3.88 ^c	3.44 ^d	0.008	$P<0.0001$
THAA	48.77 ^a	46.23 ^b	41.91 ^c	35.67 ^d	0.007	$P<0.0001$

^{a,b,c,d} Means with different letters along the column are significantly different ($P<0.05$)

2-Amino-3-methyl-3H-imidazo [4,5-F]quinoline (IQ), 2-Amino-3,8-dimethyl imidazo [4,5-f] quinoxaline (MeIQx), 2-Amino-1-methyl-6-phenylimidazo(4,5-b) pyridine (PhIP), THAA=Total heterocyclic aromatic amines; DFBS (Deep-fried beef steak), SBS (Smoked beef steak), MBS (Microwaved beef steak), RBS (Roasted beef steak)

Table 3. Physical Properties of differently cooked Beef Steaks

Parameter	Beef Steaks				SEM	P-value
	DFBS	SBS	MBS	RBS		
Cooking loss (%)	53.81 ^c	59.29 ^a	52.44 ^d	57.84 ^b	0.09	$P<0.0001$
Product yield (%)	46.13 ^b	40.13 ^d	47.81 ^a	42.43 ^c	0.08	$P<0.0001$

^{a,b,c,d} Means with different letters along the column are significantly different ($P<0.05$)

The physical properties of differently cooked beef steaks are shown in Table 3. The cooking loss of SBS (59.29%) was significantly higher ($p<0.0001$) than RBS (57.83%), DFBS (53.80%) and MBS (52.44%). The yield of MBS (47.80%) was significantly higher ($p<0.0001$) than the other steaks. This was followed by DFBS (46.12%), RBS (42.43%) and SBS (40.13%), respectively. The cholesterol content of

959.10 mg/100 g was recorded for DFBS, 666.23 mg/100 g (MBS), 505.22 mg/100 g (SBS) and 366.43 mg/100 g in RBS. This shows that DFBS was significantly higher ($p<0.0001$) than the other steaks.

The proximate composition of the beef steaks differently cooked is shown in Table 4. The crude protein of RBS (68.73%) was significant higher ($p<0.0001$) than DFBS (57.18%), SBS (52.11%) and MBS (47.75%). Ether extract of DFBS (15.15 %) was significantly higher ($p<0.0001$) than MBS (6.46%), SBS (5.97%) and RBS (3.15%). However, the ash contents of the beef steak were significantly different ($p<0.0001$). The RBS (3.21%) and MBS (3.21%) were significantly ($p<0.0001$) higher than in SBS (3.06%) and DFBS (2.36%). Also, moisture content of SBS (28.41%) was significantly higher ($p<0.0001$) than in MBS (26.45%), RBS (26.38%) while DFBS (18.30%) had the least moisture.

Table 4. Proximate Composition (%) of Beef Steak Differently Processed

Parameters	Beef Steaks				SEM	P-value
	DFBS	SBS	MBS	RBS		
Crude Protein	57.18 ^b	52.11 ^c	47.75 ^d	66.73 ^a	0.004	$P<0.0001$
Ether Extract	15.15 ^a	5.97 ^c	6.46 ^b	3.15 ^d	0.003	$P<0.0001$
Ash	2.36 ^c	3.06 ^b	3.21 ^a	3.21 ^a	0.004	$P<0.0001$
Moisture	18.30 ^d	28.41 ^a	26.45 ^b	26.38 ^c	0.002	$P<0.0001$

^{a,b,c,d} Means with different letters along the row are significantly different ($P<0.05$). DFBS (Deep-fried beef steak), SBS (Smoked beef steak), MBS (Microwaved beef steak), RBS (Roasted beef steak)

The fatty acid profile and total cholesterol of beef steaks differently cooked are shown in Table 5. Arachidonic acid of DFBS (0.018 mg/L) was significantly higher ($p<0.0001$) than in SBS (0.012 mg/L), RBS (0.012 mg/L) and MBS (0.008 mg/L). Lauric acid of DFBS (0.012 mg/L) was significantly high ($p<0.0001$). This was followed by SBS (0.008 mg/L), RBS (0.007 mg/L) and MBS (0.005 mg/L). Linoleic acid content of the beef steak followed the same trend with that of arachidonic and lauric. Also, Oleic acid of DFBS (0.017 mg/L) was significantly higher ($p<0.0001$) than in SBS (0.012 mg/L), RBS (0.11 mg/L) and MBS (0.008 mg/L). Stearic acid of DFBS (0.11mg/L) was significantly higher than in SBS (0.007 mg/L), RBS (0.006 mg/L) and MBS (0.005 mg/L). Palmitic acid of DFBS (0.015 mg/L) was significantly higher ($p<0.0001$) than SBS (0.015 mg/L), RBS (0.009 mg/L), MBS (0.007 mg/L).

Table 6 shows the mineral contents of beef steaks differently cooked. The calcium of RBS (0.96 mg/L) was higher and significantly different ($p<0.0001$) than in other three beef steaks. This was followed by SBS (0.62 mg/L), MBS (0.40 mg/L) and the least was DFBS (0.29 mg/L). Also, Magnesium (mg/L) of RBS was the highest (15.80) followed by DFBS (13.10), MBS (12.11) and SBS (6.30). However, Potassium (mg/L) of DFBS (444.50) was significantly higher ($p<0.0001$) than in RBS (437.01), MBS (430.50) and SBS (188.51). The Sodium (mg/L) of MBS (39.91), SBS (30.50) and DFBS (26.61) were significantly lower than in

RBS (56.11 mg/L). Also, the Phosphorus (%) of 5.01 in RBS was significantly higher ($p < 0.0001$) than the other 3 beef steaks SBS (4.77), MBS (4.77) and DFBS (3.50).

Table 5. Fatty Acids Profile and Total Cholesterol of Beef Steak differently cooked

Parameters (mg/L)	Beef Steaks				SEM	P-value
	DFBS	SBS	MBS	RBS		
Arachidonic acid	0.018 ^a	0.012 ^b	0.008 ^c	0.012 ^b	1.8×10^{-4}	$P < 0.0001$
Lauric Acid	0.0012 ^a	0.008 ^b	0.005 ^d	0.007 ^c	1.1×10^{-4}	$P < 0.0001$
Linoleic Acid	0.017 ^a	0.012 ^b	0.008 ^d	0.011 ^c	1.9×10^{-4}	$P < 0.0001$
Oleic Acid	0.017 ^a	0.012 ^b	0.008 ^d	0.011 ^c	1.8×10^{-4}	$P < 0.0001$
Stearic Acid	0.011 ^a	0.007 ^b	0.005 ^d	0.006 ^c	1.1×10^{-6}	$P < 0.0001$
Cholesterol (mg/100g)	959.108 ^a	505.225 ^c	666.233 ^b	366.431 ^d	0.003	$P < 0.0001$

^{a,b,c,d} Means with different letters along the row are significantly different ($P < 0.05$). DFBS (Deep-fried beef steak), SBS (Smoked beef steak), MBS (Microwaved beef steak), RBS (Roasted beef steak)

Table 6. Mineral Content of Beef Steak Differently Processed

Parameters (mg/L)	Beef Steak				SEM	P-value
	DFBS	SBS	MBS	RBS		
Calcium	0.29 ^d	0.62 ^b	0.40 ^c	0.96 ^a	0.002	$P < 0.0001$
Magnesium	13.10 ^b	6.30 ^d	12.11 ^c	15.80 ^a	0.002	$P < 0.0001$
Potassium	444.50 ^a	188.51 ^d	430.50 ^c	437.01 ^b	0.003	$P < 0.0001$
Sodium	26.61 ^d	30.50 ^c	39.91 ^b	56.11 ^a	0.003	$P < 0.0001$
Phosphorus (%)	3.50 ^c	4.77 ^b	4.77 ^b	5.01 ^a	0.015	$P < 0.0001$

^{a,b,c,d} Means with different letters along the row are significantly different ($P < 0.05$). DFBS (Deep-fried beef steak), SBS (Smoked beef steak), MBS (Microwaved beef steak), RBS (Roasted beef steak)

4. Discussion

In Table 1, the BaA of DFBS (1.84 $\mu\text{g/kg}$) was significantly higher ($p < 0.0001$) than in the other three beef steaks and RBS (0.83 $\mu\text{g/kg}$) was least. [21] It reported 0.3 $\mu\text{g kg}^{-1}$ BaA in smoked beef which was lower than 1.75 $\mu\text{g kg}^{-1}$ obtained for SBS. The trend of BbF in the beef steak was similar to that of BaA except that they were lower. The BaP were significantly different ($p < 0.0001$) across the beef steaks. The DFBS contained the highest value of 0.60 $\mu\text{g/kg}$, followed by SBS which had 0.48 $\mu\text{g/kg}$, MBS 0.43 $\mu\text{g/kg}$ and RBS 0.30 $\mu\text{g/kg}$. There is dearth of information on why DFBS had the highest BaP since it was reported that only charcoal or wood with other precursors like creatine, creatinine and amino acids which influence the deposition of PAH in foods. However, the 0.48 $\mu\text{g/kg}$ BaP in SBS was higher than 0.01-0.1 $\mu\text{g/kg}$ reported [21].

The pyrene were 1.39 $\mu\text{g/kg}$ in DFBS, 1.34 $\mu\text{g/kg}$ in SBS, 1.31 $\mu\text{g/kg}$ in MBS and 1.25 $\mu\text{g/kg}$ in RBS. [21] It did not find any BaP in smoked beef. The chrysene of the differently cooked beef steaks also followed the same pattern with the others but were not found in smoked beef as reported by [21]. The PAHs of 0.30-1.85 $\mu\text{g/kg}$ obtained from this study were within the range (1.00-230.04 $\mu\text{g/kg}$) reported by [22] for smoked fish. However, PAHs obtained in this study were lower than the maximum acceptable level of 5 $\mu\text{g kg}^{-1}$ recommended by the [23]. This shows that the differently processed beef steaks were safe for consumption. But it must be noted that DFBS significantly contained the highest PAHs

followed by SBS, MBS and RBS. This is an indication that deep frying and smoking were relatively unsafe modes of cooking.

The IQ level in DFBS 4.046 ng/g was significantly higher ($p < 0.0001$) than in the other three beef steaks (Table 2). Smoked beef steak which contained 3.970 ng/g was next to DFBS in HAA content followed by microwaved beef steak with 3.606 ng/g and the least content 2.250 ng/g was in roasted beef steak. The higher HAA in DFBS could be attributed to the oil used (1.00-230.04 $\mu\text{g/kg}$) in frying and also the presence of other precursors such as creatine and amino acid. The high IQ in SBS also showed that smoking induced IQ formation. Also, 3.606 IQ in MBS could be as a result of meat intramuscular fat since fat has affinity for HAA and other precursors. The RBS was least in HAA which was an indication that roasting was the safest means of cooking. Furthermore, the MeIQx of DFBS (4.326 ng/g) was significantly higher than in SBS (3.613 ng/g), MBS (3.476 ng/g) and RBS (3.396 ng/g). The 5.316 ng/g PhIP of DFBS was also significantly higher than 4.280 ng/g SBS, 3.876 ng/g MBS and the least 3.436 ng/g RBS. The PhIP was highest across the differently processed beef steak. These observations were contrary to the report of [11] that no IQx, IQ and MeIQx were in microwaved-cooked pepperoni but 0.01±0.01 ng/g PhIP was found.

[24] It reported that a roasted beef contained 23.44±0.77 ng/g MeIQ and 26.93±0.29 ng/g PhIP, mutton contained 21.01±0.01 ng/g MeIQ and 40.21±0.65 ng/g PhIP. These values were higher than those obtained in this study. [12] It

also showed that HAA present in deep fried and charcoal grilled breast were 0.68 ng/g MeIQ, 1.76 ng/g 4,8-DiMeIQx, 1.47 ng/g PhIP and 2.74 ng/g IQ, 2.4 MeIQx, 11.80 ng/g PhIP. However, but none was found in roasted duck breast. The HAAs of DFBS were higher than the deep fried chicken breast reported by [12]. The SBS was similar with charcoal grilled in the composition of IQ (2.74 ng/g) and MeIQx (2.40 ng/g). The HAA reported by [25] was higher than the values obtained in this study; charcoal grilled beef contained 29.68 ng/g IQ, 15.60 ng/g MeIQ and PhIP was not found, while microwaved pre-heated deep fried beef did not contain any HAA. The MeIQx of beef steak (4.4 ± 0.06 ng/g) reported by [26] was similar to MeIQx in DFBS (4.3 ng/g) obtained in this study. [11] It reported that fried beef contained 3.33 ± 0.38 ng/g MeIQ and 5.27 ± 0.81 ng/g PhIP, similar to the result obtained in this study.

A significant increase of 59.29% was observed in the cooking loss of SBS and in 57.83% RBS compared with other steaks as shown in Table 3. This could be related to the open cooking of the two steaks. The beef were directly under open heat source which could cause increased cooking loss as well as melted fat loss. Generally, cooking loss obtained in this study was higher than 28.62-33.5% and 25.4-28.9% reported by [27] and [28], respectively. It has been established that the properties of a final product is usually a reflection of the properties of the meat that was used. The product yield of MBS was highly significantly higher ($p < 0.0001$) than the other steaks. This could be that microwave reduced the rate of moisture loss. However, it was noticed that there was an inverse relationship between cooking loss and the product yield. The MBS with the least cooking loss of 52.44% had the highest product yield of 47.80%. [28] It showed a range of 70.10-73.40% which was higher than results in this study.

The cholesterol content of beef steaks differently cooked were significantly ($p < 0.0001$) different. The cholesterol of deep fried beef steak (959.11 mg/100g) was significantly higher than in the other three beef steaks. This could be attributed to the vegetable oil used in frying. The MBS was next in cholesterol content (666.23 mg/100g), this value could be that the beef used was higher in fat content. Steak provides nearly three grams of fat per ounce, which means a three-ounce of steak cut contains about 9 grams of fat. Eating a 3-ounce beef steak for dinner provides approximately 180 calories [29]. The SBS had 505.23 mg/100g cholesterol which showed that smoking reduced fat and cholesterol but not as much as roasting as the value in roasted beef steak was 366.43 mg/100g. This shows that of the four cooking methods, roasting was the best and the safest method of cooking as it reduces the cholesterol content of the beef.

The range of recommended cholesterol intake for an adult was between 200 mg/dL and 240 mg/dL as cholesterol boarder line [19]. Therefore, the cholesterol of the beef steaks in this study was higher than the recommended level though, roasted beef steak seems to be close to the cholesterol boarder line (240 mg/dL).

As shown in Table 4, moisture in SBS (28.41%) was

significantly higher than in MBS (26.45%), RBS (26.38%), while DFBS (18.30%) had the lowest value for moisture. This could be linked with the fact that there was osmosis, which was a movement of water from meat into the medium (oil) used for frying. [12] It found that the moisture contents in deep fried and roasted chicken breasts were 53.77% and 65.81% which were higher than the moisture contents in DFBS (18.30%) and RBS (26.38%) obtained in this study. It however, followed the same trend in that, the moisture content of roasted meat (chicken breast and beef steak) were higher than that of the deep fried meat.

The CP was highest in RBS (66.73%) followed by DFBS (57.18%), SBS (52.11%) and MBS (47.75%). This is an indication that roasting as a means of cooking preserved protein in meat. The CP of 66.73% in RBS was similar to a range of 58.5-61.9% reported by [30] for a roasted lamb loin but was higher than 31.41% and 33.97% reported by [12] for roasted chicken and duck breasts, respectively. [12] It reported crude protein of deep fried chicken and duck breasts as 43.69% and 43.79%. While the crude protein of DFBS (57.18%) was similar to the charcoal grilled lamb loin (58.5 %) reported by [30].

Ether extract (15.15 %) was highest in DFBS, followed by MBS (6.46%), SBS (5.97%) and RBS (3.15%). The high EE of DFBS could be attributed to the oil used during frying, while the relatively high value in MBS (6.46) could be attributed to the intramuscular fat content of the meat. But the lowest value in RBS was an indication that there was a reduction in fat content when the meat was subjected to roasting. [12] It showed 4.62% and 1.65% for deep fried and roasted chicken breasts which were very low compared to the values recorded in this study.

The ash contents in RBS (3.21%) and MBS (3.21%) were significantly higher ($p < 0.0001$) than in SBS (3.06%) and DFBS (2.36%). The high ash in RBS and MBS was an indication that their mineral contents were higher.

Fatty acids content in DFBS was significantly higher than the other beef steaks and this could be attributed to the frying vegetable oil which was unsaturated fatty acids (Table 5). The low values of RBS and MBS for all the fatty acids was an indication that these two cooking methods were the best. It was observed that the ratio of unsaturated fatty acids (Arachidonic, linoleic and oleic acids) was higher than the saturated fatty acids (Lauric, stearic and palmitic), which could be of health benefit to consumers. The observations in this study conforms with the report [31] that high stearic acid concentration does not increase cholesterol level but palmitic does. Perhaps, palmitic acid was responsible for the high cholesterol in DFBS. The fatty acids of RBS and MBS were low compared with DFBS which showed that the beef steaks cooked by roasting and microwaving were safe for consumption. The fatty acids of a goat meat products (4-50%) reported by [31] were higher than those obtained in this study.

As indicated in Table 6, RBS had the highest minerals contents (Ca-0.958 mg/L, Mg-15.803 mg/L, Na-56.106 mg/L, P-5.005%) except for potassium. This observation

was in agreement with those of [32] on mineral concentration in roasted samples and increased mineral content as the thermal temperature increases. It was expected that Ca and Na in DFBS would be higher than in MBS. However, there is a dearth of information on this. It was also noted that K and Na in SBS were lower than in MBS. [33] It reported that the value of K and Na in beef steaks were 279 mg and 58 mg, respectively. The content of Na reported for beef steak was similar with those in RBS (56.106 mg/L) while K composition reported (279 mg/L) was lower than in RBS (437.005 mg/L), MBS (430.503 mg/L) and DFBS (444.503 mg/L) but greater than in SBS (188.505 mg/L).

5. Conclusions

Among the cooking methods used deep frying increased the concentration of PAHs, HAAs, cholesterol and the essential fatty acids of beef steaks. Roasting lowered the formation of the chemicals with improved crude protein and minerals composition of the tested samples of beef steak.

REFERENCES

- [1] Sugimura, T., Wakabayashi, K., Nakagama, H., and Nagao, M. 2004. Heterocyclic amines: Mutagens/carcinogens produced during cooking of meat and fish. *Cancer Science*, 95, 290–299.
- [2] Solyakov, A. and Skog, K. 2002. Screening for heterocyclic amines in chicken cooked in various ways. *Food and Chemical Toxicology*, 40, 1205–1211.
- [3] Sinha, R., Peters, U., Cross, A. J., Kulldorff, M., Weissfeld, J. L. and Pinsky, P. F. 2005. Meat, meat cooking methods and preservation, and risk for colorectal adenoma. *Cancer Research*, 65(17), 8034–8041.
- [4] Garcia-Closas, R., Castellsague, X., Bosch, X., and Gonzalez, C. A. 2005. The role of diet and nutrition in cervical carcinogenesis: A review of recent evidence. *International Journal of Cancer*, 117(4), 629–637.
- [5] World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR). 2007. *Food, nutrition, physical activity and the prevention of cancer* (pp. 517). Washington DC: AICR.
- [6] Scientific Committee on Foods of EC. 2002. Opinion of the Scientific Committee on Food on the risks to human health of polycyclic aromatic hydrocarbons in food. SCF/CS/CNTM/PAH/29 final 4. December.: European Commission Health and Consumer Protection Directorate-General. http://ec.europa.eu/food/food/chemicalsafety/contaminants/out153_en.Pdf.
- [7] Simko P. 2002. Determination of polycyclic aromatic hydrocarbons in smoked meat products and smoke flavouring food additives. B: Analytical Technologies in the Biomedical and Life Sciences, J. Chromatogra., 770: 3-18.
- [8] Chen, J., and Chen, S. 2005. Removal of polycyclic aromatic hydrocarbons by low density polyethylene from liquid model and roasted meat. *Food Chemistry*, 90,461–469.
- [9] US Department of Health and Human Services (USDHHS). 2002. The 1999–2000 Data Release, Dietary Interview Component, Individual Foods File (DRXIFF). *National Center for Health Statistics*, Retrieved July 4, 2002 from the NHANES—Survey Questionnaire and Exam Components Page on the World Wide Web: <http://www.cdc.gov/nchs/abou/major/nhanes/NHANES99-00.htm>.
- [10] Kanithanporn, P., Gadgil, P., Houser, T. A., Hunt, M. C. and Smith, J. S. 2011. Heterocyclic amine content in cooked meat products. *Journal Meat Science*, 88,227–233.
- [11] Kanithanporn, P., Gadgil, P., Houser, T.A., Hunt, M.C. and Smith J.S. 2012. Heterocyclic amine content in commercial ready to eat meat products. *Journal Meat Science* 88: 227-233.
- [12] Liao, G.Z., Wang, G.Y., Xu, X.L. and Zhou, G.H. 2010. Effect of cooking methods on the formation of heterocyclic aromatic amines in chicken and duck breast. *Journal Meat Science* 85: 149–154.
- [13] Iwasaki, M., Kataoka, H., Ishihara, J., Takachi, R., Hamada, G. S. and Sharma, S. 2010. Heterocyclic amines content of meat and fish cooked by Brazilian methods. *Journal of Food Composition and Analysis*, 23 (1), 61-69.
- [14] Duedahl-Olesen, L., Christensen, J. H., Højgård, A., Granby, K., and Timm-Heinrich, M. 2010. The influence of smoking parameters on the concentration of PAHs in Danish smoked fish. *Food Additives and Contaminants*, 27, 1294–1305.
- [15] Yang, Y., Shi, X., Wong, P.K., Dawson, R., Xu, F., Liu, W. and Tao, S., 2006. An approach to assess ecological risk for polycyclic aromatic hydrocarbons (PAHs) in surface water from Tianjin. *Journal of Environment Science and Health, Part A: Environmental Science* 41, 1463–1482.
- [16] AasyIng, M.D., Dunedahl-Olesen, L., Jensen, K., Meinert. 2012. Content of heterocyclic amines and polycyclic aromatic hydrocarbons in pork, beef and chicken barbecued at home by Danish consumers. *Journal of Meat Science*. 93:85-91.
- [17] Kazerouni, N., Sinha, R., Hsu, C. H., Greenberg, A., and Rothmann, N. 2001. Analysis of 200 food items for benzo(a) pyrene and estimation of its intake in an epidemiologic study. *Food and Chemical Toxicology*, 39, 423–436.
- [18] Reinik, M., Tamme, T., Roasto, M., Juhkam, K., Tenno, T., and Kus, A., 2007. Polycyclic aromatic hydrocarbons (PAHs) in meat products and estimated PAH intake by children and the general population in Estonia. *Journal Food Additives and Contaminants* 24 (4), 429–437.
- [19] Meat Science and Nutrition. 2002. Cholesterol content in meat. <https://opentextbc.ca>.
- [20] SAS. 2013. Statistical Analysis System. SAS Stat. Version 9.2 SAS Institute Inc. Garry, NC, USA.
- [21] Menichini, E. and Bocca, B. 2003. Smoked foods: An overview. <http://www.sciencedirect.com>.
- [22] Essumang, D. K., Dodoo, D.K. and Adjei, J. K. 2012. Polycyclic aromatic hydrocarbon contamination in smoke-cured fish products. *Journal Food Composition and Analysis*. 27:128-138.
- [23] Official Journal of the European Union. 2005 a. L 34/3.

Commission Recommendation 2005/108/EC of 4 February 2005.

- [24] Zaidi, R., Kumar, S. and Rani, R. P. 2012. Rapid detection and quantification of dietary mutagens in food using mass spectrometry and ultra performance liquid chromatography. *Journal Food Chemistry* 135. 2012. 2897–2903.
- [25] Jinap, S., Mohd-Mokhtar, M.S., Farhadian, A., Hasnol, N.D.S., Jaafar, S.N. and Hajeb, P. 2013. Effects of varying degrees of doneness on the formation of heterocyclic aromatic amines in chicken and beef satay. *Journal Meat Science* 94:202-207.
- [26] Mardones, C., Aree, L., Rios, A., and Valcareel, M. 1998. Determination of heterocyclic aromatic amines in fried beef steaks, meat extract and fish by capillary zone electrophoresis. *Chromatographian* vol.48, 9-10.
- [27] Omotoso, A. B. 2015. Fluoroquinolone residues in some meat types in Ibadan and effects on selected biochemical indices of broiler chicken. Ph.D. thesis, Department of Animal Science, University of Ibadan.
- [28] Iyanda, O. D. 2016. Evaluation of quality and acceptability of meat patties from different meat types extended with plant proteins. Ph.D. thesis, Department of Animal Science, University of Ibadan.
- [29] Melodie, A. C. 2016. <http://www.healthyeating.sfgate.com/nutritional-information-single-serving-steak-1895.html>.
- [30] Campo, M.M., Muela, E., Olleta, J.I., Moreno, L.A., Santaliesra-Pasias, A.M., Mesana, M.I. and Sanuda, C. 2013. Influence of cooking method on the nutrient composition of Spanish light lamb. *Journal of food composition and Analysis* (31): 185-190.
- [31] Banskalieva, V., Sahlu, T., Goetsch, A.L., 2002. Fatty acid composition of goat muscles and fat depots: a review. *Small Ruminant Research* 37, 255–268.
- [32] Goran GV, Tudoreanu L, Rotaru E, and Crivineanu V. 2016. Comparative study of mineral composition of beef steak and pork chops depending on the thermal preparation method. *Meat Science*. 2016 Aug; 118: 117-21. doi: 10.1016/j.meatsci.2016.03.031.
- [33] Wikipedia. Vegetables. <https://en.wikipedia.org/wiki/vegetable> (accessed 17 -02- 2016).