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Comparative evaluation of the cholesterol and fatty acid profile of some beef cuts

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Abstract

Background: Beef is widely consumed across the globe, but its nutritional content, especially cholesterol and fatty acids, varies significantly based on the cut and cooking method used.
Objectives: This study focused on the comparative evaluation of cholesterol and fatty acid profiles in different cuts of beef, including lean steak, liver, and sirloin, when prepared through boiling and roasting methods.
Methods: Beef samples were obtained from local and butcher shops in Marian and Watt markets. Each sample was carefully collected, labeled, and identified with information regarding its source, date of collection, and type of cut. The fatty acid composition was determined using gas chromatography, and the cholesterol content was determined using the Lieberman-Burchard method.
Results: The findings showed significant variations in both cholesterol and fatty acid content (both in mg/100g) across the beef cuts prepared with different cooking methods. There was significant difference in the cholesterol content (in mg/100g) of steak when boiled (68.53±0.03), roasted (68.53±0.03), oil fried (74.78±0.02) and air fried (72.61±0.02). Boiled sirloin had significantly lower content of the saturated fatty acids, compared to the air fried and oil fried one. Roasted sirloin had an outstanding content of the important omega-6 called linoleic acid (18.13 ± 0.01) compared to oil fried sirloin which recorded the lowest value (5.45 ± 0.01).
Conclusions: This confirms that boiling is a healthier cooking method for meats – yielding less SFA content and more unsaturated fats; this is beneficial for cardiovascular health. Air frying is also preferable to oil frying, as it recorded moderate cholesterol content of the beef cuts and lower SFAs.

Keywords: Cholesterol; fatty acid; beef cuts; cooking methods; health

Introduction

Beef is one of the most popular sources of animal protein around the world, appreciated for its rich nutrient content, which includes high-quality protein, essential vitamins, and minerals[1]. However, the nutritional content of beef, especially its cholesterol and fatty acid levels, can vary greatly depending on the specific cut of meat and the cooking methods used. With the increasing rates of diet-related chronic diseases such as cardiovascular issues, obesity, and diabetes, there is growing concern about the health effects of dietary fats and cholesterol[2]. The way beef is cooked can significantly change its nutritional profile, impacting the balance between beneficial and harmful fatty acids.

The fatty acid profile of beef consists of saturated fatty acids (SFAs), monounsaturated fatty acids

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(MUFAs), and polyunsaturated fatty acids (PUFAs). SFAs have been linked to a higher risk of cardiovascular diseases, mainly due to their effect on increasing low-density lipoprotein (LDL) cholesterol levels[3]. In other words, MUFAs and PUFAs are known for their positive impact on lipid metabolism and their ability to lower the risk of heart-related conditions[4]. Given the potential health risks associated with high saturated fat intake, adjusting the fatty acid profile through suitable cooking methods may help promote healthier eating habits.

Cooking techniques directly affect the lipid composition of beef, influencing not just fat content but also lipid oxidation, which can produce harmful compounds[2]. Traditional cooking methods like boiling, roasting, and frying have been commonly used, but newer techniques such as air frying are being promoted as healthier options. Boiling can help reduce the overall fat content of the meat by allowing fat to drain into the water[5]. Roasting, while improving flavor and texture, may encourage lipid oxidation, resulting in changes to the fatty acid profile. Oil frying tends to increase fat absorption, which can lead to excessive intake of saturated fats. Air frying, a newer cooking method, utilizes hot air circulation to achieve similar textures to traditional frying but with less oil, thereby reducing overall fat content[6]. Despite its rising popularity, there is still limited comparative data on how air frying affects the cholesterol and fatty acid profiles of beef.

Examining beef cuts reveals significant differences in their fat content. Lean options like sirloin and steak have less intramuscular fat compared to organ meats such as liver[7]. This difference indicates that various cuts may react differently to cooking methods, highlighting the necessity for thorough research. Without a good understanding of how cooking techniques affect different beef cuts, it is difficult to offer evidence-based advice for healthier meat consumption.

SFAs, such as palmitic acid and stearic acid, are predominantly found in animal fats and has been found to raise low-density lipoprotein (LDL) cholesterol, a known risk factor for atherosclerosis and cardiovascular disease[3,8]. However, MUFAs like oleic acid, which is abundant in olive oil and also present in beef fat, has been found to support heart health by improving lipid profiles and reducing inflammation[9]. PUFAs, including omega-3 fatty acids (e.g., alpha-linolenic acid) and omega-6 fatty acids (e.g., linoleic acid), are essential fats commonly derived from plant oils, fatty fish, and nuts, and they have an important role in cell membrane integrity and anti-inflammatory processes[4]. Among these, omega-3 PUFAs are particularly heart-protective due to their ability to lower triglyceride levels and modulate blood pressure[10,11]. Figure 1 below provides a summary of the different fatty acid types and their examples.

This study conducted a detailed comparison of the cholesterol and fatty acid profiles of various beef cuts, including lean steak, liver, and sirloin, prepared using four popular cooking methods: boiling, roasting, oil frying, and air frying. By evaluating how these cooking methods impact the nutritional content of beef, the research aims to fill important gaps in our ascertaining how cooking methods affects the lipid content of beef cuts. The study specifically looks at changes in cholesterol levels and fatty acid profiles, including saturated, monounsaturated, and polyunsaturated fats, across different cuts and cooking techniques. The outcomes are expected to guide healthier cooking practices and dietary decisions, ultimately contributing to the prevention of diet-related cardiovascular diseases.

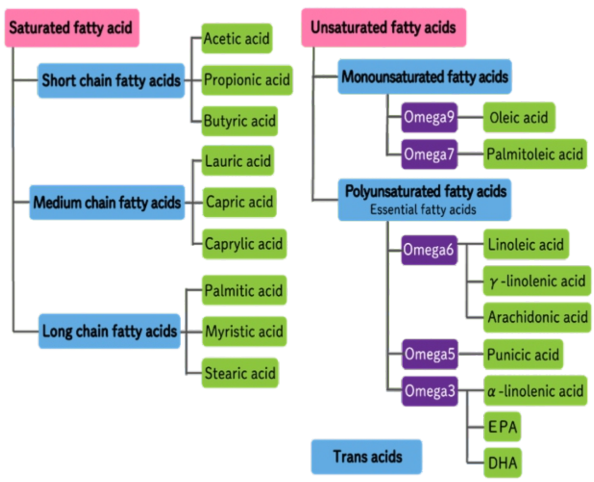

Figure 1: Prevalence of Dental Anomalies of Shape/Form

Materials and Methods

2.1 Study Location

The study was conducted in Calabar, Cross River State, Nigeria. Calabar is located in the southern region of Nigeria and serves as a major commercial hub. It is geographically positioned at latitude

4°57′0” North and longitude 8°19′0” East. The city shares boundaries with Akwa Ibom State to the west, the Republic of Cameroon to the east, and the Atlantic Ocean to the south. According to the online World Population Review, Calabar has an estimated population of over 500,000 people, with a significant portion engaged in trade, including the sale and consumption of beef products. The study focused on Marian and Watt markets, two of the largest meat markets in the city, where beef sourced from various local abattoirs is sold. These markets serve as key distribution points for meat products consumed within the metropolis and its surrounding communities.

2.2 Reagents

The major reagents used were hexane and chloroform, anhydrous sodium sulfate, acetic anhydride and sulfuric acid, methanolic potassium hydroxide, fatty acid methyl ester (fame) standards.

2.3 Sample collection and preparation

Samples of beef cuts, including lean steak, liver, and sirloin portions, were obtained from local and butcher shops in Marian and Watt markets. Each sample was carefully collected, labeled, and identified with information regarding its source, date of collection, and type of cut. The samples were trimmed of visible fat and connective tissues, washed with distilled water, and weighed. Each sample was divided into four portions, corresponding to the different cooking methods: boiling, roasting, oil frying, and air frying. Boiling was performed by submerging the beef samples in stainless-steel pots filled with distilled water and heating at 100°C for 45 minutes. Roasting was carried out by placing the samples on a baking tray and cooking in a preheated oven at 200°C for 30 minutes, with periodic turning to ensure uniform heating. Oil frying was conducted by immersing the samples in vegetable oil preheated to 180°C and frying for 10 minutes until golden brown; fresh oil was used for each batch to prevent lipid oxidation. Air frying was done using an air fryer set at 180°C for 15 minutes, with intermittent shaking at 5-minute intervals to promote even heat distribution. After cooking, the samples were allowed to cool to room temperature, reweighed to assess cooking yield, and homogenized using a laboratory blender. The homogenized samples were stored in labeled, airtight containers at -20°C until further analysis. All analyses, including cholesterol determination and fatty acid profiling, were conducted in triplicate to ensure accuracy and reproducibility.

2.4 Cholesterol determination

The cholesterol content of the processed beef samples was determined using the Liebermann-Burchard method as described by Abdulrahman et al.12. Meat extracts were prepared by homogenizing 10 g of each sample in a chloroform-methanol (2:1, v/v) solution. The extracted lipids were treated with acetic anhydride and sulfuric acid, and absorbance was measured at 640 nm using a UV/Vis spectrophotometer. A standard cholesterol calibration curve was used to quantify the cholesterol levels.

2.5 Fatty acid profile analysis

Fat extraction was performed according to the method described by Folch, & Sloane.13, using the Soxhlet extraction method with n-hexane as the extraction solvent. The extracted lipids were then converted into fatty acid methyl esters (FAMEs) through transesterification using methanolic potassium hydroxide. The FAMEs were analyzed using gas chromatography (GC) equipped with a flame ionization detector (GC-FID). A fused silica capillary column (SPTM-2560, 100 m × 0.25 mm × 0.20 μm) was used, with helium as the carrier gas at a flow rate of 0.8 ml/min. The injector and detector temperatures were set at 250°C. The oven temperature program started at 60°C, ramped to 165°C at 15°C/min, then further increased to 225°C at 2°C/min, where it was held for 20 minutes. Fatty acid identification was achieved by comparing retention times with those of known standards.

2.6 Ethical Approval

Ethical clearance was sought for and obtained from the Faculty Animal Research Ethics Committee (FAREC-FBMS) of the University of Calabar, Nigeria. The approval reference number is 300HND1724, dated October 22, 2024.

2.7 Statistical analysis

The cholesterol and fatty acid composition laboratory values were statistically analyzed using Microsoft Excel for initial data entry and calculation. Further statistical analyses were performed using one-way Analysis of Variance (ANOVA), carried out with the Statistical Package for Social Sciences (SPSS version 20.0). Differences between the means were considered statistically significant at $p < 0.05$, as indicated by the superscripts in the tables.

Table 1: Cholesterol content of some beef cuts

Cooking Methods	Steak	Liver	Sirloin
Boiled	68.53 ± 0.03^{a}	89.43 ± 0.03^{c}	92.49 ± 0.01^{d}
Roasted	68.53 ± 0.03^{a}	69.48 ± 0.03^{a}	68.79 ± 0.01^{a}
Oil fried	74.78 ± 0.02^{c}	75.82 ± 0.02^{b}	85.32 ± 0.02^{c}
Air fried	72.61 ± 0.02^{b}	89.42 ± 0.02^{c}	78.40 ± 0.00^{b}

Values are expressed as mean ±SEM, n = 2. Values in the same column with different superscripts are significantly different at p<0.05

Result

1. Cholesterol content of some beef cuts

Table 1 presents the cholesterol content (mg/100g) of steak, liver, and sirloin cuts of beef prepared using four cooking methods (boiling, roasting, oil frying, and air frying). Values are expressed as mean ± SEM (n = 2), with different superscripts within each column indicating significant differences ($p < 0.05$). Liver showed the highest cholesterol levels across all cooking methods, with boiled liver containing the highest concentration (89.43 ± 0.03 mg/100g), followed by air-fried liver (89.42 ± 0.02 mg/100g). Roasted liver had significantly lower cholesterol (69.48 ± 0.03 mg/100g), comparable to roasted steak and sirloin. Sirloin showed the most pronounced variation in cholesterol content based on cooking method. Boiled sirloin recorded the highest cholesterol (92.49 ± 0.01 mg/100g), while roasted sirloin had the lowest (68.79 ± 0.01 mg/100g). Oil-fried sirloin (85.32 ± 0.02 mg/100g) contained significantly more cholesterol than air-fried sirloin (78.40 ± 0.00 mg/100g), suggesting that oil absorption during frying may contribute to elevated cholesterol levels. Steak showed stable cholesterol levels when boiled or roasted (68.53 ± 0.03 mg/100g for both methods). However, oil frying increased its cholesterol content (74.78 ± 0.02 mg/100g), while air frying resulted in an intermediate value (72.61 ± 0.02 mg/100g).

Table 2: Fatty Acid Profile of Sirloin cut prepared using different cooking methods

Fatty Acids	Boiled Sirloin	Roasted Sirloin	Oil Fried Sirloin	Air Fried Sirloin
S.F.A C12:0	0.00 ± 0.00^{a}	8.24 ± 0.03^{i}	0.00 ± 0.00^{a}	2.39 ± 0.02^{d}
S.F.A C14:0	1.59 ± 0.02^{e}	4.23 ± 0.01^{d}	4.77 ± 0.03^{f}	1.80 ± 0.04^{c}
S.F.A C16:0	0.00 ± 0.00^{a}	7.31 ± 0.04^{h}	4.98 ± 0.02^{g}	1.30 ± 0.04^{b}
S.F.A C18:0	1.43 ± 0.04^{d}	4.44 ± 0.02^{e}	9.64 ± 0.02^{i}	5.70 ± 0.02^{j}
M.U.F.A C16:1	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
M.U.F.A C18:1	1.33 ± 0.04^{c}	4.44 ± 0.02^{e}	5.45 ± 0.02^{h}	3.14 ± 0.04^{e}
M.U.F.A C20:1	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
M.U.F.A C22:1	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
P.U.F.A C18:2	17.05 ± 0.01^{l}	18.13 ± 0.01^{j}	5.45 ± 0.01^{h}	7.42 ± 0.03^{k}
P.U.F.A C18:3	3.67 ± 0.01^{g}	4.74 ± 0.05^{f}	3.39 ± 0.02^{d}	4.85 ± 0.04^{h}
P.U.F.A C20	0.00 ± 0.00^{a}	5.43 ± 0.02^{g}	2.99 ± 0.01^{b}	0.00 ± 0.00^{a}
P.U.F.A C20:4	2.35 ± 0.03^{f}	3.03 ± 0.02^{c}	2.97 ± 0.02^{b}	4.58 ± 0.03^{f}
P.U.F.A C20:3	4.38 ± 0.02^{j}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
P.U.F.A C20:5	3.98 ± 0.02^{h}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
P.U.F.A C22:4	4.09 ± 0.02^{i}	1.48 ± 0.02^{b}	3.17 ± 0.03^{c}	4.99 ± 0.01^{i}
P.U.F.A C22:5	1.19 ± 0.02^{b}	0.00 ± 0.02^{a}	4.84 ± 0.04^{g}	4.74 ± 0.00^{g}
P.U.F.A C22:6	6.99 ± 0.01^{k}	0.00 ± 0.02^{a}	4.28 ± 0.03^{e}	4.74 ± 0.00^{g}

Values are expressed as mean ±SEM, n = 2. Values in the same row with different superscripts are significantly different at p<0.05

2. Fatty Acid Profile of Sirloin cut prepared using different cooking methods

Table 2 presents the fatty acid composition (mg/100g) of sirloin prepared using four cooking methods (boiling, roasting, oil frying, and air frying). Roasting recorded the highest lauric acid (C12:0) content (8.24 ± 0.03 mg/100g), while it was absent in boiled and oil-fried samples. Palmitic acid (C16:0) was undetectable in boiled sirloin but reached 7.31 ± 0.04 mg/100g in roasted and 4.98 ± 0.02 mg/100g in oil-fried samples. Stearic acid (C18:0) showed the highest concentration in oil-fried sirloin (9.64 ± 0.02 mg/100g), followed by air-fried (5.70 ± 0.02 mg/100g) and roasted (4.44 ± 0.02 mg/100g) preparations. For monounsaturated fatty acids, oleic acid (C18:1) was highest in oil-fried sirloin (5.45 ± 0.02 mg/100g) and lowest in boiled (1.33 ± 0.04 mg/100g). Polyunsaturated fatty acids showed distinct patterns: linoleic acid (C18:2) was most abundant in roasted (18.13 ± 0.01 mg/100g) and boiled (17.05 ± 0.01 mg/100g) sirloin, while oil-frying reduced it to 5.45 ± 0.01 mg/100g. Notably, long-chain omega-3 fatty acids EPA (C20:5) and DHA (C22:6) were only detected in boiled sirloin (3.98 ± 0.02 and 6.99 ± 0.01 mg/100g respectively), suggesting thermal degradation in other cooking methods.

Discussion

This study provides a comprehensive assessment of how various cooking methods such as boiling, roasting, oil frying, and air frying affect the cholesterol content and fatty acid profiles of different beef cuts, including steak, liver, and sirloin. Cholesterol content varied widely across the samples, both by cut and cooking method. Liver, which plays an important role in cholesterol metabolism and storage, had the highest cholesterol content across all preparation methods, with boiled liver containing 89.43 mg/100g. This aligns with previous findings from Cabrera and Saadoun[7] that organ meats typically contain higher cholesterol concentrations due to their metabolic functions. However, roasting resulted in a consistently lower cholesterol concentration compared to boiling, suggesting that dry heat may promote cholesterol loss either through physical drip or chemical alteration. This phenomenon could be attributed to oxidative reactions and moisture evaporation, which potentially affect the extractability or measurable concentration of cholesterol in the cooked product[14]. Despite cholesterol's recognized thermal stability up to approximately 150°C[12], the cooking environment, duration, and lipid-protein matrix interactions likely play important roles in modulating its final concentration.

The study also demonstrated that fatty acid profiles undergo complex alterations depending on the applied cooking technique. Saturated fatty acids (SFAs), particularly palmitic acid (C16:0) and stearic acid (C18:0), had relative thermal stability, but their concentrations were not static. Roasting, due to the significant loss of moisture, resulted in apparent concentration of SFAs, especially in sirloin and steak samples. On the other hand, boiling led to lower concentrations of SFAs, which could be explained by their partial migration into the cooking water or reduced thermal exposure compared to dry heat methods; a similar trend was observed by Franke et al.[15] The complete absence of lauric acid (C12:0) in boiled samples but its presence in roasted samples further supports the theory that shorter-chain saturated fatty acids may undergo volatilization or be more susceptible to solubilization in water-based cooking[2].

Monounsaturated fatty acids (MUFAs), mainly oleic acid (C18:1), were relatively well preserved across all methods but were particularly elevated in oil-fried samples[16]. This could be due to two factors: enhanced extraction and migration from the cooking oil into the meat matrix, and the inherent oxidative resistance of oleic acid compared to polyunsaturated fatty acids (PUFAs). The presence of isomers, even in trace amounts, is concerning given their established association with increased risk of cardiovascular disease[3]. The balance between MUFA preservation and trans-fat formation shows the dual-edged nutritional effect of oil frying and calls for cautious application of this method, especially for health-conscious consumers or individuals with pre-existing metabolic conditions.

Polyunsaturated fatty acids (PUFAs) were the most vulnerable to degradation under heat. This is consistent with their chemical structure, which includes multiple double bonds that are more prone to oxidative breakdown[17]. Omega-3 PUFAs, specifically eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), were completely lost in all cooking methods except boiling. This is significant, considering the important role these fatty acids play in cardiovascular and neurological health[10,11]. The aqueous environment in boiling may act as a thermal buffer that protects these thermolabile compounds. Minimal exposure to oxygen and lower cooking temperatures likely contribute to their retention[18]. However, oil frying and roasting, which involve higher temperatures and more oxidative environments, resulted in their complete disappearance. Linoleic acid (C18:2), an omega-6 fatty acid, showed greater thermal stability than omega-3 PUFAs but still experienced marked reductions, particularly during frying. These findings affirm previous research indicating that essential fatty acids are highly sensitive to cooking conditions and that preserving them requires careful selection of preparation techniques[4].

The distinct effects of different cooking methods can be attributed to their respective thermal and physical environments. Boiling involves the use of water as a heat transfer medium, which not only moderates the temperature but also facilitates the leaching of water-soluble and loosely bound lipid components. Roasting, a dry heat method, promotes both Maillard reactions and lipid oxidation, leading to the concentration of remaining lipids and the generation of oxidation products. Oil frying introduces an external lipid medium that can contribute additional fats to the meat while promoting complex reactions such as hydrogenation and lipid exchange. Air frying, a relatively newer method, uses circulating hot air to cook food, leading to moderate fat retention with reduced oil absorption. Although less aggressive than oil frying, air frying may still result in the loss of delicate fatty acids due to its high thermal output[6].

The findings from this study are particularly pertinent. In many cultures, beef serves as a staple protein source, and its lipid composition can significantly impact dietary fat intake[19]. The observed differences in lipid content based on cooking methods suggest that standard nutritional labeling of raw beef products may not adequately inform consumers. For instance, the near-total loss of omega-3 fatty acids in all except boiled ones emphasize the importance of not just what meat is consumed, but how it is prepared. This could be especially relevant in low- and middle-income populations, where access to diverse dietary sources of essential fatty acids is limited.

Frying and roasting generally enhance the organoleptic properties of meat, making them more appealing to consumers[20]. However, these methods also tend to promote the formation of undesirable lipid fractions, such as trans fats and oxidized PUFAs. On the other hand, boiling, while preserving essential fatty acids, may lead to textural and flavor changes that reduce acceptability. Balancing these factors presents a key challenge for nutrition educators, chefs, and food policymakers. The consumption of high cholesterol foods should be discouraged particularly for those at risk of dyslipidemias[21].

While SFAs are often associated with negative health outcomes, the context in which they are consumed alongside MUFAs, PUFAs, and in a specific cooking matrix can modulate their impact[22,23]. The results from this study suggest that the health benefits of beef are not solely dependent on its raw composition, but also on the way it is prepared. This has profound implications for epidemiological studies and dietary guidelines, which often fail to consider food preparation methods. In precision nutrition, where dietary interventions are tailored to individual metabolic needs, these insights are especially valuable. For instance, individuals with hypercholesterolemia or omega-3 deficiencies may benefit from consuming boiled beef rather than fried or roasted preparations.

Conclusion

Considering the current and rapid nutrition and culinary transitions taking place globally, the findings of this study are notably important in providing dietary counselling to people who seek to eat and stay healthy. As more populations move toward convenience cooking and processed meat consumption, the risk of nutrient loss and increased intake of harmful lipid fractions may rise. Public health awareness and food labeling must evolve to incorporate not just what foods are eaten but how they are prepared. Promoting healthier cooking methods like boiling or air frying, particularly in settings where meat is a central dietary component, could support better health outcomes without compromising cultural and sensory food values.

Conflict of interest disclosure: No conflict of interest exists.

Author Contributions: Author EO was responsible for the concept and design of the study in addition to the manuscript preparation. Author BI and Author JI carried out literature search, sample collection and data acquisition. Author AA assisted in manuscript editing and data analysis. All the authors read and approved the final version of the paper.

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