*Original Research Article*

Towards Healthier Snacks: Evaluating the Use of Unrefined Oils and Butter in Doughnuts Production.

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ABSTRACT

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| **Aims:** This study aimed to assess the health impacts of doughnuts prepared using unrefined oils and butter by evaluating the physicochemical properties, fatty acid composition, and elemental metal profile of the extracted oils.  **Study Design:** The research employed an experimental design with laboratory analyses to determine the impact of fat combinations on oil quality during frying.  **Place and Duration of Study:** The study was conducted at the Chemistry Laboratory of Akwa Ibom State University (AKSU) and CTX-ION Analytics, Ikeja, Lagos.  **Methodology:** Doughnuts were prepared using locally sourced vegetable oil and butter. Oils were extracted from the doughnuts using Soxhlet extraction with n-hexane. The extracted oils and original fat sources were analyzed for physicochemical parameters including acid value, peroxide value, iodine value, saponification value, and free fatty acids. Fatty acid methyl esters (FAMEs) were profiled using Gas Chromatography–Mass Spectrometry Detector (GC-MSD), while elemental composition (Ca, Fe, K, Mg, Na, P) was determined via Inductively Coupled Plasma–Optical Emission Spectroscopy (ICP-OES).  **Results:** The doughnut oil exhibited a significantly higher peroxide value (136.30 meq/kg), indicating extensive oxidation, likely exacerbated by high frying temperatures and elevated iron content. The iodine and saponification values reflected moderate unsaturation and shorter-chain fatty acids. GC-MSD revealed that the doughnut oil retained high levels of both saturated (Lauric, Myristoleic) and unsaturated (Linoleic/Oleic) fatty acids. Elemental analysis showed considerable potassium and iron contents in the final product, with potential implications for oxidative stability and health.  **Conclusion:** The quality of oil used in doughnut preparation is significantly compromised by deep-fat frying, resulting in oxidative degradation and potential health risks. Strategies such as antioxidant incorporation, improved frying practices, and careful selection of fat blends are recommended to enhance product stability and nutritional value. |

*Keywords: characterization, extraction, fatty acids, health implication, snacks.*

1. INTRODUCTION

Edible oils and fats play an essential role in human nutrition and health, serving as significant sources of energy, essential fatty acids, and fat-soluble vitamins. Numerous studies have demonstrated that the consumption of different types of oils influences various physiological processes, including lipid metabolism, disease development, and overall well-being (Amri et al., 2017). In addition to their dietary functions, oils are widely utilized in pharmaceutical, cosmetic, and industrial applications due to their functional and bioactive components (Asuquo et al., 2012). Fats and oils are commonly incorporated into food both directly and indirectly: added to salads, cooked meals, or used as frying media (Arif et al., 2010). Beyond their nutritional contributions, they provide desirable sensory attributes such as flavor, texture, and mouthfeel. However, during extraction, processing, and culinary use; especially involving heat treatments like frying, oils undergo various physicochemical changes. These include oxidation, hydrolysis, and polymerization, which can degrade the oil's quality and produce potentially harmful compounds (Arif et al., 2010; Anyasa et al., 2009; Lendle et al., 2005). Vegetable oils are particularly valued for their high content of unsaturated fatty acids, which contribute to cell regeneration, tissue repair, and cardiovascular health (Arif et al., 2010). These oils primarily contain lipids in the form of triacylglycerols, composed of saturated and unsaturated fatty acids. Their quality and stability are routinely assessed through key physicochemical parameters such as iodine value (IV), saponification value (SV), peroxide value (PV), viscosity, and density (Ceriani et al., 2008; Mousavi et al., 2012). Several studies have explored the effects of thermal processing on the stability of edible oils. Parameters such as PV, IV, and viscosity are particularly sensitive to temperature-induced degradation (Farhoosh et al., 2008; Li et al., 2010; Jinfeng et al., 2011). Oxidation, in particular, significantly alters the structural and functional integrity of oils. During this process, unsaturated fatty acids react with oxygen and light, generating free radicals, which subsequently form hydroperoxides, aldehydes, and ketones. If unchecked, these reactions culminate in polymerization, further diminishing oil quality and digestibility, and leading to the destruction of fat-soluble vitamins (Arif et al., 2010; Anyasa et al., 2009). Deep frying is a widespread cooking method that subjects oils to high temperatures over prolonged periods. Repeated use of frying oil accelerates oxidative and thermal degradation, altering both its nutritional and sensory characteristics (Che Man & Jasvir, 2000). Factors such as initial oil quality, replenishment frequency, frying conditions, and oxygen exposure significantly influence the rate of degradation (Choe & Min, 2007). Oxidized oils not only reduce the sensory appeal of foods but also pose potential health risks due to the accumulation of toxic degradation products (Bhattacharya et al., 2008). Given these concerns, monitoring the quality of oils used in food preparation is imperative. It ensures consumer safety, preserves the sensory quality of fried products, and minimizes economic losses associated with premature oil disposal (Zahir et al., 2017). This study aims to evaluate the quality of doughnuts prepared using different combinations of locally processed vegetable oil and butter. Specifically, the research investigates the physicochemical properties, fatty acid composition, and elemental metal profile of oils extracted from the doughnuts. The findings are expected to provide insights into how varying fat blends influence the nutritional, sensory, and functional quality of fried snack products.

2. material and methods

**2.1 Materials and reagents**

Soxhlet extractor, condenser, round bottom flak, heating mantle, retort stand, weighing balance, conical flask, beaker, electrical water bath, desiccator, burette boiling tube, cotton wool/filtered paper, oven, measuring cylinder, burette, pipette, N-hexane, potassium iodide, solvent mixture of glacial acetic acid and chloroform, Wij’s solution, distilled water, starch indicator, powdered potassium iodide, sodium thiosulfate solution, sodium hydroxide, hydrochloric acid, locally processed oil, industrially processed oil, locally processed butter, industrially processed butter, defatted butter, flour, Analytical Balance: ADAM AAA250LE Weighing Balance (UK), Vortex Mixer: Heidolph REAX 2000 (Germany), Dichloromethane: GC Ultratrace, Scharlau (Spain), n-Hexane: GC Ultratrace, Scharlau (Spain), Methanol: HPLC Grade ACS, Scharlau (Spain), Potassium Hydroxide: Mollychem, India etc.

**2.2 Sample collection**

Oils, butters, and flour used in preparing the doughnut were bought from different shops and supper market at Uyo, Uyo local Government Area, Akwa Ibom State, Nigeria. The doughnuts were prepared using locally processed oil and locally processed butter.

**2.3 Doughnut Preparation**

Active dry yeast (10 g) was combined with warm water in a bowl and set aside to activate. In a large bowl, the dry ingredients, all-purpose flour (250 g), sugar (50 g), salt (2.5 g), and flavors were thoroughly mixed together. Butter (50 g) was incorporated into the dry mixture and blended well. A well was made in the center of the dry mixture, and the activated yeast was poured in. The mixture was kneaded until a smooth dough formed. The dough was placed in a greased bowl, covered with cling film, and left to rise for 1 hour, or until it doubled in size. The risen dough was rolled out to about ½ inch thick and cut into doughnut shapes using a doughnut cutter. The shaped doughnuts were arranged on a tray, covered, and allowed to rise again for 30 minutes. The doughnuts were carefully placed in hot oil, a few at a time, and fried for about 2 minutes on each side until golden brown. They were then removed and drained on paper towels.



**Plate 1: Doughnut prepared from a locally processed oil and butter**

**2.4 Extraction of snack (doughnut**)

Extraction of oil from doughnut was carried out by soxhlet extraction. About 50 g was weighed in batches with a filtered paper on a weighing balance, wrapped and stapled then put in already set up soxhlet apparatus and n-hexane was added and extracted for an hour at a certain temperature of about 60oC.

**2.5 Physiochemical characterization of oils**

**2.5.1 Determination of Iodine Value (**Dressman et al., 2024**)**

10ml of carbon tetrachloride was added to 1.0 g of oil and dissolved. 20 ml of Wijis soluition was added and then the stopper inserted (previously moistened with potassium iodine solution) and allowed to stand in the dark for 30 minutes. About 15 ml of potassium iodide solution (10%) was added and made up to 100 ml with distilled water and swirled for the solution to mix. The mixture containing the oil was then titrated against 0.1 M thiosulphate (Na2S2O3) solution with constant swirling using 2 ml of 1% starch solution as an indicator just before the end point (i.e., when the blue colour disappears). A blank titration was conducted following the same procedure and the iodine value calculated using the expression

Where: b = titre value of blank

a = titre value of sample

N = normality of Na2S2O3

**2.5.2 Determination of Peroxide Value (**Dressman et al., 2024**)**

Approximately 1.0 g of oil was weighed into a clean dry flask and dissolved in 20 ml acetic acid/chloroform (3:2) solution and swirled in clockwise and anticlockwise direction for 60 s to dissolve the oil in the chemical mixture. 0.5 ml saturated potassium iodide solution was added followed by 25 ml of distilled water and swirled again for another 60 s to obtain homogenous mixture. The resultant mixture was then titrated with 0.01 M sodium thiosulphate (Na2S2O3) solution with constant and vigorous swirling until the yellow colour disappears. 0.5 ml of 1% starch solution was then added which turned the mixture blue. The titration continued until the blue colour disappeared at the end point and the peroxide value calculated as shown below.

, N = Normality of Na2S2O3.

**2.5.3 Determination of Free Fatty Acid and Acid Value (**Dressman et al., 2024**).**

25ml of diethyl ether was mixed with 25ml of alcohol and 1ml of phenolphthalein solu3tion (1%). It was then carefully neutralized with 0.1 M NaOH. About 1.0 g of the oil was dissolved in the mixed neutral solvent and titrated with aqueous 0.1 M NaOH with constant shaking until a pink color which persisted for 15 seconds was obtained. Free fatty acid was calculated as follows.

Acid value =

N = Normality of the potassium hydroxide or sodium hydroxide. The Free Fatty Acid figure is usually calculated as oleic acid (1 ml 0.1 M). Sodium hydroxide = 0.0282 g oleic acid), in which case the acid value = 2 x free fatty acid. For most oils, acidity is noticeable to the palate when free fatty calculated as oleic acid is about 0.5 – 1.5 %.

**2.5.4 Determination of Saponification Value (**Dressman et al., 2024**)**

The saponification value is determined by taking 1.0 g of oil sample in a conical flask and exactly 25 ml of the alcoholic potassium hydroxide solution was added. A reflux condenser was attached and flask heated in boiling water with frequent shaking until a clear solution (indicating complete saponification of the oil) is obtained. 1ml of phenolphthalein (1%) solution was added and the hot excess alkali solution was allowed to cool and later titrated against 0.5M hydrochloric acid. The volume of the acid used was recorded. A blank titration was carried out using the same procedure and saponification value calculated using the expression:

*Saponification value* =

N = Normality of Hydrochloric acid

b = Volume of HCl used in the blank

a = Volume of HCl used in the sample

**2.6 Analysis of Fatty Acid Methyl Esters by GC-MSD**

**2.6.1 Instrument Description**

An Agilent 7890B GC with an Agilent 5977B MSD System equipped with a split/splitless inlet and an Agilent 7693 Automatic Liquid Sampler was used for this analysis. The table below shows the instrumental conditions used in the data acquisition.

**Table 1: Chromatographic Conditions**

|  |  |
| --- | --- |
| GC | Agilent 7890A coupled with 5977B Mass selective Detector |
| Sampler | Agilent 7693 Injector tower with 10µL syringe |
| Carrier | Helium [flow; 1.3mL/min] |
| Injection | 1µL Splitless, 250 °C |
| Column | Rtx-1ms 15 m, 0.25 mm ID, 0.25 μm |
| Oven | 60 °C (hold 0 min) to 300 °C at 15 °C/min (hold 0 min) |
| MSD | Transfer line temp [280] Quadrupole temp [150 °C] Ion source temp [230 °C] |

**2.6.2 Calibration**

FAMES standard Mix (Catalog Number: FAMQ 005) containing 37 FAMES components was purchased from Accu Standard. Five (5) point serial dilution calibration standards (10,20,40,60,80PPM) was prepared from the stock and used to calibrate the GC-MS.

**2.6.3 Extraction Procedure**

The oil extract (1 g) was dissolved with 10 ml of n-Hexane and 1 ml of 2 N methanolic KOH was added and the mixture was shaken thoroughly for 30 seconds. The mixture was then centrifuged, and the supernatant obtained. The supernatant was transferred into 2 ml vials and injected into the GC-MS. The analysis was carried out in scan mode.

**2.7 Elemental Analysis by ICP-OES**

**2.7.1Analysis Procedure**

The Agilent 720-ES with megapixel CCD detector was used which provided simultaneous measurement while the Agilent SPS3 autosampler was used for sample introduction. Agilent Expert II Software was used to control the instrument and acquire data. Calibration and Quality Control (QC) solutions were prepared from the following reference material: Accustandard QCSTD-27 Quality Control Standard and Deionized water from Elga B114 Wall Mounted Deionizer System. Appropriate concentrations range of working standards from the multi-elements stock standard were prepared through serial dilution method. A new worksheet was created from the ICP-OES Expert software into which was programmed the individual sample codes as well as the method. After the instrument was programmed, the calibration curves were then obtained by running the standards and then the samples were also analyzed according to the sequence specified in the sequence parameters of the newly created worksheet.

3. results and discussion

**Table 2: Physiochemical properties of oils extracted from doughnuts prepared using different combination of locally processed oil and butter**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameters/sample | K1 | O | C |
| Acid values (mgKOH/g) | 7.01 | 1.07 | 3.93 |
| %Free fatty acids | 3.51 | 0.54 | 1.97 |
| Peroxide value (mequiv/kg) | 48.30 | 32.50 | 136.30 |
| Iodine value (gI2/100g) | 11.63 | 31.84 | 27.34 |
| Saponification values (mg KOH/g) | 428.44 | 348.75 | 412.29 |

***K1 = locally processed (unrefined) oil; O = locally processed (unrefined) butter; C = Oil from doughnut prepared using locally processed oil and locally processed butter***

The data provided in table 2 compares the physicochemical properties of a locally processed oil (K1), a locally processed butter (O), and an oil extracted from doughnuts prepared using a combination of these two (C). The physicochemical properties of oils, such as acid value, free fatty acids, peroxide value, iodine value, and saponification value, are crucial indicators of oil quality, stability, and suitability for consumption and industrial applications (Codex Alimentarius Commission, 2021). The acid value and free fatty acid (FFA) content are measures of hydrolytic rancidity, indicating the extent to which triglycerides have broken down into glycerol and free fatty acids. Locally processed oil (K1) has the highest acid value (7.01 mgKOH/g) and % FFA (3.51%). This suggests that the oil has undergone some hydrolytic degradation or was not optimally processed or stored. High free fatty acid content can negatively impact the flavor and smoke point of an oil (O'Brien, 2009). Conversely, the lowest values in butter (O) indicate a more stable lipid profile. Interestingly, the oil from doughnuts (C) had intermediate values, implying that while the butter may have buffered some degradation, the frying process accelerated hydrolysis, especially due to heat and moisture interactions (Choe & Min, 2007). The peroxide value (PV), a primary indicator of oxidative rancidity, was notably highest in oil extracted from doughnuts (136.30 meq/kg), a value far exceeding acceptable limits (typically <10 meq/kg for fresh edible oils per FAO/WHO standards). This suggests severe oxidative stress during frying,

**Table 3: Gc-Ms Results of Oils**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S/N | Compound Name | Sample K1  (mg/L) | Sample O  (mg/L) | Sample C  (mg/L) |
| 1 | Capric acid, methyl ester | 63.1027 | 0.367236 | 40.1666 |
| 2 | Undecanoic acid, methyl ester | 1.459 | 0.020912 | 0.82979 |
| 3 | Lauric acid, methyl ester | 255.138 | 8.13353 | 179.368 |
| 4 | Tridecanoic acid, methyl ester | 1.84318 | 0.031816 | 0.89893 |
| 5 | Myristoleic acid, methyl ester | 254.826 | 2.44357 | 167.206 |
| 6 | Myristic acid, methyl ester | 130.727 | 9.11539 | 94.1124 |
| 7 | cis-10-pentadecanoic acid, methyl ester | 0.037167 | 0.083101 | 0.134697 |
| 8 | Pentadecanoic acid, methyl ester | 0.356094 | 0.687789 | 0.777868 |
| 9 | Palmitic acid, methyl ester | 54.9887 | 84.568 | 95.642 |
| 10 | Linoleic/Oleic acid, methyl ester | 121.726 | 118.472 | 168.045 |
| 11 | Stearic acid, methyl ester | 39.0374 | 31.3202 | 49.8682 |
| 12 | cis-5,8,11,14-Eicosapentaenoic acid, methyl estes | 0.290441 | 0.057248 | 0.601366 |
| 13 | 8,11,14-Eicosatrienoic acid, methyl ester | 3.01715 | 0.376508 | 5.34533 |
| 14 | cis-11,14-Eicosadienoic acid, methyl ester | 0.896968 | 0.10823 | 2.56009 |
| 15 | cis-11-14-17-Eicosatrienoic acid, methyl ester | 2.21578 | 1.04173 | 3.10326 |
| 16 | Eicosanoic acid, methyl ester | 1.62619 | 1.61359 | 3.35813 |
| 17 | Heneicosanoic acid, methyl ester | 0.076963 | 0.038976 | 0.066248 |
| 18 | cis-13,16-Docasadienoic acid, methyl ester | 0.049436 | 0.123327 | 0.103079 |
| 19 | Erucic acid, methyl ester | 0.040072 | 0.163866 | 0.091892 |
| 20 | Behenic acid, methyl ester | 0.290146 | 0.260346 | 0.501898 |
| 21 | Tricosanoic acid, methyl ester | 0.269004 | 0.068751 | 0.250441 |
| 22 | Nervonic acid, methyl ester | 0.15058 | 0.136681 | 0.051819 |
| 23 | Lignoceric acid, methyl ester | 0.526263 | 0.21497 | 0.556829 |



















**Figure 1:** **Structures of major fatty acids and their methyl esters identified**

which involves high temperatures and oxygen exposure that lead to rapid formation of hydroperoxides and secondary oxidation products (Guillén & Cabo, 2002; Munekata et al., 2017; Dressman et al., 2024). The iodine value, reflective of unsaturation level, was lowest in locally processed oil (11.63 gI₂/100g), pointing to high saturation, while butter (O) had the highest (31.84 gI₂/100g). The doughnut oil's iodine value (27.34 gI₂/100g) aligns more with the butter, indicating the butter's higher unsaturated fatty acid content influenced the final blend. However, thermal degradation of double bonds during frying may explain the slight reduction from butter to doughnut oil (Warner, 2007). The **s**aponification value, inversely related to fatty acid chain length, was highest in the locally processed oil (428.44 mgKOH/g), suggesting more short-chain fatty acids (figure 1). The doughnut oil had a value (412.29 mgKOH/g) closer to this, indicating that the locally processed oil predominantly shaped the average molecular weight profile of the doughnut oil, despite the butter component. This study underscores the need for improved processing and storage of local oils and the importance of controlling frying conditions to limit degradation. The application of natural antioxidants or oil stabilization techniques could mitigate rancidity and extend the shelf life of products like doughnuts.

**Table 4: Results of Elemental Analysis Oils**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sample ID | Ca (ppm) | | Fe (ppm) | K (ppm) | Mg (ppm) | Na (ppm) | P (ppm) |
| K1 | 244.958 | 85.4563 | | 156106 | 30.3084 | 18.192 | 9.73751 |
| O | 178.293 | 62.1791 | | 0.00000 | 21.8344 | 684.933 | 29.31480 |
| C | 219.823 | 84.7579 | | 49006.8 | 26.0260 | 10.908 | 11.43350 |

The Gas Chromatography-Mass Spectrometry (GC-MS) analysis (table 3) provides a detailed breakdown of the individual fatty acid methyl esters present in the locally processed oil (K), locally processed butter (O), and the oil extracted from doughnuts (C). This allows for a deeper understanding of the composition and how it changes during processing. Locally processed oil (K1) exhibits a profile dominated by shorter to medium-chain saturated fatty acids, notably Lauric acid, methyl ester (255.138 mg/L), and Myristoleic acid, methyl ester (254.826 mg/L), and a significant amount of Capric acid, methyl ester (63.1027 mg/L). It also contains Linoleic/Oleic acid, methyl ester (121.726 mg/L). The presence of these saturated fatty acids and shorter chain fatty acids is consistent with its high saponification value (428.44 mg KOH/g) and low iodine value (11.63 gI2/100g), indicating a high degree of saturation and lower average molecular weight. In contrast, sample O (locally processed butter) shows a significantly different fatty acid profile. The amounts of short to medium-chain fatty acids like Capric acid (0.367236 mg/L), Lauric acid (8.13353 mg/L), and Myristoleic acid (2.44357 mg/L) are considerably lower than in sample K1. Palmitic acid, methyl ester (84.568 mg/L) and Linoleic/Oleic acid, methyl ester (118.472 mg/L) are prominent. This profile, with higher unsaturation (Linoleic/Oleic acid) and different proportions of fatty acids, aligns with its higher iodine value (31.84 gI2/100g) and lower saponification value (348.75 mg KOH/g), suggesting it is more unsaturated and contains longer chain fatty acids on average compared to oil K1. The fatty acid profile of oil C appears to be a blend influenced by both K1 and O, but with shifts likely due to the frying process. It retains significant amounts of Lauric acid, methyl ester (179.368 mg/L) and Myristoleic acid, methyl ester (167.206 mg/L), though lower than in K1. Importantly, Linoleic/Oleic acid, methyl ester (168.045 mg/L) is present in the highest amount in sample C compared to both K1 and O, suggesting a contribution from the butter and/or potential concentration during frying. Stearic acid, methyl ester (49.8682 mg/L) is also higher in C than in K1 or O. The increase in certain unsaturated fatty acids like 8,11,14-Eicosatrienoic acid, methyl ester (5.34533 mg/L) and cis-11,14-Eicosadienoic acid, methyl ester (2.56009 mg/L) in sample C, compared to K and O, is notable. The changes in fatty acid proportions, including the relative increase in Linoleic/Oleic acid and some longer-chain unsaturated fatty acids, could be related to the observed iodine value of 27.34 gI2/100g for C, which is intermediate but closer to O. The GC-MS analysis distinctly characterizes the fatty acid profiles of the locally processed oil (K1), butter (O), and doughnut oil (C). Sample K1 is rich in saturated and shorter-chain fatty acids, consistent with its physicochemical properties. Sample O, the butter, shows a higher degree of unsaturation. The doughnut oil (C) presents a mixed profile, inheriting characteristics from both initial components, but significantly impacted by the frying process. The increased amount of Linoleic/Oleic acid in the doughnut oil, coupled with the dramatic rise in its peroxide value, strongly suggests that the unsaturated fatty acids are major sites of oxidative degradation during doughnut preparation. This detailed fatty acid composition provides a molecular basis for the observed changes in the physicochemical properties and highlights the importance of managing frying conditions to minimize oxidative stress on the oil components.

Table 4 reveals the elemental analysis results of oil samples K, O and C. Locally processed oil (K1) had an exceptionally high potassium content (156106 ppm). Butter (O) had no detectable potassium (0 ppm). The doughnut oil (C) showed a significant amount of potassium (49006.8 ppm), indicating a substantial contribution from the locally processed oil to the final product's mineral content. Butter (O) had the highest sodium content (684.933 ppm), while K1 and C had much lower levels (18.192 ppm and 10.908 ppm, respectively). This suggests that the butter is a major source of sodium in the blend. Both locally processed oil (K1) and doughnut oil (C) had comparable and relatively high iron levels (85.4563 ppm and 84.7579 ppm, respectively), while butter (O) had a lower amount (62.1791 ppm). Iron can act as a pro-oxidant, potentially accelerating oxidative rancidity, especially at frying temperatures. The high iron content in the locally processed oil and subsequently in the doughnut oil could contribute to the observed high peroxide values. Calcium, magnesium, and phosphorus were present in all samples, with varying concentrations. The levels in the doughnut oil (C) generally fell between those of the locally processed oil (K1) and butter (O), reflecting the combined nature of the blend. For instance, C had 219.823 ppm Ca, 26.026 ppm Mg, and 11.4335 ppm P. The comprehensive analysis of physicochemical properties, fatty acid composition, and elemental content provides a thorough understanding of the locally processed oil, locally processed butter, and the oil extracted from doughnuts. The locally processed oil (K1) is characterized by high hydrolytic rancidity, a high degree of saturation, and very high potassium and iron content. The locally processed butter (O) shows better initial oxidative and hydrolytic stability, a more unsaturated fatty acid profile, and is a significant source of sodium. Crucially, the doughnut preparation process significantly impacts the oil's quality. The oil extracted from the doughnuts (C) exhibits a dramatic increase in oxidative rancidity, evidenced by its very high peroxide value. This is likely accelerated by the combination of high frying temperatures and the presence of pro-oxidant minerals like iron from the locally processed oil (Che Man & Jasvir, 2000; Choe & Min, 2007; Munekata et al., 2017). While the butter contributes beneficial unsaturated fatty acids to the blend, these become susceptible to oxidation during frying. The elemental profile of the doughnut oil reflects the combined contributions of the raw oil and butter. In conclusion, while the locally sourced ingredients offer unique profiles, the method of preparation (deep-fat frying) introduces significant challenges, particularly regarding oxidative stability. The substantial increase in oxidation products in the doughnut oil highlights the need for strategies to mitigate rancidity, such as optimizing frying conditions, incorporating antioxidants, or re-evaluating the blend proportions to enhance the quality and shelf-life of products made with these locally processed oils and butter. Furthermore, the presence of various minerals, particularly iron, warrants attention for its potential role in accelerating degradation.

High acid value and FFA levels, as observed in the locally processed oil (K1) and the doughnut oil (C), are indicators of lipid hydrolysis and early-stage rancidity. Consumption of oils with elevated FFAs has been linked to gastrointestinal irritation and may impair nutrient absorption (Naz et al., 2005). Chronic intake of degraded fats can contribute to metabolic disorders and increase the risk of cardiovascular disease due to inflammatory responses (Farhoosh et al., 2009). While butter (O) had the lowest FFA, the doughnut oil (C) presented moderate levels, suggesting that frying exacerbates lipid breakdown, raising health concerns over repeated or long-term consumption of such products. The peroxide value of the doughnut oil (C) was extremely high (136.30 meq/kg), far exceeding acceptable safety limits (<10 meq/kg for edible oils) set by food safety guidelines (Codex Alimentarius Commission, 2021). This suggests extensive lipid oxidation during frying—a process that produces **lipid hydroperoxides, aldehydes**, and **ketones**, which have been linked to DNA damage, inflammation, and increased risk of chronic diseases such as **cancer, atherosclerosis**, and **neurodegenerative disorders** (Esterbauer et al., 1991; Gutteridge & Halliwell, 2010). The locally processed oil (K1) contains high levels of **medium-chain saturated fatty acids** (Lauric and Myristoleic acids), which, while easily metabolized, have also been shown to elevate **low-density lipoprotein (LDL)** cholesterol when consumed in excess, contributing to **cardiovascular disease risk** (Mensink et al., 2003). Conversely, the butter (O) and doughnut oil (C) have higher levels of **unsaturated fatty acids** (Linoleic/Oleic acids), which are typically cardioprotective when intact (Mozaffarian et al., 2010). However, these unsaturated fats are **highly prone to oxidation**, especially under high frying temperatures, forming **toxic lipid peroxidation products** that can promote **oxidative stress, cell membrane damage**, and **pro-inflammatory responses** (Choe & Min, 2007). The frying process not only induces oxidation but also degrades **vitamins A, D, E, and K**, and essential fatty acids. As a result, even oils originally rich in beneficial nutrients (like butter) may lose their health-promoting properties when used repeatedly or at high temperatures, such as during doughnut preparation (Naz et al., 2005). The elemental composition of edible oils directly influences not only their **nutritional value** but also their **oxidative stability** and potential health effects. In this study, locally processed oil (K1), locally processed butter (O), and doughnut oil (C) were also analyzed for their content of essential minerals including calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), sodium (Na), and phosphorus (P). Iron is vital for oxygen transport and metabolic processes. However, **excess iron in oils** can promote the formation of **free radicals** through Fenton reactions, accelerating lipid oxidation (Choe & Min, 2007). Both locally processed oil (K1: 85.46 ppm) and doughnut oil (C: 84.76 ppm) showed **high iron content**, which likely contributed to the high peroxide value (136.30 meq/kg) observed in sample C. Oxidized fats are associated with **inflammation, atherosclerosis, and potential carcinogenic effects** (Esterbauer et al., 1991). Excess sodium intake is linked to **hypertension, stroke, and cardiovascular disease** (Mozaffarian et al., 2014). Butter (O) had a notably high sodium content (684.93 ppm), while locally processed oil and doughnut oil had much lower levels. Although the sodium content in the final doughnut oil (C) was diluted (10.91 ppm), cumulative dietary exposure from butter-based fried foods could pose risks, particularly in populations with pre-existing cardiovascular concerns. Potassium helps regulate blood pressure and counteracts the effects of sodium. The locally processed oil contained an exceptionally high potassium level (156,106 ppm), significantly higher than in the doughnut oil (C: 49,006.8 ppm). While this could be beneficial, **the bioavailability and daily intake levels from oils are uncertain**. Also, extremely high mineral concentrations in cooking oils may raise **concerns about contamination or improper refining**, which should be investigated further (Naz et al., 2005). These minerals are essential for bone health, enzymatic reactions, and neuromuscular function. Though present in moderate concentrations, their nutritional contribution from oil intake is limited due to **low oil consumption volumes** and **questionable bioavailability** from lipid matrices (Trumbo et al., 2001). Nonetheless, the mineral profile adds some nutritional value. The **elemental composition** of the oils analyzed reveals several critical health implications: i**ron** levels are high in the locally processed and doughnut oils, acting as pro-oxidants and potentially **worsening oil degradation during frying**, thus increasing exposure to harmful compounds; **sodium** is excessive in the butter, indicating **hypertension risk** if such oils are frequently used in fried or processed foods; **potassium**, while generally beneficial, is present in unexpectedly high amounts in the locally processed oil, requiring further validation for safety and source integrity and **other minerals** like calcium, magnesium, and phosphorus contribute to nutritional content but do not offset the risks posed by oxidized lipids or mineral imbalance. **Monitoring of mineral content** (especially iron and sodium) in locally processed oils should be a public health priority, use of **antioxidants or iron chelators** may improve the stability of such oils during frying and **public awareness** on the risks of excessive sodium and degraded frying oils should be promoted, especially in areas where these local oils are widely used in street foods are recommended.

**4. CONCLUSION**

This comprehensive study thoroughly characterized the locally processed oil ~~(K),~~ locally processed butter ~~(O),~~ and the oil extracted from doughnuts ~~(C),~~ providing insights into their physicochemical properties, fatty acid composition, and elemental content. The locally processed oil ~~(K)~~ was notably defined by high hydrolytic rancidity, a high degree of saturation, and significant levels of potassium and iron. Conversely, the locally processed butter ~~(O)~~ demonstrated superior initial oxidative and hydrolytic stability, a more unsaturated fatty acid profile, and was a considerable source of sodium. Crucially, the doughnut preparation process significantly compromised the quality of the oil. The oil extracted from the doughnuts ~~(C)~~ showed a dramatic surge in oxidative rancidity, evidenced by an exceptionally high peroxide value. This degradation was likely accelerated by the combination of high frying temperatures and the presence of pro-oxidant minerals like iron originating from the locally processed oil. While the butter contributed beneficial unsaturated fatty acids to the blend, these became highly susceptible to oxidation during the frying process. The elemental profile of the doughnut oil ultimately reflected the combined contributions of both the raw oil and the butter used. In conclusion, while the locally sourced ingredients possess unique profiles, the method of preparation, specifically deep-fat frying, introduces substantial challenges, particularly concerning oxidative stability. The significant increase in oxidation products within the doughnut oil underscores the urgent need for strategies to mitigate rancidity. Such strategies could include optimizing frying conditions, incorporating antioxidants, or re-evaluating the proportions of the fat blend to enhance the overall quality and extend the shelf-life of products prepared with these locally processed oils and butter. Furthermore, the presence of various minerals, especially iron, warrants close attention due to its potential role in accelerating oil degradation.

References

Amri, Z., Lazreg-Aref, H., Mekni, M., El-Gharbi, S., Dabbaghi, O., Mechri, B., et al. (2017). Oil Characterization and Lipids Class Composition of Pomegranate Seeds. *BioMed Research International*, 1 – 8, <https://doi.org/10.1155/2017/2037341>

Asuquo, J. E., Etim, E. E., Ukpong, I. U. & Etuk, S. E. (2012). Extraction, Characterization and Fatty Acid Profile of *Poga oleosa Oil, International Journal of Modern Analytical and Separation Sciences*, 1(1): 23-30.

Arif, M. L. & Abbas, A. N. M. (2010). Investigating peroxides and acid value in used edible vegetable oils. *The Iraqi Journal of Agricultural Sciences*, 41(4), 123-132

Anyasa, G.N., Ogunwenmo, K.O., Ogelana, O.H., Ajayi, D., & Dangana, J. (2009). "Chemical analyses of groundnut (Arachis hypogaea) oil " *Pakistan Journal* *of Nutrition,* 8 (3), 269-272.

Lendle, B.M., Diaz, A.M. & Ayora-Canada, M.J. (2005). "Direct monitoring of lipid oxidation in edible oils by fourier transformation raman spectroscopy" *Chemistry and Physics of Lipids,* 134, 175-182.

Ceriani, R., Paiva, F.R., Alves, C.B.G., Batista, E.A.C. & Meirelles, A.J.A. (2008). Densities and viscosities of vegetable oils of nutritional value*. J. Chem. Eng. Data,* 53 (8), 1846–1853.

Mousavi, K., Shoeibi, S. & Ameri, M., (2012). Effects of storage conditions and PET packaging on quality of edible oils in Iran. Adv. *Environ. Biol*. 6 (2), 694–701.

Farhoosh, R., Moosai, S.M.R. & Sharif, A. (2008). Investigation on frying oils quality in terms of color index, refractive index and viscosity during frying process. *J. Food Sci. Tech*. 5(1), 13–19.

Li, H., Zhou, G., Zhang, H. & He, Y., (2010). Chemical constituents and biological activities of saponin from the seed of *Camellia oleifera*. *Sci. Res. Essays,* 5(25), 4088–4092.

Jinfeng, P., Huixing, S., Juan, Y. & Yong, K.L. (2011). Changes in physiochemical properties of Myofibrillar protein from Silver Carp (Hypophthalmichthys mollitrix) during heat treatment. *J. Food Biochem*. 35, 939–952.

Che Man, Y.B. & Jasvir, I. (2000). Effect of rosemary and sage extracts on frying performance of refined, bleached and deodorized (RBD) palm olein during deep fat frying. *Food Chem.* 69, 301–307. https://doi.org/10.1016/S0308-8146(99)00270-8

Choe, E., & Min, D. B. (2007). Chemistry of deep-fat frying oils. Journal of Food Science, 72(5), R77–R86. <https://doi.org/10.1111/j.1750-3841.2007.00352.x>

Bhattacharya, A.B., Sajilata, M.G., Tiwari, S.R. & Singhal, R. (2008). Regeneration of thermally polymerized frying oils with adsorbents*. Food Chem*. 110, 562–570.

Zahir, E., Saeed, R., Hameed, M. A. & Yousuf, A. (2017). Study of physicochemical properties of edible oil and evaluation of frying oil quality by Fourier Transform-Infrared (FT-IR) Spectroscopy. *Arabian Journal of Chemistry,* 10, S3870–S3876

Dressman O. H., Akpan I. O., Achugasim O., Abayeh O. J. & Ogali R. E. (2024) Physicochemical analysis and antimicrobial activity of modified and unmodified forms of extracts of *Dialium guineense* (Velvet tamarind) seed.*Journal of Materials and Environmental Science*, 15(6), 839-849

Codex Alimentarius Commission. (2021). Standard for Named Vegetable Oils (CODEX-STAN 210-1999). FAO/WHO.

O'Brien, R. D. (2009). Fats and oils: Formulating and processing for applications (3rd ed.). CRC Press.

Guillén, M. D., & Cabo, N. (2002). Fourier transform infrared spectra data versus peroxide and anisidine values to determine oxidative stability of edible oils. *Food Chemistry*, 77(4), 503–510. <https://doi.org/10.1016/S0308-8146(01)00357-0>

Munekata, P.E.S., Domínguez, R., Campagnol, P.C.B., Franco, D., Trindade, M.A. & Lorenzo, J.M. (2017). Effect of natural antioxidants on physicochemical properties and lipid stability of pork liver pâté manufactured with healthy oils during refrigerated storage. J. Food Sci. Technol., 54, 4324–4334.

Warner, K. (2007). Chemistry of frying oils. In E. A. Decker, R. J. Elias, & D. J. McClements (Eds.), Oxidation in foods and beverages and antioxidant applications (pp. 37–58). CRC Press.

Naz, S., Sheikh, H., Siddiqi, R., & Sayeed, S. A. (2005). Oxidative stability of olive, corn and soybean oil under different conditions. Food Chemistry, 88(2), 253–259. <https://doi.org/10.1016/j.foodchem.2004.01.050>

Farhoosh, R., Einafshar, S., & Sharayei, P. (2009). The effect of commercial refining steps on the rancidity measures of soybean and canola oils. Food Chemistry, 115(3), 933–938. <https://doi.org/10.1016/j.foodchem.2008.12.087>

Esterbauer, H., Schaur, R. J., & Zollner, H. (1991). Chemistry and biochemistry of 4-hydroxynonenal, malonaldehyde and related aldehydes. Free Radical Biology and Medicine, 11(1), 81–128. <https://doi.org/10.1016/0891-5849(91)90192-6>

Gutteridge, J. M. C., & Halliwell, B. (2010). Antioxidants: Molecules, medicines, and myths. Biochemical and Biophysical Research Communications, 393(4), 561–564. <https://doi.org/10.1016/j.bbrc.2010.02.083>

Mensink, R. P., Zock, P. L., Kester, A. D., & Katan, M. B. (2003). Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: A meta-analysis of 60 controlled trials. The American Journal of Clinical Nutrition, 77(5), 1146–1155. <https://doi.org/10.1093/ajcn/77.5.1146>

Mozaffarian, D., Micha, R., & Wallace, S. (2010). Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: A systematic review and meta-analysis of randomized controlled trials. PLoS Medicine, 7(3), e1000252. <https://doi.org/10.1371/journal.pmed.1000252>

Mozaffarian, D., Fahimi, S., Singh, G. M., Micha, R., Khatibzadeh, S., Engell, R. E., et al. (2014). Global sodium consumption and death from cardiovascular causes. New England Journal of Medicine, 371(7), 624–634. <https://doi.org/10.1056/NEJMoa1304127>

Trumbo, P., Yates, A. A., Schlicker, S., & Poos, M. (2001). Dietary reference intakes: Vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Journal of the American Dietetic Association, 101(3), 294–301. <https://doi.org/10.1016/S0002-8223(01)00078-5>.