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Original Article

Deep frying impact on the polycyclic aromatic hydrocarbon, textural, thermal and nutritional properties of African Snail

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ABSTRACT

Processing conditions are important in the quality and preservation of meat of various kinds and sources. Frying is one of the processing techniques often employed in meat products, snail meat inclusive. This study evaluated the effect of deep frying on the polycyclic aromatic hydrocarbon, textural, thermal, and nutritional properties of African snail meat. Fasted snails were processed and deep-fried at varying time intervals (0, 4, 8, 12, and 16 minutes) before retrieval for analysis. The polycyclic Aromatic Hydrocarbons (PAHs) of deep fried African snails at varying times revealed that Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3–cd}, phyrene, Dibenzo(a,h), Anthracene, Benzo(g,h,i), perylene were detected in all the snails irrespective of the frying time. The thermal properties of the fried snail samples for different time intervals revealed that thermal conductivity, specific heat capacity and thermal diffusivity ranged from 901.62 - 4,849.13 w/m^{2}k, 485.68 - 2169.19 Jkg^{-1o}C^{-1} and 0.1932 – 0.2375 m2/s, respectively. The proximate composition showed the impact of frying condition. The mineral composition showed that the calcium, iron, potassium, sodium, zinc, and magnesium elemental content of the fried snail meat ranged from 195.50 - 277.50 mg/100g, 8.10 - 9.85 mg/100g, 22.50 - 37.50 mg/100g, 212.50 - 297.50 mg/100g, 0.18 - 0.35 mg/100g, and 67.50 - 92.50 mg/100g, respectively. The deep frying caused a significant reduction in the moisture content of the snail meat and influenced the textural properties of the snails significantly. The values obtained for Polycyclic aromatic hydrocarbons compared with the recommended limit determined do not pose any danger to consumers.

KEYWORDS: *Aromatic hydrocarbons, Deep frying, Polycyclic, Snail meat, Textural properties, Thermal*

INTRODUCTION

Snail meat has been an important alternative since reported rich in protein and essential mineral content and also low cholesterol (Adeyeye *et al.,* 2021). Snails are also a good source of amino acids and their content in essential amino acids, leucine and lysine (Ahmad *et al.,* 2018). Also, snail meat has been discovered to have high quality protein, important amino acids, minerals, vitamins B complex and C, respectively (Djikeng *et al.,* 2022). Most meat consumed are usually processed into edible meat through heat energy application in form of cooking, roasting, frying and grilling (Oyedeji *et al.*, 2017; Adeyeye *et al.*, 2021; Djikeng *et al.*, 2022). According to Oyedeji *et al.* (2021), texture is a quality attribute which is important in determining the acceptability of fried products as the resulting texture of fried foods is dependent on the

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properties of raw materials such as starch content, size of starch granules, cell wall polysaccharides, nonstarch polysaccharides, pectin substances, and the processing conditions which include frying time and temperature. Dueik *et al*. (2010) stated that, frying as a complex unit operation is essentially a cooking process that has been widely used in the preparation and production of food. It involves the immersion of foods in frying oil chambers at varying dept, mostly at temperatures above the boiling point of water. This in most cases, cause a counter-flow of bubbles of water and oil on the surface of the food product. Deep fat frying is usually carried out at atmospheric pressure conditions and high temperatures of between 170 and 200°C (Saguy & Dana, 2003;Oke *et al.*, 2017). Frying techniques vary in the amount of fat required, the cooking time, the type of cooking vessel required, and other changes made to the food. Sautéing, stir frying, pan frying, shallow frying, and deep frying have been reported as standard frying techniques (Dana & Saguy, 2001; Saguy & Dana, 2003;Oke *et al.*, 2017). Deep frying of food are usually achieved by completely submerging food materials in hot oil at temperatures typically between 177 and 191°C in some cases it may exceed this temperature (Saguy & Dana, 2003; Bittman, 2013). However, it is pertinent to study the effect of processing method (deep frying) on the quality and textural properties of snail (*Achartinal marginata*) considering the possible shift to snail meat as alternative and healthy meat be consumed. Deep-frying is a popular cooking method. It has tendency to impact the snail meat quality, texture, thermal properties and polycyclic aromatic hydrocarbon (PAHs) content with increase in frying time and other processing conditions. This, the study attempted to evaluate.

According to Wangboje (2024) effort have been made by many researchers to study the PAHs because of the possibility of being hazardous to health (genotoxic, carcinogenic, mutagenic and teratogenic effects) on human being and wildlife when consumed. According to Ifegwu & Anyakora (2015) the possibility of PAHs to bind with DNA often aid the carcinogenicity of PAH impact that can cause tumor initiation. The possible sources of PAHs is not limited to natural sources like volcanic eruptions, forest fires, combustion of fossil fuels, coal gasification, many human activities, like processes employed in the food value chain can also initiate the possibilities of PAHs on food materials (Alomirah *et al*.,2011;Sakin et. al., 2022; Wangboje, 2024). Wangboje, 2024 reported that PAHs may be made up of either a light molecular weight or heavy molecular weight subject to mode of formation. However, irrespective of these, they have serious implication if consumed beyond recommended quantities (Akpambang *et.al.* 2009; Ifegwu & Anyakora , 2015; Sakin et. al., 2022; Wangboje, 2024;)!

MATERIALS AND METHODS

Source of Snail

The snails used for this experiment were purchased from Sabo market in Ikorodu Lagos State, Nigeria. A total of Fifty (50) adult snails (*Archachatina marginata*) were purchased and used for the study. The snails were fasted for 24 h to empty their guts and to reduce contamination during processing. The snails were weighed and separated into meat, shell, waste and fluid. The separated meat was also weighed. Snail meats were fried with the aid of Chief master Crown star 3.5L Deep Fryer MC-DF3139 at 180°C . The snail meats were fried at varying time of 0, 4, 8, 12 and 16 min. respectively. Thermal probe was inserted into the centre of the snail meat to measure the temperature at the centre and placed in a deep fryer with vegetable oil. After frying, meats were removed from oil, allowed to cool and weighed. Snail meat products were allowed to cool before packaging for subsequent analysis. All products were sealed in low density cellophanes.

Polycyclic Aromatic Hydrocarbons

The GC-MS/MS method validation was used to evaluate the Polycylic Aromatic Hydrocarbon of fried snail samples according to method reported by Hokkane *et al.* (2018). The parameters tested were specificity, selectivity, linearity, repeatability, within-laboratory reproducibility, apparent recovery, the limit of detection (LOD), the limit of quantification (LOQ), and trueness as reported by Hokkane *et al.* (2018). Deep fried snail meat sample test material was analyzed for B[a]P, B[a]A, and B[b]FA, and z-scores were fixed as -0.7, 0.1, and -0.4, respectively. Each GC-MS/MS run was preceded by a system performance check with the standard solutions containing 0.011 and 0.064 $mg\text{-}mL^{-}1$ of PAH4 standards (PAH-Mix 183, Dr. Ehrenstorfer GmbH, and Augsburg, Germany). The standard solutions were injected at varying period (beginning, in the middle, and at the end of each sample batch).

Textural Analysis

Determination of mechanical properties of fried snail

Texture of the Snail samples was determined by using texture analyser (Model CT310K Texture Analyzer,USA).Texture profile analysis was performed on central snail slices by TPA test with a 3mm cylindrical stainless steel (TA 44 probe).Downward speed was 0.5mm/sand upward speed 0.5mm/s with a trigger load of 4.0g.Texture TA-RK-KI/Load cell;10kg.TeTPA parameters were calculated according to techniques reported by Guinee (2003) such as hardness(g) (Force required for a pre-determined deformation).

Determination of specific heat capacity

The heat energy needed to increase the temperature of a unit mass of a substance (snail meat) by a unit of temperature (1°C) is referred to as the specific heat capacity. This is usually expressed in joules per kilogram per Kelvin and was determined using the expression in equation 1 as reported by Bolaji *et al.* (2018)

$$C = \frac{Q}{m\Delta T} \qquad (1)$$

Where Q is in joule, quantity of Heat energy applied to the snail meat, m in Kg (Mass of snail meat) and ΔT in ºC (Change in Temperature).

Determination of thermal conductivity

Thermal conductivity is the property of a snail meat which indicates the ability of snail meat to conduct heat. This was derived from the Fourier's law for heat conduction as shown in equation 2 and equation 3, respectively.

$$H = \frac{\Delta Q}{\Delta t} = K \; x \; A \; x \; \frac{\Delta T}{h} \qquad (2)$$

Where $\frac{\Delta Q}{\Delta t}$ is the rate of heat flow in the snail meat, K is the thermal conductivity of the snail, A is the Cross sectional area of snail surface and ΔT is the temperature difference and h is the thickness of conducting surface separating the two temperatures. A re- arrangement of the equation 2 gives thermal conductivity as shown in equation 3

$$K = \frac{\Delta Q}{\Delta t} \; X \; \frac{1}{A} \; x \; \frac{h}{\Delta T} \qquad (3)$$

Determination of thermal diffusivity

The molecular diffusivity of heat is a measure of the ratio of heat transmission and energy storage capacities (Saguy & Dana, 2003; Elansari & Hobani, 2009; Bolaji *et al.* 2018). The thermal diffusivity is a quantity which measures the rate of temperature changes and indicates the speed at which temperature equilibrium will be reached. The thermal conductivity experiment was used to determine thermal diffusivity since it's a function of conductivity, specific heat and bulk density of materials (Saguy & Dana, 2003; Elansari & Hobani, 2009; Bolaji *et al.* 2018) as the equation above implies.

$$\alpha = \frac{K}{PC} \qquad (4)$$

where α is the thermal diffusivity (m^2/s), K is the thermal conductivity (w/m ºC), P is the bulk density and C is the specific heat capacity (J/KgK)

Determination of densities of snail meat

Density is the ratio of mass to the volume of a snail meat(Kg/m^3). It explains how loosely or tightly a snail meat is packed (Elansari & Hobani, 2009; Bolaji *et al.* 2018).

$$\rho = \frac{m}{v} \qquad (5)$$

Where, ρ is the density, m is the mass and V is the volume of snail meat

Different food materials usually have different densities.

Color Analysis

Color of the samples was measured using a colorimeter (Konica Minolta CR-210 chronometer) and recorded in the *L**, *a**, *b** color system. The colorimeter was calibrated using a standard white plate. Samples were placed in the sample holder for measurement. Color values were recorded as *L**(lightness), *a** (redness), *b** (yellowness) color system as described by Akissoe *et al. (2003)*.

Proximate and mineral composition of grilled Snail Samples

The moisture content, crude protein, fat content, crude fibre, ash and carbohydrate were determined using standard methods (AOAC, 2005) . The Mineral Elements were determined using wet ashing technique and spectrophotometric measurement of the mineral content (Shahidi, 2000).

Sensory Evaluation

Twenty (20) panelists were used to access the following attributes - taste, aroma, texture and colour, flavour and overall acceptability using 9-point hedonic scale ranging from 1-9, 1 representing extreme dislike and 9, extreme like.

Statistics Analysis

The riplicate Data obtained for the parameter measured were subjected to statistical analysis using SPSS 17. Analysis of variance (ANOVA) and difference among means were conducted using Duncan multiple range test. Sigma plot was used to compute and model the thermal properties.

RESULTS AND DISCUSSION

Polycyclic Aromatic Hydrocarbon of Fried African Snails at Different Frying Times

The polycyclic aromatic hydrocarbon of fried African snails for different frying time are shown in Table 1. The polycyclic aromatic hydrocarbon (PAH) of deep fried African snails at varying time revealed that identified PAH and their content in mg/1000g: naphthalene (8.27467×10^{-6} - 1.00490×10^{-5}), Acenaphthylene, Acenaphthene (4.73062×10^{-6} - 2.84674×10^{-5}), Fluorene(8.454683×10^{-5} – 3.08275×10^{-3}), Phenanthrene (1.62930×10^{-3}-2.70157×10^{-3}-), Anthracene(8.17624×10^{-3} – 2.60615×10^{-3}), Fluoranthene(9.9664×10^{-4} – 1.27823×10^{-4}), Pyrene(8.77023×10^{-4} - 1.19790×10^{-3}) , Benzo(a) anthracene (7.18858×10^{-5} - 1.05074×10^{-4}), Chrysene (8.17624×10^{-5} - 1.10014×10^{-4}), Benzo(b)fluoranthene (9.31622×10^{-6} - 1.11118×10^{-5}), Benzo(k)fluoranthene(6.86913×10^{-6} – 2.359470×10^{-5}), Benzo(a)pyrene (8.95485×10^{-5} - 1.05244×10^{-4}), Indeno (1,2,3–cd) phyrene (9.97640×10^{-7} - 3.3153×10^{-7}), Dibenzo (a, h) anthracene (5.99440×10^{-6} – 1.7589×10^{-6}) and Benzo (g, h, i) perylene (9.86829×10^{-7} - 2.81192×10^{-6}).

Assessment based on the frying method with average concentration of each polycyclic aromatic hydrocarbon (PAHs) in the sample under study with different frying time was displayed in Table 1. All samples include PAHs, but in comparatively small amounts. All the fried snails had IP and B[a]P at concentrations lower than 1 µg/kg and also lower than the reported by by Manda *et al*. (2012). Additionally, the values found in this study are less than those found in samples of grilled fish in Nigeria by Akpanbang *et al.* (2009). The presence of PAHs in food depends not only on the type of food but also on how the food is prepared and combined with other factors, such as environmental contaminants (Kim *et al.*, 2011; Olatunji *et al.*, 2014; Jiang *et al*., 2018; Onopiuk *et al.*, 2021).

Table 1: Polycyclic Aromatic Hydrocarbon of Fried African Snails at varying frying times

PAHs	**M3G (mg/Kg)**	K8P (mg/Kg)	S4N (mg/Kg)	M12 (mg/Kg)	W16 (mg/Kg)	**Maximum permissible level (EU)**
Naphthalene	7.016×10^{-6}	8.275×10^{-6}	1.005×10^{-6}	7.110×10^{-6}	6.078×10^{-6}	2.0
Acenaphthylene	1.594×10^{-5}	2.829×10^{-5}	1.438×10^{-5}	1.045×10^{-5}	4.731×10^{-6}	2.0
Acenaphthene	5.108×10^{-5}	3.867×10^{-5}	6.013×10^{-5}	3.683×10^{-5}	2.847×10^{-5}	2.0
Fluorene	8.4547×10^{-5}	4.761×10^{-5}	5.98×10^{-5}	5.3666×10^{-5}	2.945×10^{-5}	2.0
Phenanthrene	1.629×10^{-3}	2.291×10^{-3}	3.082×10^{-3}	3.043×10^{-3}	2.703×10^{-3}	2.0
Anthracene	8.542×10^{-2}	6.609×10^{-3}	6.226×10^{-3}	3.205×10^{-3}	2.606×10^{-3}	2.0
Fluoranthene	9.96644e-4	5.763×10^{-4}	2.946×10^{-4}	1.80793e-4	1.278×10^{-4}	2.0
Pyrene	1.198×10^{-3}	8.770×10^{-4}	1.336×10^{-3}	1.608×10^{-3}	1.631×10^{-4}	2.0
Benzo(a)anthracene	1.051×10^{-4}	7.188×10^{-5}	6.1495×10^{-5}	2.758×10^{-5}	2.136×10^{-5}	2.0
Chrysene	8.176×10^{-5}	7.965×10^{-5}	1.100×10^{-4}	1.458×10^{-4}	1.379×10^{-4}	2.0
Benzo(b)fluoranthene	9.316×10^{-6}	1.111×10^{-5}	3.880×10^{-5}	2.449×10^{-5}	1.319×10^{-5}	2.0
Benzo(k)fluoranthene	6.869×10^{-6}	5.767×10^{-6}	4.755×10^{-6}	2.838×10^{-6}	2.359×10^{-5}	2.0
Benzo(a)pyrene	1.052×10^{-4}	1.089×10^{-4}	3.164×10^{-4}	2.112×10^{-4}	8.955×10^{-5}	2.0
Indeno(1,2,3–cd}phyrene	9.976×10^{-7}	7.225×10^{-7}	7.155×10^{-7}	$5.162 \times 10^{-}$	3.315×10^{-7}	2.0
Dibenzo(a,h) Anthracene	5.722×10^{-6}	5.994×10^{-6}	5.788×10^{-6}	2.23×10^{-6}	1.759×10^{-6}	2.0
Benzo(g,h,i)perylene	3.915×10^{-6}	2.811×10^{-6}	2.150×10^{-6}	9.868×10^{-7}	7.409×10^{-7}	2.0

M3G: *Control (unfried snails meat),* ***K8P:*** *snail meat fried for 4 min,* ***S4N*** *snail meat fried for 8 min.,* ***M12:*** *snail meat fried for 12 min. and* ***W16*** *snail meat fried for 16 min.*

The cooking technique employed in this investigation was shown to considerably lower the levels of PAHs. The detected level of B[k]F was below the limit of detection. Manda *et al*. (2012) stated that PAHs are not present in oil produced under ideal circumstances. However, repeated use of oil during frying may influence the PAHs quantity in the oils or the product it is used for (Alomirah *et al*., 2011; Olatunji *et al*., 2014; Jiang *et al*., 2018; Onopiuk *et al*., 2021). Some researchers reported that the source of the PAH contamination may be connected to unethical processes in food production and as well the level of ignorance of food processor about the implication of such practices (Chung *et al*., 2011; Adeyeye *et al*., 2021;Zhang *et al*., 2022). This could also be related to the usage of certain ingredients and cooking processes (Adeyeye *et al*., 2022; Chen *et al*., 2021; Zhang *et al*., 2021).

Textural Properties of Fried Snail Samples for Different Time Interval

The textural properties of properties of fried snail meat at different time interval are shown in Table 2. The peak force of the snail samples ranged from 7274.00 – 20740.50 g. There was no significant difference ($p>0.05$) among the samples except sample M3G and M12. Hardness which is often described as the compactness of structural organization for starch and protein complexes of the fried snail samples decreased with increase in the heat energy and time of heat treatment. Contrary to the report of Jiang *et al*. (2018), where higher frying temperatures was implicated to have tendency to cause the surface of the sample to form a harder crust much faster, resulting in a greater hardness. The decreasing hardness could be due to gradual loss of moisture content of the snail meat and the internal cooking nature of the meat (Chen *et al*., 2021). The height of the fried snail meat samples measured by the textural analyser although showed no significant difference ($p>0.05$) ranged from 12.53-25.59 mm. The individual weight of the snail meat samples ranged from 4.00-14.50 g. There was no significant difference ($p>0.05$) in the values recorded for springiness of fried snail meat. This however reflect the degree to which fried snail meat product should returns to its original shape once it has been compressed between the teeth during consumption(Ibadullah *et al*., 2019). The high values of springiness is indicated there will be need for increased mastication energy in the mouth (Ibadullah *et al*., 2019). This is expected to decrease with increased mastication and reduction in size (Szczesniak 2002;Ibadullah *et al*., 2019)

Table 2: Textural Properties of Fried Snail Samples for Different Time Interval

Samples	**Peak Force (g)**	**Height (g)**	**Weight (g)**	**Springiness**	**Area (J)**	**Stickiness (g)**
M3G	20740.50±3007.33[a]	12.53±5.80[b]	10.50±0.71[a]	0.25±0.03[a]	57061.91±19327.56[ab]	-29.00±22.63[a]
K8P	16936.00±6870.25[ab]	23.27±1.81[a]	14.50±0.71[a]	0.62±0.09[ab]	73621.79±23768.89[ab]	-2.50±2.12[a]
S4N	16359.50±194.45[ab]	25.59±1.73[a]	14.00±135.77[a]	0.84±0.23[a]	92598.08±8078.01[a]	-12.50±143.50[a]
M12	7274.00±2586.21[b]	24.13±1.26[a]	8.00±2.83[a]	0.83±0.25[a]	37112.27±6781.16[b]	-4.00±2.83[a]
W16	14570.00±4068.69[ab]	23.05±2.87[a]	4.00±0.00[a]	0.63±0.05[ab]	67724.83±4546.51[ab]	-3.00±0.00[a]
Samples	Resilience	Stringiness	Adhesiveness	Gumminess	Chewiness	Cohesiveness
M3G	0.18±0.01[c]	1.78±2.12[a]	20.37±28.10[a]	7699.00±1961.30[a]	1944.50±666.80[a]	0.37±0.04[b]
K8P	0.39±0.06[a]	0.38±0.53[a]	0.45±0.64[a]	13360.00±6870.25[a]	8586.50±5931.69[a]	0.77±0.10[a]
S4N	0.43±0.05[a]	1.95±2.75[a]	218.45±308.93[a]	11442.00±250.32[a]	9637.50±2762.67[a]	0.70±0.03[a]
M12	0.33±0.04[ab]	0.01±0.01[a]	0.00±0.00[a]	5397.00±2626.20[a]	4760.50±3500.89[a]	0.73±0.11[a]
W16	0.24±0.06[bc]	1.06±0.35[a]	1.16±0.06[a]	9470.50±4148.60[a]	6037.50±3121.88[a]	0.64±0.11[a]

**Mean± standard deviation with same superscripts along the column are not significantly different at (p>0.0)*

M3G: Control (unfried snails meat), **K8P:** snail meat fried for 4 min, **S4N** snail meat fried for 8 min., **M12:** snail meat fried for 12 min. and **W16** snail meat fried for 16 min.

The stickiness of the snail meats ranged from – 29.00 to – 2.50. The resilience of the snail meat samples ranged from 0.18 - 0.43. There was no significant difference ($p>0.05$) for snail meat 's Adhesiveness. Adhesiveness represent the possible work required to overcome the attractive forces between the surface of fried snail meat and the surface of other materials with which the food comes into contact (; Adeyeye *et al*., 2021; Adeyeye *et al*., 2022; Chen *et al*., 2021). The chewiness of the snail samples ranged from 1944.50 - 9637.50. Chewiness is the energy required to masticate a solid food to a state ready for swallowing (Szczesniak 2002). Chewiness is a function of the fried snail meat hardness, cohesiveness, and springiness (Szczesniak 2002). The chewiness differences in the samples could be attributed to the size of the snail pieces, heat treatment, and protein-water and protein-protein interactions that most likely occurred during frying given the high moisture and protein contents in the meat muscle (Iheagwara *et al*., 2021). The snail meat samples exposed to minimal heat treatment had significantly higher chewiness compared to other samples with high heat treatment 4 to 12 min. in particular. Chewiness can also be influenced by the mode/nature of heat treatment and salt concentration as reported by Iheagwara *et al*.(2021).

The cohesiveness of the snail meat ranged from 0.37-0.77 and these were similar to values reported by Iheagwara *et al*.(2021). The cohesiveness of control sample was significantly lower ($p<0.05$) than that of fried sample compared with fried snail meat samples this was in line with report of previous studies (Iheagwara *et al*.2021). The textural properties (height, weight, springiness, area, resilience, chewiness and cohesiveness) of the fried snail samples, increased with increase in frying time. This could be due to the intensity of the heat. According to Chen *et al*. (2021), revealed the influence of deep frying on the microstructure of food materials as the snail meat subjected to heat application which causes rapid water loss at the surface.

Thermal Properties of Fried Snail Samples at Different Time Interval

The thermal properties **o**f fried snail samples for different time interval are shown in Figure 1,2 and 3. The thermal conductivity of the fried snails ranged from 901.62-4,849.13 w/m^2 ^{o}C. The highest value was observed in sample M3G while the lowest value was recorded in sample WI6 as shown in Figure 1 and 2. There was a linear relationship between the frying time and the temperature at the center of the snail meat!. The snail meat temperature was directly proportional to the deep frying time. The snail center temperature increased from 0 to 22.88^{o}C/min, this subsequently decreased as shown in figure 1. The snail center temperature after 16 min was averagely 154.9 ^{o}C. The specific heat capacity reduced with increase in temperature and time of frying (Figure 3). This corroborated with the findings of some researchers (Pan & Singh, 2001; Hobani & Elansari, 2004; Oke *et al*., 2012; Bolaji *et al*., 2018) where there was reduction in the value of specific heat capacity with decrease in moisture content. The thermal diffusivity of the fried snails ranged from 0.1932 – 0.2375 m^2/s and also decrease with increase in the frying time and decrease in moisture content. This revealed the capacity of the snail meat to conduct heat compared to its heat-storing capacity. The thermal properties of the fried snail samples decreased with increase in frying time. This decreasing trend as a function of frying time corresponded with the report of Oke *et al*. (2012).

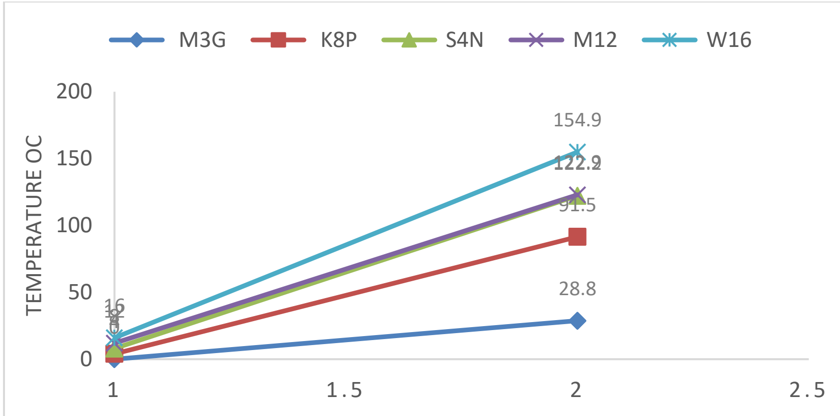


Figure 1:Relationship between snail meat center Temperature-deep frying time

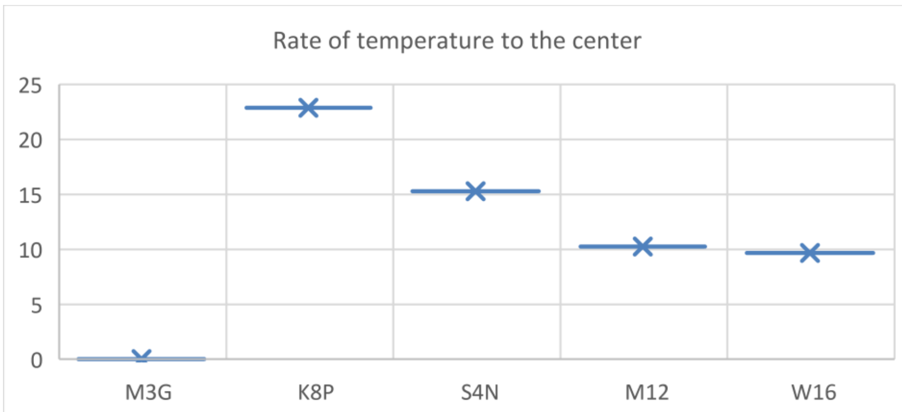
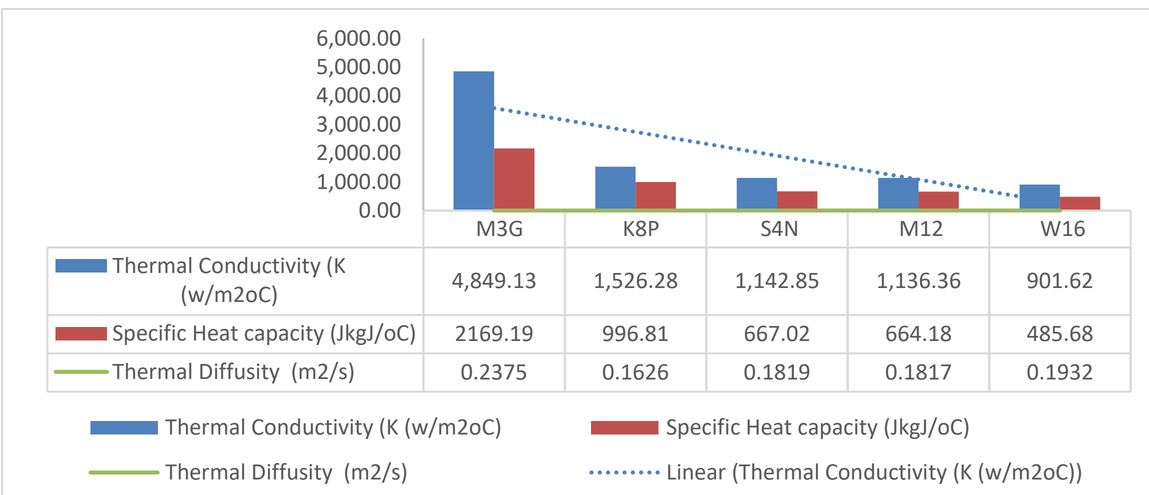


Figure 2 : Rate of Snail meat center temperature



	M3G	K8P	S4N	M12	W16
Thermal Conductivity (K (w/m2oC)	4,849.13	1,526.28	1,142.85	1,136.36	901.62
Specific Heat capacity (JkgJ/oC)	2169.19	996.81	667.02	664.18	485.68
Thermal Diffusity (m2/s)	0.2375	0.1626	0.1819	0.1817	0.1932

Figure 3 : Thermal Properties of Fried Snail Samples at Different Time Interval

Proximate Composition of Fried Snail Samples at Different Time Interval

The proximate composition of fried snail samples for different time interval are shown in Table 3. The moisture content of the fried snails ranged from 22.55-68.72%. Significant reduction was observed in the moisture content of the snail samples with increase in frying time. The moisture content of the samples reflected the sensitivity in the choice of storage and handling before consumption or distribution in the case of large production.

The result aligned with the findings of Djiken *et al*.(2022) for snails processed with different processing methods. The value obtained for protein in this study were higher than crude protein reported for some processed food (Iwanegbe *et al.,* 2019;Djiken *et al*. 2022). The protein range obtained in this study was significantly lower compared to 82.96% reported by Engmann *et al*. (2012)

Table 3 : Proximate Composition of Fried Snail Samples for Different Time Interval

Samples	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)	Total Ash (%)	Carbohydrate (%)
M3G	68.72±0.40[a]	18.85±0.35[e]	0.94±12.83[a]	0.00±0.00[a]	1.89±0.06[d]	8.65±0.60[c]
K8P	57.60±0.85[b]	26.69±1.53[d]	3.16±0.08[a]	0.00±0.00[a]	2.03±0.19[cd]	10.54±0.96[c]
S4N	53.91±1.29[c]	34.42±0.45[c]	2.93±0.33[a]	0.00±.0.00[a]	2.72±0.26[a]	6.35±0.70[d]
M12	35.05±1.34[d]	39.13±0.18[b]	8.31±0.20[a]	0.00±0.00[a]	2.53±0.11[ab]	14.99±1.08[b]
W16	22.55±0.64[e]	46.67±0.49[a]	4.23±0.32[a]	0.00±0.00[a]	2.45±0.32[ab]	24.12±0.15[a]

**Mean± standard deviation with same superscripts along the column are not significantly different at (p>0.05)*
***M3G:** Control (unfried snails meat), **K8P:** snail meat fried for 4 min, **S4N** snail meat fried for 8 min., **M12:** snail meat fried for 12 min. and **W16** snail meat fried for 16 min.*

However, they were closed values reported by Envin *et al*. (2020) The significant increase in protein content observed with frying time can be explained by the fact that heat and processing time have released some proteins that were attached to other molecules by breaking the low energy bond and making them more available (Oke *et al*., 2012; Iwanegbe *et al*., 2019;Djiken *et al*. 2022). This result is in agreement with the findings of Djikeng*et al*.2022) who signaled that frying, oven baking and grilling significantly increase the protein content of sardine fillets. The crude fat content ranged from 0.94-8.31 and there was no significant difference (p>0.05) among the samples. The value obtained in this study were similar compared to the value reported by Iwanegbe *et al*.(2018). A significant increase (p<0.05) in this parameter was registered with all the fried samples compared to the control. The high fat content obtained with the fried samples was obviously due to the absorption of oil by snail meat during frying (Saguy & Dana, 2003). The total ash content of the fried snail samples ranged from 1.89-2.72 and the carbohydrate content ranged from 6.35 - 24.12 %. The range of the carbohydrate content of snail samples is in good harmony with the range reported by Djikeng *et al*. (2022) A significant decrease (p<0.05) in this parameter compared to the control was noted in all the samples.

Mineral Composition of Fried Snail meats at Different Time Interval

The mineral composition of fried snail samples for different time interval are shown in Table 4, significant difference existed in values obtained for the mineral content. The calcium, iron,, Magnesium, content of the fried snails ranged from 195.50 - 277.50 mg/100g, 8.10 - 9.85 mg/100g, 67.50 - 92.50 mg/100g.

According to Khlyntseva *et al.* (2009). Calcium present in food material plays important role in the body. Zinc participates in nucleic acid and protein metabolism and is a good antioxidant Magnesium is an important element in cellular biochemistry and function. It can be noted that all fried snail samples the processed samples exhibited significantly higher (p<0.05) mineral contents compared to the control sample. A significantly higher value of calcium was reported by Uboh *et al*. (2014) for unprocessed snail meat (A. marginata), however, a contrary lower values were reported in this work for fried snail meat when compared with values reported for boiled and roasted snail meat. The relatively high calcium content compared to the control can be explained by the release of bound calcium molecules by the heat (Pereira *et al*., 2013).

Table 4: Mineral Composition of Fried Snail Samples for Different Time Interval

Samples	Calcium (mg/100g)	Iron (mg/100g)	Potassium (mg/100g)	Sodium (mg/100g)	Zinc (mg/100g)	Magnesium (mg/100g)
M3G	195.50±3.54[d]	8.10±0.14[d]	22.50±3.54[b]	212.50±3.54[c]	0.18±0.04[c]	67.50±3.54[d]
K8P	242.50±3.54[c]	9.05±0.21[c]	32.50±3.54[a]	282.50±3.54[b]	0.28±0.04[b]	77.50±3.54[b]
S4N	262.50±3.54[b]	9.35±0.07[c]	37.50±3.54[a]	297.50±.3.54[a]	0.32±0.04[a]	87.50±3.54[a]
M12	270.00±0.00[ab]	9.55±0.21[ab]	32.50±3.54[a]	285.00±0.00[b]	0.28±0.01[b]	72.50±3.45[bc]
W16	277.50±3.54[a]	9.85±0.07[a]	35.00±0.00[a]	297.50±3.54[a]	0.35±0.00[a]	92.50±3.54[a]

*Mean± standard deviation with same superscripts along the column are not significantly different at (p>0.0)

***M3G:** Control (unfried snails meat), **K8P:** snail meat fried for 4 min, **S4N** snail meat fried for 8 min., **M12:** snail meat fried for 12 min. and **W16** snail meat fried for 16 min.*

Similarly, low iron content for snail meat was reported by some researchers (Djikeng *et al.* 2022) The zinc content in this study was significantly lower when compared with values reported (Engmann *et al.* 2012 ;Pereira *et al.,* 2013). Along with vitamin A, zinc plays a role in dark adaptation and night vision for human(Djikeng *et al.* 2022)

Colour Attributes of Fried Snail Samples at Different Time Interval

The colour attributes of fried snail samples at different time interval are shown in Table 5. The color of the product was measured by the Hunter system using L, a and b. . The L (brightness) value of the fried snails ranged from 23.63 - 38.92.. L value is a measure of the light-dark (brightness) fraction of food surface color. As shown in Table 6, the L* value increased with the increase in frying time although decreased by 8 min. of frying. Colour of food could be due to browining reactions as a result of thermal treatment used in processing methods (Saguy & Dana, 2003). The a* value of the fried snails ranged from -0.02 - 2.34. The b* value of the fried snails ranged from 1.67 - 9.24. There was no significant difference (p>0.05) among the samples except sample K8P and M12. The colour parameters of the snail samples gradually decreased after eight (8) minutes of frying. The significant decrease in b* and other colour parameters could be attributed to the browning effect of the snail meat during deep frying.

Table 4: Colour Attributes of Fried Snail Samples for Different Time Interval

Samples	L*	a*	b*	ΔE*
M3G	27.01±1.00^{d}	1.39±0.01^{b}	8.29±0.57^{ab}	9.63±0.15^{c}
K8P	33.70±0.14^{c}	1.42±0.03^{b}	9.24±0.38^{a}	11.56±0.21^{b}
S4N	38.92±0.05^{a}	-0.02±0.74^{c}	6.64±0.35^{c}	12.44±.0.16^{a}
M12	36.52±0.04^{b}	2.34±0.03^{a}	7.37±0.01^{bc}	11.52±0.01^{b}
W16	23.63±0.06^{e}	1.44±0.04^{b}	1.67±0.75^{d}	6.19±0.71^{d}

L Lightness (+) blackness (-); a* Redness (+) and greenness (-); b* Yellowness (+) and blueness (-); ΔE - Total colour change.*
**Mean± standard deviation with same superscripts along the column are not significantly different at (p>0.05).*
***M3G:** Control (unfried snails meat), **K8P:** snail meat fried for 4 min, **S4N** snail meat fried for 8 min., **M12:** snail meat fried for 12 min. and **W16** snail meat fried for 16 min.*

similarly, The colour difference value in the snail samples could be due to the ingredient composition and red pigmentation resulting from the Maillard reaction or non-enzymatic browning which depends on the content of reducing sugars and amino acids or proteins on the surface, temperature, and (Pereira *et al.,* 2013)

Sensory Evaluation of Fried Snail at Different Time Interval

The sensory evaluation of fried snail for different time interval are presented in table 6. The colour ranged from 3.25-7.75. The most preferred colour was observed in sample W16 while the least preferred colour was recorded in sample M3G probably for its unprocessed nature. Generally, sample MSG was poorly scored and was significantly different ((p<0.05) from all the fried snail meat. The taste of the snail samples ranged from 1.00-7.00. The most preferred taste was recorded in sample W16. The aroma ranged from 1.20-7.50. There was no significant different among the samples except sample M3G. The texture of the snail ranged from 3.25-7.75. The results of the sensory parameters showed similar score trend which were observed to increase with increase in frying time. It could be therefore noted that the frying process influenced the sensory attributes of the snail meat positively. The samples showed no significant difference in terms of colour, taste, appearance, texture and overall acceptability except with sample M3G.

Table 6: Sensory Evaluation of Fried Snail at Different Time Interval

Sample	Colour	Taste	Aroma	Texture	Appearance	Overall Acceptability
M3G	3.25±0.00^{b}	1.00±0.58^{b}	1.20±0.50^{b}	3.25±0.50^{b}	2.50±0.82^{b}	1.00±0.82^{b}
K8P	5.00±1.50^{a}	4.50±0.50^{a}	4.50±2.38^{a}	4.50±1.92^{a}	5.00±1.41^{ab}	5.20±1.71^{a}
S4N	6.25±1.50^{a}	5.50±1.71^{a}	5.50±0.58^{a}	5.25±1.50^{a}	6.00±2.36^{ab}	6.75±1.50^{a}
M12	6.25±1.26^{a}	6.00±1.41^{a}	6.50±1.50^{a}	6.50±0.98^{a}	6.25±1.50^{ab}	7.25±1.29^{a}
W16	7.75±2.50^{a}	7.00±0.82^{a}	7.50±1.00^{a}	7.75±0.96^{a}	7.50±1.73^{ab}	7.50±0.58^{a}

*Mean± standard deviation with same superscripts along the column are not significantly different at (p>0.05)

***M3G:** Control (unfried snails meat), **K8P:** snail meat fried for 4 min, **S4N** snail meat fried for 8 min., **M12:** snail meat fried for 12 min. and **W16** snail meat fried for 16 min.*

CONCLUSION AND RECOMMENDATION

The frying processing method caused reduction in the moisture content of the snail samples with increase in protein content. The frying also influenced the textural properties of the snails meat positively. The sensory attributes: colour, appearance, aroma, taste and overall acceptability of fried snail meat were rated high between like moderately and like extremely and relatively higher compared to the control samples. This is an indication that frying at a moderate temperature and time can be used to process snail meat for human consumption which will enhance the eating quality and suitability of the food and satisfied consumer's perception. The PAHs readings were comparatively low compared with maximum permissible for consumption. This study's findings demonstrated that the outcomes for polycyclic aromatic hydrocarbons fell within a reliable safe range.

Considering the outcome of this study, further studies on the Fried Snail meats' shelf life stability of varying packaging materials and at different storage conditions is recommended. This stands the chance of providing valuable information for handling, transportation, distribution and exportation of fried snail meats. Also, there may be need to conduct comparative studies on the quality status of fried snail meats using common vegetable oils available in the market!

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Authors' Contributions

OTB Conceptualization, Data curation, Formal Analysis, Funding, Methodology, project administration, Resources, Supervision, validation,Visualization,Writing – original draft. TAA: Funding, Methdology, Visualization, project administration, Resources, Supervision. SD: Data curation, Funding, Resources, Formal Analysis, investigation. RRD: Supervision, validation,Visualization,Writing – original draft. JFF: validation, Visualization, Writing – original draft.

Ethical Statement

Not applicable

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