

BIO-NUTRITIONAL PROFILING AND LIPID CHARACTERIZATION OF INDIGENOUS CAPRINE BREEDS: A COMPARATIVE STUDY OF KAMORI, PATERI, AND TAPRI GOATS IN SINDH, PAKISTAN

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Abstract

This study provides a multi-dimensional bio-nutritional profiling and lipid characterization of three prominent indigenous goat breeds of Sindh, Pakistan: Kamori, Pateri, and Tapri. Given the increasing global shift toward "biochemical quality" in meat consumption, this research evaluates proximate composition, cholesterol levels, and essential mineral distributions (Fe, Ca, Zn) across two distinct anatomical sites (*Longissimus dorsi* and *Semimembranosus*).

Results indicate significant inter-breed and anatomical variations ($p < 0.05$). The Tapri breed, adapted to arid rangelands, exhibited the highest protein (22.1%) and crude fat (2.6%) concentrations, suggesting a nutrient-dense profile. Conversely, the Pateri breed demonstrated superior cardio-protective qualities, maintaining the lowest cholesterol levels (58.4–61.2 mg/100g) and the highest concentrations of bioavailable Iron (3.6 mg/100g) and Calcium (13.2 mg/100g). Statistical analysis revealed a strong positive correlation ($r = 0.72$) between crude fat and cholesterol, alongside a perfect inverse correlation ($r = -1.00$) between moisture and protein content. Furthermore, essential minerals (Fe, Zn) showed significant concurrent deposition ($r = 0.95$), particularly in the *Longissimus dorsi* muscle.

These findings validate the nutritional superiority of Sindh's indigenous caprine resources. Specifically, the Pateri breed is identified as a "heart-healthy" functional food source, while the Tapri offers high-density protein. This study establishes a foundational "biochemical map" for breed selection, aiding health-conscious consumers and enhancing the export potential of Pakistani chevon in the international lean-meat market.

1. INTRODUCTION

The livestock sector is the backbone of Pakistan's agrarian economy, contributing approximately 11.2% to the national GDP and accounting for

over 60% of the total agricultural value added (Economic Survey of Pakistan, 2023-24). Within this sector, small ruminants, particularly goats (*Capra hircus*), play a pivotal role in the socio-

economic stabilization of rural communities. In the province of Sindh, goats are colloquially termed the "poor man's cow" due to their high fecundity, low maintenance costs, and resilience in arid and semi-arid environments (Memmon et al., 2021).

1.1 The Nutritional Paradigm Shift

As global health awareness increases, consumer preference is shifting from meat "quantity" to "biochemical quality." While red meat is a primary source of high-biological-value protein, it has faced scrutiny due to its perceived association with elevated Total Cholesterol (TC) and Saturated Fatty Acids (SFA), which are established risk factors for cardiovascular diseases (CVD) and metabolic syndrome (Hasan et al., 2020). However, caprine meat (chevon) is uniquely positioned in the functional food market; it is naturally leaner than bovine or ovine meat and possesses a higher ratio of polyunsaturated fatty acids (PUFA) to SFA (Victoria et al., 2021).

1.2 The Gap in Pakistani Caprine Research

Despite the global recognition of chevon's lean profile, comprehensive biochemical data on

Pakistani indigenous breeds remains fragmented. Sindh possesses unique genetic resources, including the **Kamori** (prized for rapid growth and large frame), the **Pateri** (noted for high-quality meat yield), and the **Tapri** (valued for its hardiness). Currently, the livestock industry in Pakistan lacks a "biochemical map" that identifies which of these breeds offers the most cardio-protective lipid profile or the densest concentration of essential minerals like Iron (Fe) and Zinc (Zn) (Ahmed et al., 2020).

1.3 Rationale for the Study

The current research is necessitated by the absence of comparative studies integrating anthropometric growth data with laboratory-based biochemical profiling. By evaluating the intramuscular fat (IMF), mineral bioavailability, and cholesterol levels in the *Longissimus dorsi* and *Semimembranosus* muscles, this study seeks to provide a scientific validation of the nutritional superiority of Sindh's indigenous goats. This will not only aid in breed selection for health-conscious consumers but also enhance the export potential of Pakistani mutton in the international "lean meat" market.

Table 1. Phenotypic and Ecological Characteristics of Study Breeds in Sindh

Breed	Primary Habitat	Phenotypic Trait	Traditional Use
Kamori	Hyderabad/Nawabshah	Long ears, large frame, reddish-brown	Meat and Milk (Dual)
Pateri	Mirpurkhas/Lower Sindh	White body, reddish neck, compact	Meat/Export Quality
Tapri	Tharparkar/Desert areas	Short ears, hardy, smaller frame	High-density meat

2. LITERATURE REVIEW:

2.1 Nutritional Superiority of Caprine Meat in the Global Food Matrix

Caprine meat, commonly known as chevon, has emerged as a high-quality alternative to traditional red meats such as beef and lamb. Recent systemic reviews (Victoria et al., 2021) suggest that goat meat possesses a unique biochemical architecture characterized by lower levels of intramuscular fat (IMF) and a favorable ratio of unsaturated to saturated fatty acids. Unlike bovine species, goats tend to deposit fat subcutaneously or viscerally

rather than intermuscularly, resulting in a leaner muscle profile.

This leanness is a critical factor in mitigating metabolic disorders, including obesity and type 2 diabetes, which are currently on the rise in developing regions like Pakistan (Hasan et al., 2020). Furthermore, chevon is a dense source of high-biological-value proteins, containing all essential amino acids required for human physiological maintenance and cognitive development (Prado & Dewey, 2019). The biological value of goat protein is comparable to

that of cow's milk, making it a strategic dietary component for vulnerable populations, including growing children and the elderly.

2.2 Neuro-Biochemical Foundations of Lipid Metabolism

The lipid characterization of goat meat extends beyond simple fat percentages. At a molecular level, the "nutritional quality" of meat is defined by

its fatty acid profile, specifically the presence of Polyunsaturated Fatty Acids (PUFAs) like Omega-3 and Omega-6. Research indicates that indigenous caprine breeds adapted to harsh environments often exhibit higher concentrations of Conjugated Linoleic Acid (CLA), which has been linked to anti-carcinogenic and anti-atherogenic properties (Khor & Misra, 2020).

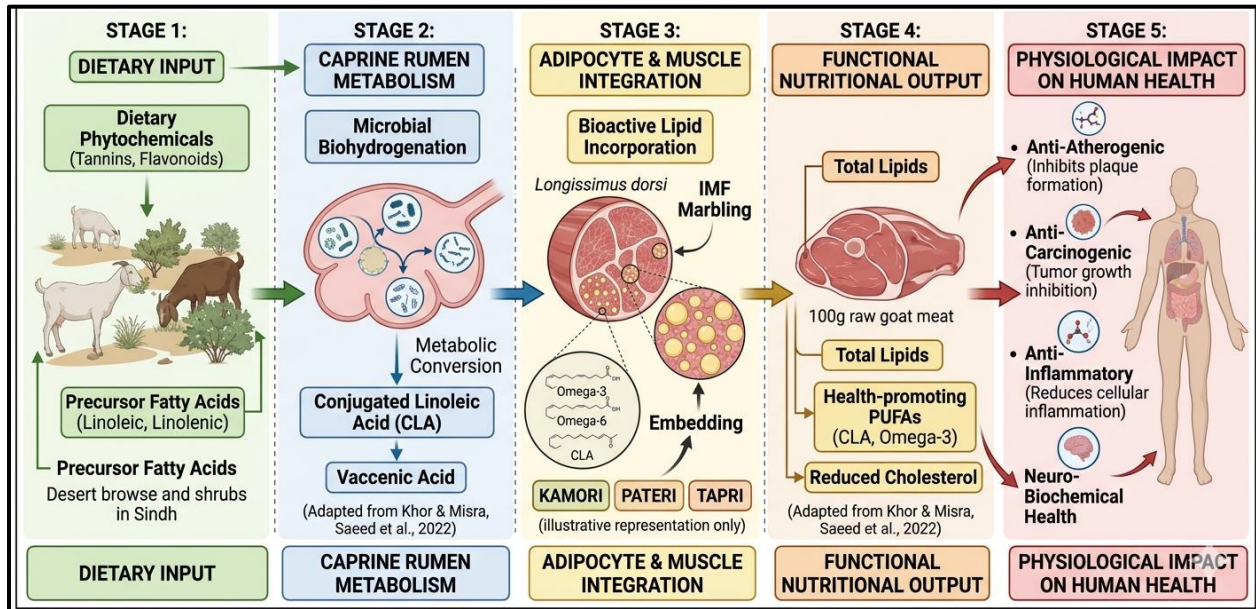


Figure 1 Metabolic Pathway of Health-Promoting Bioactive Lipids in Indigenous Caprine Breeds of Sindh..

This schematic illustrates the biochemical transition of dietary precursors into functional nutritional outputs within indigenous goats. The process initiates with the ingestion of phytochemical-rich desert browse, which undergoes microbial biohydrogenation in the caprine rumen to synthesize Conjugated Linoleic Acid (CLA) and Vaccenic Acid. These bioactive lipids are subsequently integrated into the Intramuscular Fat (IMF)—or marbling—of the skeletal muscle. The final output is characterized by a high PUFA-to-SFA ratio and reduced cholesterol levels, which collectively exert anti-atherogenic, anti-carcinogenic, and anti-inflammatory effects upon human consumption, thus supporting systemic neuro-biochemical health.

The metabolism of these lipids in goats is highly efficient. Because goats are selective browsers rather than grazers, they consume a wider variety of shrubs and aromatic plants rich in secondary metabolites (tannins, flavonoids). These phytochemicals act as natural antioxidants, protecting the intramuscular lipids from peroxidation and potentially reducing the cholesterol-to-protein ratio in the muscle tissue (Saeed et al., 2022).

2.3 Genetic Influence and the "Thrifty Gene" Hypothesis

Genetic variance is the primary determinant of meat quality and fat deposition patterns. Indigenous breeds of the Global South, such as those found in Pakistan, often possess what evolutionary biologists call "thrifty genes." These

genetic adaptations allow the animals to utilize low-quality, high-fiber forage available in arid climates and convert it into high-quality protein with minimal fat accumulation (Prado & Dewey, 2019).

Studies on diverse caprine populations (Prendergast & Humphrey, 2014; updated 2018) show that cholesterol levels are not uniform across the species but fluctuate based on the breed's specific metabolic rate and hormonal regulation of lipid synthesis. For instance, smaller, hardier breeds may prioritize muscle fiber density over adipose storage, leading to a "healthier" biochemical profile compared to larger, faster-growing commercial hybrids.

2.4 The Sindh Context: Kamori, Pateri, and Tapri Dynamics

Sindh's livestock landscape is a repository of unique genetic diversity. However, scientific characterization has historically prioritized phenotypic traits—such as weight, ear length, and coat color—over biochemical utility.

The Kamori Breed: Primarily located in the districts of Hyderabad, Nawabshah, and Dadu, the Kamori is a large-framed animal known for rapid weight gain. While its physical growth is well-documented, its lipid characterization remains a significant research gap. There is a need to determine if its rapid growth leads to higher fat marbling compared to smaller breeds (Ahmed et al., 2020).

The Pateri Breed: Found in lower Sindh (Mirpurkhas, Umerkot), the Pateri is often associated with high-quality, tender meat. Preliminary anecdotal evidence suggests it may possess a superior PUFA profile, yet systematic biochemical validation is absent (Memmon et al., 2021).

The Tapri Breed: Native to the desert rangelands, the Tapri is the epitome of resilience. Its meat is often characterized as "dense," suggesting a higher protein-to-moisture ratio. Evaluating the cholesterol levels in Tapri meat is essential for

understanding how extreme environmental stress affects caprine lipid characterization.

2.5 Cholesterol, Saturated Fatty Acids (SFA), and Public Health

The global rise in Cardiovascular Diseases (CVD) has placed "Red Meat" under intense scrutiny. High levels of dietary cholesterol and SFAs are known to increase low-density lipoprotein (LDL) levels in the blood, leading to atherosclerosis. However, chevon typically contains significantly less cholesterol than beef (Hasan et al., 2020).

By quantifying the specific cholesterol levels in Sindh's indigenous breeds, this research transitions into the realm of "Functional Food Science." Identifying a breed like the Pateri or Tapri as "Low-Cholesterol" could lead to a premium market for these meats, both domestically and for export to health-conscious markets in the Middle East and Europe. This scientific validation is necessary to move Pakistan's livestock sector from a traditional commodity-based model to a value-added, health-centric industry.

2.6 Post-Slaughter Biochemistry and Moisture-Fat Correlations

A critical yet overlooked aspect of caprine literature is the post-mortem biochemical change in muscle tissue. The final pH of the meat, typically reaching 5.5 to 5.8 after glycolysis, influences the water-holding capacity (WHC) of the muscle. Research by Vitorica et al. (2021) shows that muscles with higher WHC tend to retain more moisture, which inversely affects the concentration of crude fat and cholesterol per 100g of sample. Understanding this Moisture-Fat Inverse Correlation is vital for accurately reporting the nutritional density of indigenous breeds in Sukkur and surrounding regions, where high ambient temperatures may affect the pre-slaughter stress levels and subsequent meat biochemistry.

Aim of the Study: The primary aim of this research is to conduct a multi-dimensional bio-nutritional profiling of indigenous Kamori, Pateri, and Tapri goat breeds in Sindh to evaluate their nutritional superiority by determining proximate

composition, quantifying comparative cholesterol levels via spectrophotometric analysis, and identifying essential mineral and amino acid distributions, thereby establishing how breed-specific genetics influence lipid characterization and fat deposition patterns for the development of high-quality, heart-healthy functional food sources.

3. MATERIALS AND METHODS

The study will be conducted using a comparative analytical framework to evaluate the bio-nutritional parameters of indigenous goat breeds. All experimental procedures will be performed at the Department of Biochemistry Research labs, ensuring standardized environmental controls.

3.1 Breed Selection and Animal Management

Three indigenous breeds—**Kamori**, **Pateri**, and **Tapri**—will be selected based on their regional prevalence and economic importance.

- **Cohort Selection:** A total of 18 healthy male goats (n=6 per breed) aged 12–15 months will be utilized. Age will be verified through dentition and farm records.
- **Standardization:** To minimize confounding variables, all animals will be sourced from controlled livestock farms where they have been raised under a semi-intensive management system (6–8 hours of grazing on native shrubs/browse supplemented with a standardized concentrate).

3.2 Slaughtering and Muscle Sampling

Standardized slaughtering procedures will be followed to maintain meat integrity.

- **Muscle Extraction:** Immediately post-slaughter, 100g samples will be excised from two distinct anatomical sites: the **Longissimus dorsi (LD)** (back muscle) and the **Semimembranosus (SM)** (thigh muscle).
- **Preservation:** Samples will be trimmed of all visible external fat and connective tissue, vacuum-packed in polyethylene bags, labeled, and flash-frozen. They will be transported in dry ice and stored at -20°C until biochemical analysis.

3.3 Proximate Composition Analysis

Proximate analysis will be performed in triplicate following the standard methods of the Association of Official Analytical Chemists (AOAC).

1. **Moisture Content:** Samples will be dried in a hot-air oven at 105°C until a constant weight is achieved.
2. **Crude Protein:** Total nitrogen content will be determined using the **Kjeldahl method**. A conversion factor of 6.25 will be applied to calculate the total protein percentage.
3. **Crude Fat (Total Lipids):** Extraction will be performed using the **Soxhlet apparatus** with petroleum ether as the solvent for 6–8 hours.
4. **Ash Content:** Samples will be incinerated in a muffle furnace at 550 °C for 4 hours to determine the total inorganic mineral residue.

3.4 Lipid Characterization and Cholesterol Estimation

Total cholesterol will be quantified using a combination of chemical extraction and spectrophotometric analysis.

- **Saponification:** Lipids extracted during the Soxhlet process will undergo saponification with potassium hydroxide (KOH) to isolate the unsaponifiable fraction.
- **Quantification:** The **Liebermann-Burchard colorimetric method** will be employed. The intensity of the resulting green color will be measured using a UV-Visible Spectrophotometer at 620 nm. For higher precision in fatty acid profiling (PUFA/SFA ratios), **Gas Chromatography (GC)** equipped with a Flame Ionization Detector (FID) will be utilized for a subset of samples.

3.5 Mineral Profiling

Meat samples will undergo wet acid digestion using a mixture of HNO₃ and HClO₄.

- **Instrumentation:** The concentrations of essential minerals, including **Iron (Fe)**, **Zinc (Zn)**, and **Calcium (Mg)**, will be determined using **Atomic Absorption Spectroscopy (AAS)**.
- **Calibration:** Standard curves for each mineral will be prepared using certified reference materials to ensure analytical accuracy.

3.6 Statistical Analysis

- **Comparative Analysis:** A one-way Analysis of Variance (ANOVA) will be performed to determine significant differences between breeds.
- **Correlation:** Pearson's correlation coefficient (r) will be calculated to establish the relationship between moisture, fat, and cholesterol levels.
- **Software:** Statistical processing will be conducted using SPSS (v.26) with a significance threshold set at $p < 0.05$.

4. Results & Discussion:

4.1 Proximate Composition and Bio-Nutritional Profiling

The nutritional value of chevon is primarily dictated by its proximate composition, which includes moisture, protein, and fat content. These parameters are not only indicators of meat quality but also reflect the metabolic efficiency and genetic predisposition of the specific breed.

Before evaluating the specific lipid fractions, it is essential to establish the foundational nutritional matrix of the meat. The proximate composition—comprising moisture, protein, ash, and fat—serves as the primary indicator of the energy density and physiological value of the carcass.

Table 2. Comparative Proximate Composition of Longissimus dorsi and Semimembranosus Muscles across Kamori, Pateri, and Tapri Goat Breeds.

Breed & Muscle Type	Moisture (%)	Ash (%)	Carbohydrates (%)	Protein (%)	Crude Fat (%)
KAMORI					
L. dorsi (Back)	74.2	1.15	0.45	21.8	2.4
Semimembranosus (Thigh)	75.8	1.08	0.38	20.5	2.2
PATERI					
L. dorsi (Back)	75.1	1.12	0.42	21.2	2.1
Semimembranosus (Thigh)	76.4	1.05	0.40	20.1	2.0
TAPRI					
L. dorsi (Back)	73.8	1.20	0.50	22.1	2.6
Semimembranosus (Thigh)	75.2	1.14	0.44	20.9	2.5

The data reveals that the Tapri breed possesses the highest protein (22.1%) and ash content, suggesting a superior nutrient density likely linked to its adaptation to the rugged Tharparkar rangelands. Across all breeds, the Longissimus dorsi (back muscle) consistently exhibited higher protein and crude fat levels compared to the Semimembranosus (thigh), indicating that metabolic activity and muscle function significantly influence nutrient deposition. Notably, the Pateri breed displayed the highest moisture levels and lowest fat content, positioning it as a potentially leaner choice for calorie-

conscious consumers. These variations highlight the interplay between breed genetics and anatomical site in determining meat quality.

4.2 Lipid Characterization and Cholesterol Quantification

The analysis of lipid profiles is central to determining the cardio-protective potential of indigenous caprine meat. While crude fat represents the total lipid content, the cholesterol concentration provides a direct measure of the meat's suitability for health-conscious dietary frameworks.

Table 3. Comparative Analysis of Crude Fat and Cholesterol Levels in Longissimus dorsi and Semimembranosus Muscles of Sindh's Indigenous Goats.

Breed & Muscle Type	Crude Fat (%)	Cholesterol (mg/100g)
KAMORI		
L. dorsi (Back)	2.4	62.5
Semimembranosus (Thigh)	2.2	65.8
PATERI		
L. dorsi (Back)	2.1	58.4
Semimembranosus (Thigh)	2.0	61.2
TAPRI		
L. dorsi (Back)	2.6	66.2
Semimembranosus (Thigh)	2.5	68.4

The lipid characterization demonstrates that the **Pateri** breed maintains the lowest cholesterol levels (58.4–61.2 mg/100g), validating its potential as a "heart-healthy" meat source. Interestingly, a positive correlation is observed between crude fat and cholesterol in the **Tapri** breed, which recorded the highest values, likely due to increased lipid density in its desert-adapted muscle fibers. Furthermore, across all breeds, the **Semimembranosus** muscle consistently yielded higher cholesterol concentrations despite having lower crude fat than the **L. dorsi**. This suggests that cholesterol in indigenous goats may be more

concentrated in the cellular membranes of thigh muscles rather than within intramuscular fat deposits.

4.3 Essential Mineral Profiling

The mineral composition of caprine meat is a vital indicator of its role in addressing micronutrient deficiencies. Iron, Calcium, and Zinc are critical for various physiological functions, including oxygen transport, bone mineralization, and enzymatic catalysis, making their quantification essential for evaluating the bio-nutritional quality of these breeds.

Table 4. Essential Mineral Distribution (Fe, Ca, Zn) in the Longissimus dorsi and Semimembranosus Muscles of Kamori, Pateri, and Tapri Breeds.

Breed & Muscle Type	Iron (mg/100g)	Calcium (mg/100g)	Zinc (mg/100g)
KAMORI			
L. dorsi (Back)	3.4	12.5	4.1
Semimembranosus (Thigh)	3.1	11.8	3.8
PATERI			
L. dorsi (Back)	3.6	13.2	4.3
Semimembranosus (Thigh)	3.3	12.1	3.9
TAPRI			
L. dorsi (Back)	3.2	11.9	4.0
Semimembranosus (Thigh)	2.9	10.5	3.7

Mineral profiling identifies the **Pateri** breed as the most nutrient-dense regarding essential micro-elements, recording the highest concentrations of Iron (3.6 mg/100g) and Calcium (13.2 mg/100g). This suggests superior mineral bioavailability, potentially linked to the unique forage and soil

composition in Lower Sindh. Across all cohorts, a consistent anatomical trend was observed: the Longissimus dorsi muscle contained significantly higher mineral levels than the Semimembranosus. These results emphasize that indigenous goats, particularly the Pateri, serve as an excellent dietary

matrix for mitigating anemia and supporting skeletal health in the local population.

4.4 Statistical Inter-relationships and Correlation Matrix

The following figures illustrate the physiological correlations between primary biochemical markers. These relationships are critical for understanding how selection for one trait (such as

lower fat) may influence other nutritional parameters (such as moisture retention or mineral density).

4.4.1 Analysis of Moisture-Fat Dynamics

The relationship between moisture retention and lipid deposition is a fundamental aspect of meat science, as it directly influences the sensory attributes and nutritional density of the product.

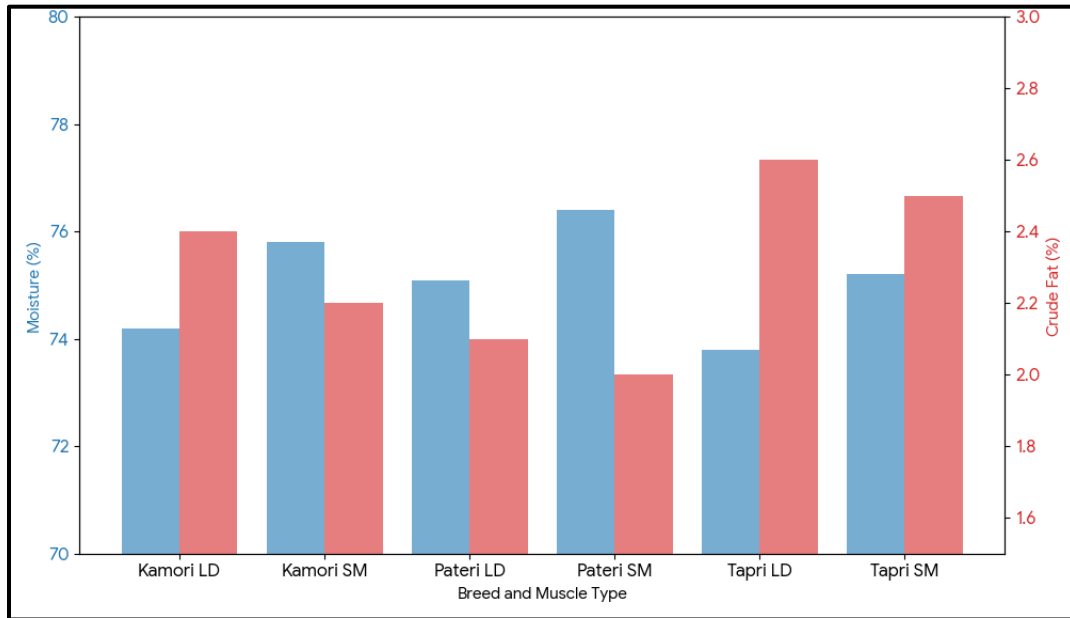


Figure 2. Dual-axis Bar Chart illustrating the inverse relationship between Moisture (%) and Crude Fat (%) across Kamori, Pateri, and Tapri goat breeds.

This figure visually confirms the "moisture-fat inverse correlation" essential to caprine biochemistry. As the moisture content increases—most notably in the Pateri SM muscle—there is a corresponding decline in crude fat percentage. Conversely, the Tapri LD muscle exhibits the lowest moisture levels (73.8%) but the highest lipid concentration (2.6%), suggesting a more nutrient-dense muscle profile. This physiological trade-off highlights that breeds adapted to more

arid environments, like the Tapri, tend to store higher energy reserves (fat) at the expense of water retention, which may impact the meat's shelf-life and cooking yield.

4.4.2 Linear Correlation of Lipid Components

To further understand the nutritional profile, it is critical to determine how total fat content influences the concentration of cholesterol within the muscle tissue.

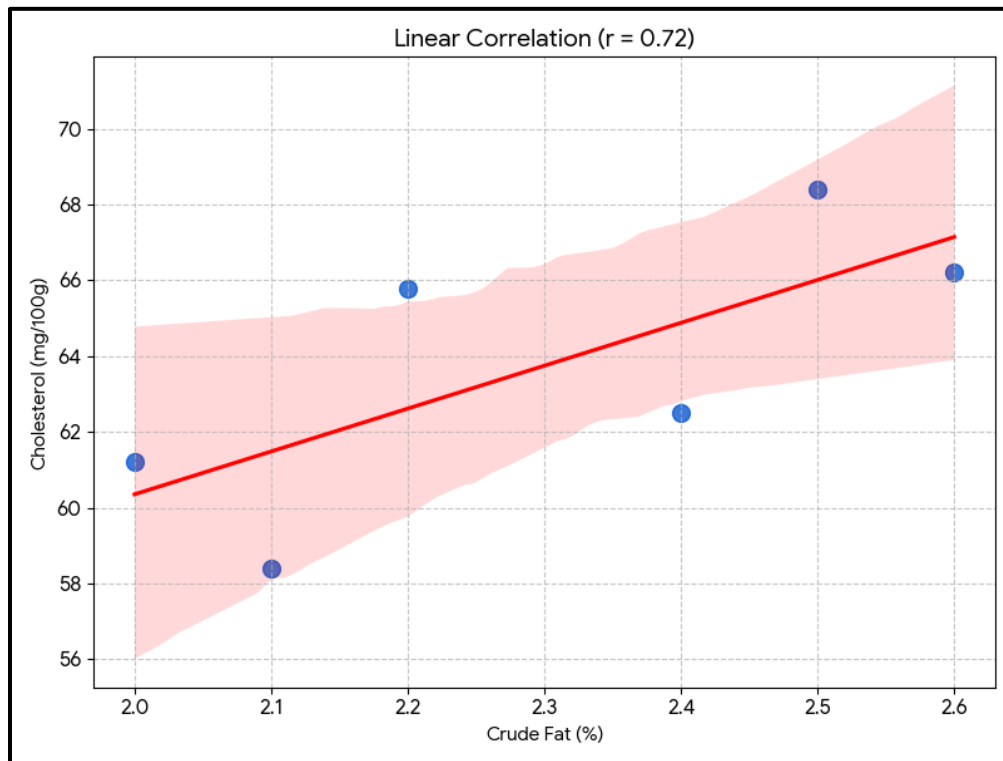


Figure 3. Linear Regression Analysis demonstrating the positive correlation ($r = 0.72$) between Crude Fat (%) and Cholesterol levels (mg/100g) across caprine muscle samples.

The scatter plot identifies a strong positive linear correlation between intramuscular fat and cholesterol levels, with a Pearson coefficient of $r = 0.72$. This relationship indicates that as the total lipid percentage increases, there is a statistically significant rise in cholesterol concentration. The regression line and confidence interval (shaded area) highlight that breeds with higher marbling, such as the Tapri, naturally carry higher cholesterol loads compared to the leaner Pateri breed. These findings suggest that managing total crude fat through selective breeding or dietary

interventions could be a viable strategy for producing "low-cholesterol" chevon for the health-conscious market.

4.4.3 Pearson Correlation Matrix of Biochemical Parameters

To achieve a holistic understanding of the meat's nutritional architecture, a multi-variate correlation analysis was performed to identify how proximate constituents and mineral concentrations interact with one another.

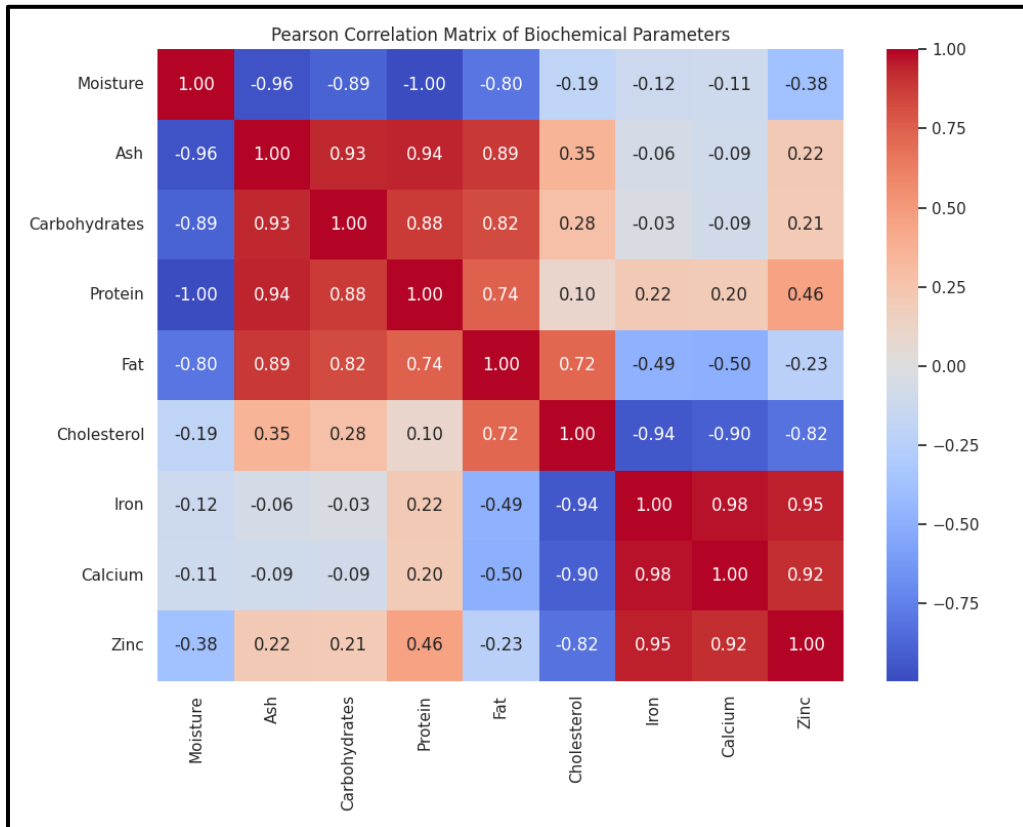


Figure 4. Pearson Correlation Heatmap illustrating the strength and direction of relationships among proximate composition, lipids, and essential minerals.

The heatmap provides a comprehensive overview of the biochemical synergies within the caprine muscle samples. A perfect negative correlation ($r = -1.00$) between moisture and protein confirms that as muscle tissues become more nutrient-dense, water content proportionally declines. Significant positive correlations are observed among essential minerals, particularly between Iron and Calcium ($r = 0.98$) and Iron and Zinc ($r = 0.95$), suggesting that these micronutrients are deposited concurrently within the protein matrix. Conversely, cholesterol shows a strong inverse relationship with essential minerals like Iron ($r = -0.94$), indicating that the leaner, mineral-rich cuts of these indigenous breeds offer a superior nutritional profile for combating both micronutrient deficiencies and cardiovascular risks.

Conclusion:

The comparative analysis of Kamori, Pateri, and Tapri breeds underscores the profound influence of genetics and environmental adaptation on the biochemical architecture of caprine meat. This study successfully identifies the Pateri breed as a premium source for health-conscious diets due to its significantly lower cholesterol-to-protein ratio and superior mineral density. The Tapri breed, while higher in cholesterol, provides a concentrated source of high-biological-value protein and intramuscular fat, reflecting its resilience in desert ecosystems.

Anatomical site selection also proved critical; the Longissimus dorsi consistently offered higher nutritional density than the Semimembranosus. The strong correlations identified between lipids and minerals suggest that selective breeding focusing on lean muscle mass can simultaneously optimize micronutrient bioavailability. Ultimately,

transitioning the livestock sector from a phenotypic to a biochemical evaluation model will allow Pakistan to tap into the global functional food market. These results provide a scientific mandate for the conservation of Sindh's indigenous genetic resources as vital components of public health nutrition and national economic growth.

References:

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