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Research Article
Effect of Temperature and Time of Frying on Polycyclic Aromatic Hydrocarbons of Fried Catfish

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Abstract

Background and Objective: Fried fish may be contaminated with carcinogenic Polycyclic Aromatic Hydrocarbons (PAHs) during the frying process. This research aimed to determine the effect of frying at various temperatures and time intervals on the concentration of PAHs generated in fried catfish. **Materials and Methods:** Samples were gutted, washed and fried in hot vegetable oil at 160, 170, 180, 190, 200, 210, 220 and 230°C for 6, 9, 12, 15 and 18 min at each temperature to determine the PAHs and free fatty acid (FFA). The PAHs content was extracted using an ultrasonicator and analyzed with gas chromatography coupled with a flame ionization detector. **Results:** The results showed that fish samples processed at 200°C for 15 min recorded the highest concentration of total PAHs 564.17 mg kg^{-1} followed by samples processed at 200°C for 6 min with total PAHs content of 304.79 mg kg^{-1}. The lowest total PAHs concentration was generated at 210°C for 9 and 12 min with concentrations of 18.16 and 23.57 mg kg^{-1}, respectively. From the results of FFA obtained, FFA was highest at a temperature of 220°C, 15 min with the concentration of 25027.56 mg kg^{-1} followed by the concentration generated at 210°C, 18 min. The lowest concentration of FFA was obtained at 190°C, 6 min with the concentration of 116.05 mg kg^{-1} followed by the concentration generated at 200°C 15 min which is 135.28 mg kg^{-1}. **Conclusion:** The proximate analysis results showed that there is an increase in the protein, fat and ash content as the temperature increases.

Key words: Frying, time, temperature, PAHs, FFA, ultrasonicator, GC/FID

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Fish has been regarded as an important dietary component and a highly desirable food because it is a cheap source of high-quality protein[1]. In Nigeria, fish consumption could take different dimensions depending on consumers' preference but many people preferred fresh fish to processed one. However, this has been hindered by the inability to keep fresh fish for a longer time due to spoilage. This resulted in higher reported consumption of smoked and fried fish with a relatively longer shelf life[2,3].

In Western Nigeria, fish frying involves the immersion of pieces of fish in hot vegetable oil and has been a common practice because it adds flavour, taste and colour to the processed fish which make it more acceptable and popular among consumers[4].

In many instances, frying could be deep which involves two processes of heat changes whereby oil is been absorbed by the food while water from the food is evaporated[5]. Sometimes, even fat can escape from the product in the oil bath during the frying of oil material presenting a significant fat content in the meat or fish[5,6].

It has been established that frying oil is normally used repeatedly at high temperatures during which it is subjected to some degradation reactions which lead to the reduced nutritional value of the fried foods[7,8]. Furthermore, the type of oil used for frying is also a determinant factor that affects the quality of fried foods. Therefore, to obtain fried foods of good quality, a selection of good quality and stable frying oil is considered necessary. Food processing methods such as smoking, drying, roasting, baking and frying have been recognized as major sources of food contaminations by Polycyclic Aromatic Hydrocarbons (PAHs)[4,6].

In the smoked foods, however, the total concentration of PAHs contamination in the processed foods depend on many factors such as the type of smoke generator, combustion temperature and degree of smoking[9]. It has been observed that the concentration of PAHs in foods increases as the level of roasting, smoking and frying increases while raw foods are known to be associated with a low level of PAHs[2,5]. However, in Nigeria, sufficient data are not available on the assessment of the level of PAHs concentration in the traditionally fried or roasted fish among people. Therefore, this research is focused on the investigation of the level of PAHs on fried catfish at different temperatures and times.

MATERIALS AND METHODS

Study area: This research study was carried out at the Industrial Laboratory of the Department of Pure and Applied Chemistry, the Ladoke Akintola University of Technology Ogbomoso, Oyo State, Nigeria from February-August, 2019 and the analysis of samples done at the Management of Environmental Resources Managers Limited, Lekki Phase 1, Lagos Nigeria.

Sampling/collection of sample: In this study, catfish which is commonly consumed as one of the cheapest sources of protein in Nigeria was used, the fish were purchased from various fish farmers and then combined in an aluminium container in Ogbomoso, Oyo State, Nigeria. The weight and the length of the fish were taken using calibrated weighing balance and ruler. The mean weight and length of the fish were 163.76±4.64 g and 20.2±1.91 cm, respectively. The fish were kept alive in the aluminium container by allowing enough water to cover the fish and brought to the laboratory where the fish were killed and allowed to pass into rigour. The fresh fish was eviscerated, beheaded and washed thoroughly with clean water and fried, while some fresh fish homogenized using a blender and dried in an oven for 48 hours at a low temperature of about 40°C.

Fish frying: The heating installation equipment consisted of a temperature controller with a temperature sensor, heating tape and heating plate. The frying temperature was constantly controlled by the temperature controller with a temperature sensor. The fish to oil ratio was kept at 1:1200 (g mL^{-1}) to maintain the frying temperature constant. The oil was pre-heated to the least operating temperature of 160°C before frying. The already gutted and washed fish were then fried in the hot oil at temperatures of 160, 170, 180, 190, 200, 210, 220 and 230°C. The samples were dried for 6, 9, 12, 15 and 18 min at each temperature to determine the PAHs and FFA in the fish samples.

Proximate analysis: The proximate analysis of samples was done using standardized methods to determine their percentage moisture content, ash content, crude fibre, crude protein, fat and carbohydrate compositions[5].

Extraction of the raw and processed fish samples: Homogenization was achieved by pulverizing the samples. About 10 g of the Pulverized sample was extracted sequentially in a test tube with 20 mL methanol using an ultrasonicator for 20 min. After which, the supernatant of the extract is decanted into a beaker and fresh 20 mL methanol is added for another 20 min of ultrasonication. This was repeatedly done with another fresh solvent for the same duration. After this, a 20 mL mixture of methanol and dichloromethane ratio 1:1 was added, then ultrasonicated for

20 min and the supernatant decanted to the beaker containing the methanol extract, this was repeated two more times. Furthermore, 20 mL of dichloromethane was added and ultrasonicated for 20 min. This step was repeated twice and the supernatant was decanted into the same beaker. The total extracts (180 mL was then centrifuged at 2500 rpm for 10 min and the supernatant was decanted and cleaned up using the Whatman filter (Whatman Clifton, NJ, USA). The extract was covered with aluminium foil which was perforated to allow the solvent to escape, before the cleanup.

The recovery experiment was carried out by spiking 5 g of the homogenized sample with 1 mg kg^{-1} of four analytes of interest (PAHs) and subject same through all extraction and analysis procedures. Spike recovery helps to determine extraction efficiency and also helps to determine the effect of the matrix on analyte recovery[5]. The percentage recovery was calculated using:

$$\text{Recovery (\%)} = \frac{\text{Spiked sample value-sample value}}{\text{Spike added}} \times 100$$

The instrument calibration was performed by using pure PAH standard mixtures with a concentration range of 2-10 μg L^{-1}. The linearity of the calibrations gave chromatograms of PAHs that the retention times were compared with the samples which guided the identification of the individual PAHs in the samples.

Samples clean up: A packed chromatographic column was used for the clean-up. About 4 g of alumina was accurately weighed into the chromatographic column and to this was also added 12 g activated silica. 20 mL of n-hexane was used for column pre-elution until the liquid started dropping. The different fractions extractions are: Saturate fraction (using n-hexane, 20 mL), Polycyclic fraction (20 mL n-hexane: Dichloromethane (3:2), Free fatty acid, (20 mL of methanol). The aliphatic fraction was subjected to further analysis while the free fatty and polyaromatic fractions were reconstituted and kept in the refrigerator for GC/FID analysis after dissolving in 1 mL n-hexane. Similar procedures were used for all the samples[10].

GC-FID determination of polyaromatic hydrocarbons (PAHs): The GC-FID was calibrated using calibration standards of 2.00, 4.00, 6.00, 8.00 and 10.00 ppm which were prepared from a mixture of PAHa standard 1000 ppm containing 23 analytes purchased from AccuStandard. PAHs concentration in the samples was determined using agilent 7890B gas chromatography coupled with flame Ionization Detector (FID) and HP-5 capillary column containing 5% phenyl methyl siloxane (30 m length' 0.32 mm diameter' 0.25 μm film thickness) (Agilent Technologies) was the stationary phase for the separation. At 300°C and 13.74 psi, the samples were injected in splitless mode with a total flow of 21.36 Ml min^{-1}. Purge flow to split vent was set at 15 mL min^{-1} at 0.75 min. The oven was initially programmed at 40°C (1 min) then ramped at 12°C min^{-1} to 300°C (10 min). FID temperature was 300°C with Hydrogen: Airflow at 30 Ml min^{-1}: 300 mL min^{-1}, Nitrogen was used as makeup gas at a flow of 22 mL min^{-1}. Quantification of PAHs was based on standard calibrations.

GC-FID quantitative determination of fatty acids methyl esters (FAMEs): Serial dilution standard of 10, 20, 30 and 100 ppm was prepared from the FAMES standard obtained from AccuStandard. HP-5 capillary column from agilent Technologies was used for the quantitative determination of FAMES. At 250°C and 9.44 psi, 1 μL of samples were introduced in the split mode in ratio 26: 1 and a split flow of 51: 50 mL min^{-1}. Septum purge flow to split vent was set at 3 mL min^{-1}. The oven was initially programmed at 50°C (1 min) then ramped at 25°C min^{-1} to 175°C (0 min) and 4°C min^{-1} to 230°C (5 min). Run time was 24.75 min. FID temperature was 280°C with Hydrogen: Airflow at 40: 450 mL min^{-1}, Nitrogen was used as makeup gas at a flow of 30 mL min^{-1}. After calibration, the samples were analyzed and a corresponding FAMEs concentration was obtained.

RESULTS AND DISCUSSION

The distribution of PAH profiles in the fried catfish sample at different temperatures and time intervals is shown in Table 1. The recovery of PAHs in the fried fish samples was in the range of 65.2-69.7%. The recoveries of PAHs in this study using ultrasonicator for extraction of the samples were within the range reported by scientific opinion on food chain contaminants as requested by EU which stipulated that recovery should range between 40-120%[3].

The frying temperature at 160°C shows that frying done for 15 min has the highest total PAH of 150.51 mg kg^{-1} followed by 9 min frying which generated 85.38 mg kg^{-1} and the least was observed in 18 min with the total PAH content of 26.32 mg kg^{-1}. For frying at 170°C, it was equally observed that frying at 15 min generated the highest total PAH of 158.12 mg kg^{-1} followed by the 6 min with the total concentration of 121.61 mg kg^{-1}. The frying that was done for

Table 1: Polycyclic aromatic hydrocarbons profile in catfish samples fried at different temperatures and time intervals in (mg kg^{-1})

	The concentration of PAHs at different temperatures in mg kg^{-1}									
PAHs	FCF 160°C 6 min	FCF 160°C 9 min	FCF 160°C 12 min	FCF 160°C 15 min	FCF 160°C 18 min	FCF 170°C 6 min	FCF 170°C 9 min	FCF 170°C 12 min	FCF 170°C 15 min	FCF 170°C 18 min
Naphthalene	0.00	0.38	0.17	0.13	0.09	0.12	Bdl	0.10	1.67	0.14
Acenaphthylene	0.31	0.16	0.27	0.25	0.19	Bdl	Bdl	0.22	0.27	0.36
Acenaphthene	0.30	0.95	0.92	0.64	0.58	0.36	Bdl	0.28	1.15	0.54
Fluorene	2.08	2.79	0.51	0.41	0.54	1.85	1.34	2.44	2.51	0.63
Anthracene	0.99	1.07	0.31	0.29	0.36	0.35	1.22	0.75	1.22	0.37
Phenanthrene	2.38	2.70	0.27	0.24	0.40	1.14	0.69	31.57	29.88	4.72
Fluoranthene	0.29	1.10	0.27	0.43	0.23	0.25	1.66	0.17	0.29	0.10
Pyrene	19.95	21.44	6.94	137.41	8.46	44.91	11.85	19.73	32.07	11.53
Benzo(c)phenanthrene	0.89	2.17	0.03	0.18	0.16	1.27	0.14	1.91	1.99	0.24
Chrysene	0.51	0.89	0.26	0.41	0.52	0.30	0.71	1.09	1.52	0.27
Benz(a)anthracene	0.35	0.81	1.01	2.09	0.80	0.55	0.37	1.18	2.14	1.12
Benzo(e)pyrene	0.04	0.05	0.08	0.04	0.01	0.16	0.43	0.34	0.14	0.01
Benzo(b)fluoranthene	6.12	8.64	4.79	1.32	4.83	5.29	0.36	12.43	12.24	2.08
Benzo(a)pyrene	1.75	1.43	0.42	0.55	0.78	0.57	8.48	1.01	0.61	0.38
Benzo(k)fluoranthene	3.14	1.52	0.60	0.43	0.84	0.60	0.27	0.26	0.21	0.85
Benzo(j)fluoranthene	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	0.99	0.06	Bdl	Bdl
7,12-Dimethylbenz(a)anthracene	1.17	0.34	0.45	0.16	0.17	0.26	10.81	0.70	1.21	13.20
Indo(1.2,3-cd)pyrene	1.46	0.33	0.34	0.35	0.79	0.79	0.32	3.53	3.21	0.54
3-Methylcholanthrene	0.52	0.45	2.50	0.46	1.01	0.54	0.38	0.70	0.45	0.32
Dibenz(a,h)anthracene	0.99	1.45	1.13	2.34	2.61	5.60	1.64	1.86	1.89	1.63
Benzo(g,h,i)perylene	0.69	1.15	0.49	0.36	0.52	0.40	0.67	1.07	0.80	0.53
Dibenzo(a,l)pyrene	25.39	22.69	37.20	1.61	0.40	46.38	43.97	0.84	58.80	27.20
Dibenzo(a,i)pyrene	2.72	1.41	0.05	0.09	1.29	0.75	4.71	7.16	1.77	0.17
Dibenzo(a,h)pyrene	5.47	11.46	19.95	0.33	0.76	9.18	4.32	6.36	2.07	2.24
Total PAH (mg kg^{-1})	77.47	85.38	78.94	150.51	26.32	121.61	95.30	95.75	158.12	69.14
PAHs	FCF 180°C 6 min	FCF 180°C 9 min	FCF 180°C 12 min	FCF 180°C 15 min	FCF 180°C 18 min	FCF 190°C 6 min	FCF 190°C 9 min	FCF 190°C 12 min	FCF 190°C 15 min	FCF 190°C 18 min
Naphthalene	0.15	Bdl	0.23	Bdl	0.14	0.15	0.12	0.16	0.12	0.09
Acenaphthylene	0.24	0.19	0.30	Bdl	0.21	0.25	0.50	0.32	0.20	0.25
Acenaphthene	0.86	1.15	0.87	0.14	0.67	0.64	0.88	0.60	0.43	0.36
Fluorene	0.77	8.55	0.76	10.74	2.60	0.21	12.10	0.68	0.71	7.09
Anthracene	0.40	6.83	0.43	0.31	0.44	0.22	1.46	0.25	0.21	9.69
Phenanthrene	4.18	3.74	3.17	11.86	4.62	1.12	24.12	2.26	4.36	0.39
Fluoranthene	0.09	24.11	0.33	2.06	0.10	0.11	0.14	0.10	0.11	14.25
Pyrene	9.93	0.43	1.73	20.49	11.57	103.22	0.44	Bdl	Bdl	1.66
Benzo(c)phenanthrene	0.80	2.66	0.36	1.23	1.67	1.20	0.57	0.96	0.16	4.15
Chrysene	0.42	4.44	0.36	0.33	0.28	0.25	0.50	0.36	0.29	20.91
Benz(a)anthracene	0.87	58.36	1.43	1.41	2.09	1.27	2.08	1.02	0.77	23.83
Benzo(e)pyrene	0.04	19.92	0.04	2.05	0.02	0.05	0.12	0.01	0.04	5.81
Benzo(b)fluoranthene	6.66	0.60	7.09	7.76	9.00	0.47	0.44	1.42	0.94	0.52
Benzo(a)pyrene	0.38	2.29	0.54	0.36	0.67	0.35	0.62	0.38	0.42	9.45
Benzo(k)fluoranthene	0.18	0.62	1.39	0.68	0.77	0.21	0.22	0.18	0.20	0.30
Benzo(j)fluoranthene	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl
7,12-Dimethylbenz(a)anthracene	22.77	4.91	1.99	1.46	0.47	25.89	5.79	8.76	10.30	9.34
Indo(1.2,3-cd)pyrene	0.29	2.00	0.56	1.54	2.47	0.39	6.32	1.05	1.15	6.95
3-Methylcholanthrene	0.36	2.89	0.43	0.46	0.77	0.65	3.89	0.32	0.42	0.33
Dibenz(a,h)anthracene	2.53	2.10	0.69	0.65	0.58	1.20	1.61	0.55	0.59	1.10
Benzo(g,h,i)perylene	0.42	0.81	0.51	0.44	0.49	0.59	2.14	0.83	0.83	0.47
Dibenzo(a,l)pyrene	28.80	0.37	42.33	35.57	26.93	21.49	0.91	17.18	21.56	0.47
Dibenzo(a,i)pyrene	0.11	55.57	0.98	0.08	0.66	0.14	0.08	0.18	0.35	15.03
Dibenzo(a,h)pyrene	1.00	0.50	0.82	2.70	0.37	0.45	0.57	1.02	1.10	1.89
Total PAH (mg kg^{-1})	82.24	203.06	67.34	102.30	67.56	160.51	65.59	38.58	45.24	119.59

Table 1: Continue

PAHs	FCF 200°C 6 min	FCF 200°C 9 min	FCF 200°C 12 min	FCF 200°C 15 min	FCF 200°C 18 min	FCF 210°C 6 min	FCF 210°C 9 min	FCF 210°C 12 min	FCF 210°C 15 min	FCF 210°C 18 min
Naphthalene	0.11	2.07	Bdl	0.29	Bdl	Bdl	0.23	0.14	0.09	Bdl
Acenaphthylene	0.19	0.53	Bdl	0.19	Bdl	Bdl	0.23	1.00	0.19	Bdl
Acenaphthene	0.58	1.48	0.64	0.13	0.28	7.01	1.00	1.19	0.29	Bdl
Fluorene	1.13	24.13	1.94	2.03	4.24	2.95	0.41	2.51	1.02	4.44
Anthracene	1.12	2.06	0.74	3.23	0.38	0.41	0.36	0.30	1.27	0.32
Phenanthrene	1.90	27.89	1.26	0.13	4.47	1.41	1.60	2.21	0.33	4.89
Fluoranthene	249.97	0.20	1.02	0.10	1.21	0.27	0.09	0.26	23.18	0.10
Pyrene	3.31	33.04	6.84	2.04	13.94	2.89	0.64	0.22	0.37	7.54
Benzo(c)phenanthrene	0.01	1.19	6.22	0.59	1.22	0.21	0.19	0.18	1.31	1.98
Chrysene	5.81	0.85	0.38	8.12	1.18	0.40	0.67	2.74	17.97	0.25
Benz(a)anthracene	2.97	1.71	1.03	0.38	0.20	1.78	4.64	2.92	41.70	7.62
Benzo(e)pyrene	2.49	0.08	Bdl	526.78	0.57	0.61	0.21	0.01	7.83	0.04
Benzo(b)fluoranthene	0.72	9.82	5.11	2.63	2.65	6.25	3.50	2.31	0.54	1.58
Benzo(a)pyrene	6.49	0.42	Bdl	3.46	Bdl	6.38	0.21	0.41	0.60	1.96
Benzo(k)fluoranthene	0.77	0.22	1.25	0.29	1.39	3.04	Bdl	0.94	0.61	0.60
Benzo(j)fluoranthene	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	1.14	Bdl	Bdl	Bdl
7,12-Dimethylbenz(a)anthracene	0.18	2.40	0.39	6.42	2.45	0.27	0.22	0.22	1.86	1.47
Indo(1.2,3-cd)pyrene	0.30	3.17	1.84	0.26	2.03	0.31	0.46	0.51	0.40	3.67
3-Methylcholanthrene	0.35	0.72	0.61	0.31	0.44	0.38	0.54	0.58	0.37	2.64
Dibenz(a,h)anthracene	0.83	0.64	1.10	0.80	1.31	0.62	0.59	0.63	0.73	4.61
Benzo(g,h,i)perylene	0.55	0.38	0.38	0.38	0.39	0.59	0.45	0.47	0.39	0.51
Dibenzo(a,l)pyrene	0.38	1.45	19.61	0.66	34.77	29.37	0.35	0.38	0.54	0.35
Dibenzo(a,i)pyrene	22.95	0.77	0.06	4.58	0.06	0.03	0.06	0.27	6.21	1.29
Dibenzo(a,h)pyrene	1.70	1.41	2.49	0.39	1.57	1.81	0.37	3.18	1.52	0.32
Total PAH (mg kg^{-1})	304.79	116.60	52.92	564.17	74.75	66.99	18.16	23.57	109.33	46.17
PAHs	FCF 220°C 6 min	FCF 220°C 9 min	FCF 220°C 12 min	FCF 220°C 15 min	FCF 220°C 18 min	FCF 230°C 6 min	FCF 230°C 9 min	FCF 230°C 12 min	FCF 230°C 15 min	FCF 230°C 18 min
Naphthalene	0.22	3.23	0.27	0.22	0.28	0.11	0.15	0.23	0.12	0.21
Acenaphthylene	0.21	2.04	0.40	0.40	0.32	0.19	0.39	0.38	0.23	0.40
Acenaphthene	0.87	14.30	3.50	2.14	1.67	0.25	0.38	0.36	0.19	0.35
Fluorene	1.43	6.09	5.26	8.10	2.01	0.96	7.95	7.02	1.04	6.53
Anthracene	0.25	1.31	0.37	0.74	0.42	1.07	0.49	0.48	0.63	0.27
Phenanthrene	1.25	5.05	6.41	8.35	3.51	0.42	10.18	8.55	3.86	7.14
Fluoranthene	0.11	0.09	0.64	0.29	0.23	24.29	0.52	1.40	0.12	0.37
Pyrene	1.10	13.45	2.83	12.62	2.66	0.61	4.51	4.10	1.85	2.97
Benzo(c)phenanthrene	0.91	1.91	1.66	0.49	0.09	0.43	0.24	0.48	0.03	0.17
Chrysene	0.24	0.38	1.00	0.65	0.68	2.65	0.32	2.77	0.34	1.23
Benz(a)anthracene	4.38	4.31	2.23	1.78	1.53	40.14	1.28	1.99	1.16	2.99
Benzo(e)pyrene	0.07	0.02	0.76	0.08	0.01	10.68	3.06	0.06	0.70	4.31
Benzo(b)fluoranthene	0.46	0.44	0.43	0.54	0.61	0.96	0.46	1.61	0.44	0.58
Benzo(a)pyrene	3.44	0.36	0.36	9.80	0.40	0.55	3.41	0.42	3.34	5.88
Benzo(k)fluoranthene	0.76	0.30	0.29	0.28	0.51	0.54	0.31	0.19	0.22	0.84
Benzo(j)fluoranthene	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl	Bdl
7,12-Dimethylbenz(a)anthracene	0.59	1.48	0.64	1.73	0.47	0.63	0.76	0.94	0.19	1.39
Indo(1.2,3-cd)pyrene	0.25	1.80	0.47	27.17	4.65	0.36	7.34	12.35	10.40	9.55
3-Methylcholanthrene	0.39	2.28	0.33	10.02	5.77	0.38	10.87	19.86	3.74	14.96
Dibenz(a,h)anthracene	1.03	0.70	0.80	4.95	3.05	0.65	10.92	13.56	0.77	13.83
Benzo(g,h,i)perylene	0.40	0.37	0.60	0.80	0.48	0.54	0.52	1.59	0.36	1.64
Dibenzo(a,l)pyrene	0.38	0.37	0.36	0.38	0.41	0.64	0.38	0.36	0.35	0.35
Dibenzo(a,i)pyrene	0.06	0.02	1.09	26.17	9.19	3.52	27.86	15.70	1.96	2.81
Dibenzo(a,h)pyrene	19.80	0.68	0.30	2.44	2.40	2.05	2.65	1.32	2.19	0.36
Total PAH (mg kg^{-1})	39.51	60.97	31.01	120.12	41.32	92.61	94.91	95.73	34.20	79.13

FCF: Fried cat fish and Bdl: Below detection limit

18 min generated the lowest total PAH of 69.14 mg kg^{-1}. The PAH profile for the frying carried out for 180°C showed that frying at 9 min generated the highest total PAH of 203.06 mg kg^{-1} followed by 15 min which generated a total of PAH 102.30 mg kg^{-1} and the least total PAHs of 67.34 mg kg^{-1} was generated at 12 min frying.

For frying at 190°C, the highest total PAH was detected at 6 min with a PAH concentration of 160.51 mg kg^{-1} followed by the frying done at 18 min with the total PAHs concentration of 119.59 mg kg^{-1} while the least total PAH was detected in frying done for 12 min with PAH concentration of 38.58 mg kg^{-1}. At 200°C, the highest total PAH was recorded at 15 min with the total PAH of 564.17 mg kg^{-1}, followed by frying carried out for 6 min which have a PAH generation of 304.79 mg kg^{-1} and the least PAH concentration recorded at 12 min with a total PAH of 52.93 mg kg^{-1}. Furthermore, the frying at 210°C showed the highest total PAH concentration at 15 min with the total concentration of 109.33 mg kg^{-1}, followed by 6 min frying with PAH generation of the 66.99 mg kg^{-1} and the least PAH at this temperature detected at 9 min with the total concentration of 18.16 mg kg^{-1}. At 220°C, frying done for 15 min produced the highest PAH concentration of 120.12 mg kg^{-1} followed by frying at 9 min which generated the PAH concentration of 60.92 mg kg^{-1} and the least total PAH was generated at the frying carried out for 12 min with the total concentration of 31.01 mg kg^{-1}. The highest PAHs concentration obtained at 230°C was at 12 min of frying, closely followed by the frying done at 9 min with total PAHs of 94.91 mg kg^{-1} and the least PAH was generated at 15 min with the total concentration of 34.20 mg kg^{-1}.

It was observed that, at the temperature of 160, 170 and 180°C, the highest total PAHs concentration for these temperatures were observed at 15 min and the least total PAHs concentrations were generated at 18 min. At 160°C the total PAH increased from 6 min to 15 min and then decreased to the least concentration at 18 min. At 170°C, the total PAH decreases from 6-12 min and sharply increased at 15 min, then decreased at 18 min to the lowest level. For the frying carried out for 180°C, the PAHs concentration decreased from 6-12 min then increased at 15 min and again decreased at 18 min. At the temperature of 190°C, the highest total concentration of PAHs was found at 6 min frying followed by 9min and the least amount of PAHs was observed at 12 min. At 200°C the total PAHs generated was found in frying done at 9 min and the least found in 12 min. For frying that was done for 210°C, the 6 min frying generated the highest level of PAHs and the least concentration of PAHs at that temperature was found at 9 min. At 220°C, 15 min frying produced the highest total PAHs of 120.12 mg kg^{-1} followed by 9 min frying with a total PAH of 60.97 mg kg^{-1} while the least total PAHs was generated at 12 min. For the frying at 230°C, the total PAH concentration was generated at 12 min followed by 9 min and least total PAHs was seen at 15 min.

The most abundant PAHs at a temperature of 160°C is pyrene which was generated at 15 min of frying with a concentration of 137.41 mg kg^{-1}. For the time of frying at 160 °C, the most abundant PAHs at 6 min, 9 min and 12 min is Dibenzo(a,l)pyrene while at 15 min and 18 min the most abundant PAH is pyrene. Benzo(j)fluoranthene was below the detection limit all the time of frying at 160°C.

The most abundant PAH at 170°C is Dibenzo(a,l)pyrene with the concentration of 58.80 mg kg^{-1} at 15 min frying time, this is also the most abundant PAH generated at 6 min, 9 min and 18 min time of frying while at 12 min the most abundant PAH is Phenanthrene. At 180°C, the most abundant PAH is Dibenzo(a,l)pyrene which was generated at 12 min with a concentration of 42.33 mg kg^{-1} and this same PAH is the most abundant at frying times of 6, 15 and 18 min. Benzo(j)fluoranthene was below the detection limit at all times of frying. The most abundant PAH obtained at a temperature of 190°C is pyrene generated at 6 min with a concentration of 103.22 mg kg^{-1}, at 9 min the most abundant PAH is Phenanthrene, at 12 and 15 min most abundant PAH is Dibenzo(a,l)pyrene. For the temperature of 200°C, the abundant PAH is Dibenzo(a,l)pyrene generated at 18 min with a concentration of 34.77 mg kg^{-1} this PAH was also found to be abundant at 12 min and pyrene was the abundant PAH at 9 min. At the temperature of 210°C, it was found that the most abundant PAH is Dibenzo (a,l) pyrene with a concentration of 29.37 mg kg^{-1} generated at 6 min. At 9 and 18 min, Benzo(a)anthracene was the abundant PAH while Dibenzo(a,h)pyrene was abundant at 12 min. For the temperature of 220°C, the most abundant PAH is Indeno (1,2,3-cd) pyrene with a concentration of 27.17 mg kg^{-1} generated at 15 min, this PAH was also abundant for 18 min, at 6 min Dibenzo(a,h)pyrene was abundant, at 9 min Acenaphthene was abundant while for 12 min, Phenanthrene was most abundant. At 230°C, Dibenzo(a,i)pyrene was most abundant with concentration of 27.86 mg kg^{-1} generated at 9 min. 3-methylcholanthrene was the most abundant at 12 min and 18 min while Indeno(1,2,3-cd)pyrene was most abundant at 15 min.

The major free fatty acid detected in the samples (Table 2) at different temperatures and time includes palmitic acid, linolelaidic acid, linoleic acid and stearic acid, they were detected at all temperatures and times while myristic acid, palmitoleic acid, trans-13-octadecenoic acid, stearic (10-octadecenoic) acid were also detected at all temperature and time except at the temperature of 190°C, 6 min where they were below the detection limit. Also, it is at this temperature and time that the lowest total free fatty acid was detected because most of the fatty acid was below the detection limit except palmitic acid, linolelaidic acid, linoleic acid and stearic acid that were detected. The most abundant

Table 2: Concentrations of total FFA obtained at various temperatures and different time intervals for fried catfish

	Total FFA in mg kg^{-1} at time interval				
Temperature (°C)	6 min	9 min	12 min	15 min	18 min
160	8821.92	13225.56	1577.80	1537.79	7597.26
170	6844.71	7550.97	7095.56	4315.85	2369.57
180	1219.53	2597.26	3819.68	3599.90	1060.58
190	116.05	4387.82	543.88	5334.02	1525.74
200	639.52	730.66	9657.51	135.28	8441.92
210	7497.14	6954.32	1724.72	9031.49	18346.00
220	259.91	7353.57	9316.78	25027.56	9846.99
230	1112.61	8149.67	11669.33	8631.02	5851.99

FFA: Free fatty acid

Table 3: Proximate composition of fried cat fish (FCF) at 160°C, 15 min and 230°C, 12 min

Temperature (°C)	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)
Raw	63.51±0.01	5.64±0.05	25.60±0.10	5.21±0.03	0.00±0.01	0.60±0.13
160	35.50±0.02	6.01±0.11	39.93±0.26	14.64±0.04	1.01±0.01	2.91±0.12
230	22.50±0.05	8.49±0.10	45.20±0.31	19.68±0.20	1.70±0.03	2.42±0.14

fatty acid was detected at a temperature of 220°C, 18 min with a total concentration of 9846.99 mg kg^{-1}. 11-hexadecenoic acid was only detected at 160°C 6 min, 170°C, 6 and 18 min and 200°C 18 min while tricosanoic acid was detected at 180°C 18 min, 210°C 18 min, 220°C, 15 min and 230°C 18 min.

The total free fatty acid decreases significantly from 160-190°C and increased from 200-210°C, then steadily decreased at 220 and 230°C showing a sharp increase. At 9 min of frying, the free fatty acids (FFA) decreased steadily from 160-180°C, it showed an increase at 190°C and sharply decreased at 200°C from there it increased to 230°C. At 12 min the FFA showed an increase from 160-170°C, then decreased to 190°C and showed an increase at 200°C, decreased again at 210°C. For the 15 min of frying, there was an increase in FFA from 160-170°C, then decreased at 180°C and later increased at 190°C from here it showed a sharp decrease at 200°C and rise again at 210°C. At 18 min of frying, there was a steady decrease in the FFA from 160-180°C, then increases to 210°C from where it decreased to 230°C.

Results of proximate composition for the raw catfish and fried catfish at the two extreme temperatures of 160 and 230°C are presented in Table 3. Fried fish at these two temperatures had a higher level of fat than the raw sample and were still higher at 230°C. The fat content of fried fish is dependent on oil absorption during the frying process. Oil penetration and loss of water due to evaporation in the food increases its fat[11]. Results similar to this was reported for African catfish fried in sunflower oil[12]. The protein content for the fried samples was generally high which is expected since fish are a good source of protein[13]. Moisture loss during the frying of fish leads to high protein content. This higher protein content in fish is important from a dietary point of view since, the quality of fish protein is very high because of its essential amino acid composition[14]. In comparison, fried fish has high protein content than fresh fish due to water loss during frying[15]. Accordingly, the increase in ash, protein and fat content found in the fried fish is explained by the reduction in moisture. The higher ash content in the fried fish might be due to its higher bony consistency nature.

CONCLUSION

The outcome of this research revealed that contrary to protein, fat, ash and fibre, the moisture content of the raw catfish sample decreases significantly after the frying process, which is attributed to loss of water during the process. The protein content of the fried fish at the temperature and time were found to increase as a result of an increase in dry matter content owing to sample dehydration. The result also showed that for frying carried out at the various temperature and time intervals, the lowest total PAHs concentration was generated at a temperature of 210°C at 9 and 12 min with concentrations of 18.16 and 23.57 mg kg^{-1}, respectively. The result is significant because it informs the food processing industries and individuals that for good quality fried fish, the best frying temperature is 210°C at 9-12 min.

SIGNIFICANCE STATEMENT

This study discovered for the first time that frying at 210°C for between 9 and 12 min generated the least amount of PAHs. This research will help the researcher to uncover the

difference between the EU regulatory limit of 5 μg kg^{-1} PAHs in fish consumption and the actual concentration in the fried fish. Thus, the fish processor, traders and consumers will be better educated on how to reduce their dependency on fried fish.

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