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Comparative Physico-Chemical Analysis of Animal Fats from Abattoirs in Sokoto Metropolis for Sustainable Waste-to-Value and Environmental Management Applications

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ABSTRACT

The increasing volume of lipid-rich waste generated from abattoirs and meat processing activities presents both environmental and economic concerns, particularly in regions with limited waste management infrastructure. In many Nigerian cities, rendered animal fats are often discarded without treatment, contributing to environmental pollution and sanitation issues. At the same time, these fats possess significant industrial value as raw materials for soap production, cosmetics, lubricants, and biofuel generation. In this study, fats rendered from cow, goat, camel, and sheep tissues collected within Sokoto Metropolis, Nigeria, were examined to determine their physicochemical characteristics and possible end-use applications. Physical properties (colour, melting point, specific gravity, and density) and chemical parameters (ash content, moisture content, acid value, free fatty acid, saponification value, iodine value, and peroxide value) were determined in triplicate (n = 3). All physical and chemical analyses strictly adhered to standard protocols recommended by the Association of Official Analytical Chemists. The results showed significant differences among the samples. Cow fat recorded the highest ash content (26.0 ± 0.264 %), moisture content (31.5 ± 0.265 %), and saponification value (98.035 ± 0.004 mg KOH/g), suggesting stronger potential in soap and detergent production. Camel fat exhibited the highest acid value (3.506 ± 0.004 mg KOH/g), free fatty acid (1.753 ± 0.003 %), and peroxide value (0.030 ± 0.003 meq/kg), indicating a higher tendency toward hydrolytic and oxidative degradation. Goat fat showed the highest iodine value (0.761 ± 0.003 g I_2/100 g), which may favor its use in biodiesel production due to a relatively higher level of unsaturation. Overall, the findings highlight the viability of converting animal fat waste into useful industrial feedstocks while reducing environmental burden.

KEYWORDS: animal fat, physicochemical analysis, biodiesel, waste valorization, industrial application.

1. INTRODUCTION

Large quantities of animal-derived waste are generated daily from slaughterhouses, meat processing facilities, and livestock markets across Nigeria.[1] Among these wastes, adipose tissues are often rendered into fats or simply discarded.[2] In many urban and semi-urban areas, indiscriminate disposal of these fatty wastes contributes to drainage blockage, offensive odour, and contamination of nearby soil and water systems.[3] Sustainable approaches that convert such wastes into useful materials are therefore increasingly important.[4]

Animal fats are composed primarily of triglycerides and have been utilized for centuries in food preparation and in the manufacture of soaps, candles, and skin-care products.[5] In recent years, renewed interest has emerged in their use as low-cost feedstocks for renewable energy production, particularly biodiesel.[6] Compared with edible vegetable oils, animal fats are less expensive and do not directly compete with food supply chains.[7] Their suitability for industrial use, however, depends strongly on their physicochemical composition.[8]

Parameters such as acid value, free fatty acid content, and peroxide value provide insight into the extent of hydrolysis and oxidation within fat samples.[9,8] Saponification value reflects the average molecular weight of the constituent fatty acids and can indicate suitability for soap production.[5] Iodine value reveals the degree of unsaturation, which affects oxidative stability and biodiesel performance.[6] In addition, physical characteristics such as density, specific gravity, and melting point influence handling, storage, and processing conditions.[10]

Sokoto Metropolis is one of the largest centers of livestock slaughter and trade in northern Nigeria.[3] Despite the abundance of animal fat generated in this region, there is limited published information comparing the properties of fats obtained from different species under the same environmental conditions. This work therefore evaluates the physicochemical properties of rendered fats from cow, goat, camel, and sheep collected within Sokoto Metropolis and considers their suitability for selected industrial and bioenergy applications.

2. MATERIALS AND METHODS

2.1 Sample Collection

Fresh adipose tissues were obtained from slaughtered cow, goat, camel, and sheep at selected abattoirs within Sokoto Metropolis, Sokoto State, Nigeria. The samples were collected immediately after slaughter into clean polyethylene bags and transported to the laboratory for processing.

2.2 Rendering and Preparation of Fat Samples

Each adipose tissue sample was rinsed thoroughly with clean water to remove adhering blood and dirt. The tissues were then cut into smaller portions and heated gently in clean metallic containers to release the fat. The rendered fat was separated from the residual tissues and filtered through a fine-grade Muslin cloth (100 % cotton, pore size ≈ 100 μm) to remove suspended particles. The filtrate was stored in airtight sample bottles under dry, cool conditions prior to analysis.

2.3 Determination of Physical Properties

All physical measurements were conducted in triplicate (n = 3). Visual appearance and color were evaluated under natural sunlight. Melting point was evaluated by the open capillary tube method. Specific gravity (dimensionless ratio) and density (kg/m³) were determined at 25 °C.

2.4 Determination of Chemical Properties

All chemical determinations were performed in triplicate (n = 3). Moisture and volatile matter content were determined by oven-drying a known mass at 105 °C to constant weight. Total ash content was measured by dry ashing in a muffle furnace at 550 °C. Acid value and percentage free fatty acid (FFA, calculated as oleic acid equivalent) were determined by titration with standardized ethanolic 0.1 M KOH in a neutralized solvent mixture. Saponification value was determined by alcoholic potassium hydroxide reflux and back-titration with 0.5 M HCl in accordance with AOAC Official Method 920.160. The degree of unsaturation (iodine value) was determined using the Wijs halogen absorption technique. Primary oxidative stability (peroxide value) was evaluated by iodometric titration against standardized sodium thiosulfate solution.

All analytical protocols for physical and chemical parameter determinations implemented in this study strictly followed the standard methods approved and recommended by the Association of Official Analytical Chemists.[10]

3. RESULTS AND DISCUSSION

3.1 Physical Properties and Assessment

Table 1. Physical Properties of Selected Animal Fats (n = 3, Mean ± Standard Deviation)

Parameter	Sample A (Cow)	Sample B (Goat)	Sample C (Camel)	Sample D (Sheep)
Colour	Pale yellow	White	Cream colour	White
Melting Point (°C)	43.7 ± 0.1	45.2 ± 0.265	43.5 ± 0.173	44.4 ± 0.361
Specific Gravity (dimensionless)	0.985 ± 0.001	0.914 ± 0.004	0.968 ± 0.003	0.939 ± 0.002
Density (kg/m³)	985.000 ± 4.000	914.000 ± 2.000	968.000 ± 2.000	938.000 ± 1.154

Physical properties serve as vital indicators of sample purity, thermal behavior, and mass-transport dynamics required in industrial chemical processing. The visual colour assessment reflects pigment retention, thermal exposure during rendering, or potential contamination. Cow fat displayed a distinct pale-yellow hue due to carotenoid pigments retained from pasture grazing, whereas goat and sheep fats were pure white. From a waste-valorization perspective, white fats are highly preferred for cosmetic formulations, personal care products, and skin creams, as they eliminate the need for costly industrial bleaching steps. Conversely, yellowish or cream-coloured fats, such as cow and camel fat, are better suited for biofuel generation or industrial grease production.

The observed melting points (43.5 °C – 45.2 °C) fall squarely within established literature ranges for refined animal tallows (42.-0 °C – 48.0 °C).[9,7] High melting points indicate an elevated proportion of long-chain saturated fatty acids, primarily palmitic and stearic acids. Goat fat recorded the highest melting point (45.2 ± 0.265 °C), pointing directly to its suitability for hard bar soap production, candle making, and heavy-duty industrial greases. In biodiesel applications, high melting points signify higher cetane numbers but necessitate fuel pre-heating systems to prevent cold-weather gelation.[8]

The observed density values (914.0 – 985.0 kg/m³) align closely with standard animal fat ranges (910.0 – 950.0 kg/m³).[10] Cow fat showed slightly elevated density (985.0 kg/m³), which can be attributed to residual bound water and suspended non-lipid particles from traditional open-pan rendering. Analytically, density and specific gravity govern fluid dynamics, mass-to-volume metering, and phase separation efficiency within industrial transesterification or saponification reactors.

3.2 Chemical Properties and Applications

Table 2. Chemical Properties of Selected Animal Fats (n = 3, Mean ± Standard Deviation)

Parameter	Sample A (Cow)	Sample B (Goat)	Sample C (Camel)	Sample D (Sheep)
% Moisture Content	31.5 ± 0.265	28.5 ± 0.100	10.5 ± 0.361	26.5 ± 0.360
% Ash Content	26.0 ± 0.264	21.5 ± 0.200	14.5 ± 0.360	22.0 ± 0.264
Acid Value (mg KOH/g)	3.086 ± 0.001	3.029 ± 0.004	3.506 ± 0.004	2.244 ± 0.003
Free Fatty Acid (%)	1.543 ± 0.003	1.515 ± 0.004	1.753 ± 0.003	1.112 ± 0.002
Saponification Value (mg KOH/g)	98.035 ± 0.004	55.259 ± 0.002	57.362 ± 0.003	43.478 ± 0.002
Peroxide Value (meq/kg)	0.025 ± 0.003	0.020 ± 0.002	0.030 ± 0.002	0.010 ± 0.001
Iodine Value (g I_2/100 g)	0.508 ± 0.003	0.761 ± 0.001	0.508 ± 0.004	0.254 ± 0.002

While commercial refined fats strictly require moisture below 1.0% and ash below 0.5%, the unrefined abattoir waste fats exhibited higher moisture (10.5 % – 31.5 %) and ash (14.5 % – 26.0 %) contents due to direct thermal rendering. Analytically, high moisture promotes triglyceride hydrolysis during storage, while high ash indicates inorganic mineral residues. In terms of end-use, high moisture interferes with base-catalyzed transesterification by causing unwanted emulsion and soap formation.[9] Therefore, pre-treatment steps involving centrifugal dewatering and fine filtration are essential before these waste streams can be efficiently valorized into biodiesel or chemical lubricants.

The determined acid values (2.24 – 3.51 mg KOH/g) and free fatty acid (FFA) levels (1.11 % – 1.75 %) are moderately lower than those typically reported for highly degraded waste cooking oils (>5.0 mg KOH/g), indicating that rendered tissues were processed shortly post-slaughter. Analytically, FFA content dictates the choice of catalytic pathway. Sheep, goat, and cow fats (1.11 % – 1.54 % FFA) can undergo direct homogeneous base-catalyzed transesterification, whereas camel fat (1.75 % FFA) approaches the threshold requiring a two-step acid-esterification process to prevent catalyst neutralization.[9,6]

Saponification value measures the alkali needed to saponify a given mass of fat, providing an inverse index of average molecular weight.[5] Lower overall saponification values compared to pure refined tallow (190 – 202 mg KOH/g) stem from non-lipid matrix inclusions in crude rendering. Nevertheless, cow fat recorded a significantly higher saponification value (98.035 mg KOH/g) relative to other species, directly demonstrating its superior reactivity for soap and commercial detergent manufacturing.

The iodine values (0.254 – 0.761 g I_2/100 g) are substantially lower than vegetable oil feedstocks (80 – 140 g I_2/100 g), confirming high structural saturation.[6] Analytically, iodine value measures double bond concentration, where lower unsaturation grants exceptional oxidative stability during extended storage. Goat fat exhibited the highest iodine value (0.761 g I_2/100 g), pointing to better cold-flow properties (lower cloud point) in biodiesel applications, whereas sheep fat (0.254 g I_2/100 g) offers maximum resistance to oxidative rancidity. Furthermore, peroxide values (0.010 – 0.030 meq/kg) remained well below the standard rancidity threshold (10.0 meq/kg), confirming minimal primary lipid oxidation and validating that these waste fats maintain sufficient quality for high-value applications, including pharmaceutical ointments, cosmetics, and bio-based lubricants.

3.3 Integrated Valorization Matrix for Abattoir Waste Management

To establish a sustainable waste-to-value framework within urban abattoir management, the analytical results directly inform species-specific valorization pathways. Cow fat, characterized by its high saponification value (98.04 mg KOH/g) and density, is primarily targeted for soap and detergent manufacturing, which directly diverts organic pollutant loading from municipal aquatic discharges. Goat fat, exhibiting the highest iodine value (0.761 g I_2/100 g) and a clear white colour, serves as an optimal feedstock for biodiesel production and cosmetics, offsetting fossil fuel dependency while reducing solid waste accumulation.

Camel fat displays relatively lower moisture (10.5 %) but elevated free fatty acid content, making it best suited for bio-lubricant synthesis and energy recovery following two-step acid-esterification pre-treatment, thereby preventing soil contamination and offensive odour emissions from land dumping. Finally, sheep fat offers superior oxidative stability and a low iodine value (0.254 g I_2/100 g), rendering it ideally suited for industrial greases and extended-storage fuel blends, which further advances circular economy principles within local livestock waste networks.

4. CONCLUSION

Based on the obtained results, it was concluded that rendered animal fats obtained from common livestock species in Sokoto Metropolis differ significantly in both physical and chemical properties. Cow fat exhibited characteristics that favor soap and detergent production due to its high saponification value (98.035 ± 0.004 mg KOH/g). Goat fat may serve as a better biodiesel feedstock because of its comparatively higher iodine value (0.761 ± 0.001 g I_2/100 g) and lower peroxide content. Camel fat showed signs of greater hydrolytic and oxidative degradation (3.506 ± 0.004 mg KOH/g acid value), which indicates the need for pre-treatment before industrial utilization. Sheep fat displayed comparatively superior oxidative stability. Converting these slaughterhouse-derived waste fats into high-value industrial feedstocks offers a viable pathway for effective waste management and sustainable environmental management in urban centers.

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