Meat Research
Vol 5, Issue 5: 1-10, Article 126, October 2025
ISSN: 2790-1971
https://doi.org/10.55002/mr.5.5.126 http://www.bmsa.info/meatresearch

[1]Department of Animal Science at, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[2]Department of Poultry Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[3]Graduate Training Institute, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

Research Article

Fatty acid profiling and nutritional lipid indices of raw and cooked indigenous cattle meat and fat in Bangladesh

R Jahan[1], D Ghosh[1], RA Deen[1], M Habib[3], MM Rahman[1], MS Ali[2], MA Hashem[1*]

Abstract

Fatty acid composition and lipid nutritional quality are important determinants of the health value of meat products. However, information regarding the lipid profile of indigenous cattle in Bangladesh and the influence of thermal processing on fatty acid stability remains limited. This study characterized the fatty acid composition and nutritional lipid indices of ribeye muscle (*longissimus dorsi*) and perirenal adipose tissue from indigenous cattle and evaluated the effects of cooking on lipid composition. Samples obtained from nine animals were analyzed in raw and cooked states, yielding 36 experimental samples. Total lipids were extracted using the Folch method, converted into fatty acid methyl esters, and analyzed by gas chromatography. The effects of tissue type (muscle vs adipose), cooking treatment (raw versus cooked), and their interaction were evaluated using two-way analysis of variance. Adipose tissue contained significantly higher total lipid content than muscle (68.66% versus 5.82%; $p < 0.001$). Tissue types strongly influenced fatty acid distribution, with muscle exhibiting higher proportions of monounsaturated fatty acids, whereas adipose tissue contained greater levels of polyunsaturated fatty acids. Oleic acid (C18:1) was the predominant fatty acid in both tissues. Cooking induced moderate compositional shifts, characterized by increased relative proportions of saturated fatty acids and reduced unsaturated fatty acids ($p < 0.001$), indicating preferential thermal degradation of unsaturated lipids. Nutritional lipid indices were moderately affected, although the overall fatty acid profile remained monounsaturated fatty acid dominant across treatments. These findings demonstrate that tissue type is the primary determinant of lipid composition in indigenous cattle, whereas thermal processing induces moderate but measurable changes in fatty acid distribution. The results provide baseline information on the lipid nutritional quality of indigenous Bangladeshi beef and indicate that typical cooking conditions do not substantially compromise its favorable fatty acid profile.

***Corresponding Author:**
MA Hashem
E-mail: hashem_as@bau.edu.bd

Keywords:
Beef lipid profile
Fatty acid composition
Thermal processing
Nutritional lipid indices
Gas chromatography

Article Info:
Received: August 11, 2025
Accepted: October 10, 2025
Published online: October 31, 2025

Introduction

Beef is a major source of high-quality protein, essential fatty acids, fat-soluble vitamins, and bioactive lipids that contribute significantly to human nutrition. In addition to its macronutrient value, increasing attention has been directed toward the qualitative characteristics of meat lipids, particularly the composition of saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA), which are known to influence both human health outcomes and sensory properties of meat (Mititelu et al., 2024; Sherratt et al., 2023). Consequently, fatty acid composition and derived lipid health indices such as the atherogenic index (AI), thrombogenic index (TI), and hypocholesterolemic/hypercholesterolemic ratio (h/H) are widely used indicators for evaluating the nutritional quality of animal-derived foods (Carneiro et al., 2021; Goluch and Eng, 2021).

Fatty acid composition of beef is influenced by several biological and environmental factors, including breed genotype, feeding system, age at slaughter, muscle type, and adipose tissue deposition patterns. These factors regulate lipid metabolism and the activity of enzymes involved in fatty acid synthesis, elongation, and desaturation (Sakowski et al., 2022; Momot et al., 2020). Indigenous cattle raised under extensive or semi-intensive systems in tropical regions often exhibit distinct lipid deposition patterns and fatty acid profiles compared with intensively reared commercial breeds, primarily due to differences in diet composition, growth rate, and metabolic adaptation to local environments. Despite their economic and cultural importance in many developing countries, comprehensive information regarding the lipid quality of indigenous cattle remains limited, particularly in South Asian production systems (Rahman et al., 2024; Islam et al., 2021).

In addition to intrinsic biological factors, post-mortem processing and culinary preparation can significantly modify lipid composition. Thermal processing promotes a series of physicochemical reactions, including lipid oxidation, hydrolysis, and structural rearrangements of fatty acids, which may alter both the proportion and stability of unsaturated fatty acids. Polyunsaturated fatty acids are particularly susceptible to oxidative degradation during cooking due to their multiple double bonds, whereas saturated fatty acids exhibit greater thermal stability (Khalid et al., 2023; Domínguez et al., 2019). As a result, cooking may change the nutritional lipid profile of meat and influence indices used to assess cardiovascular health risks (Bhat et al., 2021).

In Bangladesh, beef production relies predominantly on indigenous zebu-type cattle raised under forage-based feeding systems utilizing crop residues, native grasses, and limited concentrate supplementation. Although these production systems differ substantially from intensive beef production systems commonly studied in developed countries, scientific data describing the lipid composition and nutritional quality of beef from indigenous Bangladeshi cattle remain scarce. Furthermore, information regarding how typical cooking conditions influence the fatty acid composition of both muscle and adipose tissues is largely unavailable (Samad, 2020).

Therefore, the present study aimed to characterize the fatty acid composition and nutritional lipid indices of rib eye muscle (*longissimus dorsi*) and perirenal adipose tissue from indigenous cattle in Bangladesh and to evaluate the effects of thermal processing on lipid stability and nutritional quality. By comparing raw and cooked tissues, this study provides baseline information on the lipid nutritional value of indigenous beef and contributes to a better understanding of how culinary preparation influences its health-related lipid characteristics.

Materials and methods

Experimental Design

This study employed a paired factorial experimental design to evaluate the effects of tissue type and cooking treatment on fatty acid composition and lipid nutritional indices. Two tissue types were analyzed: ribeye muscle (*longissimus dorsi*) and perirenal adipose tissue. For each tissue type, samples were analyzed in both raw and cooked states, allowing the effect of thermal processing to be evaluated within the same biological sample.

Sample collection and preparation

Ribeye muscle (*longissimus dorsi*) and perirenal adipose tissue were obtained from local meat retailers in Mymensingh, Bangladesh. Samples originated from indigenous beef cattle slaughtered under standard commercial conditions. Based on vendor-provided information, all animals were male and approximately 1.5–2.5 years of age at slaughter, with reported slaughter weights ranging from 190 to 250 kg. Because samples were obtained from commercial retail markets, detailed feeding regimes, breed composition, and pre-slaughter management conditions could not be independently verified.

Immediately after purchase, samples were transported to the Meat Laboratory, Department of Animal Science, Bangladesh Agricultural University, in insulated containers containing ice packs to maintain a temperature below 4 °C.

Upon arrival, visible external fat and epimysial connective tissues were removed. Each ribeye steak was divided longitudinally into two equal portions: one designated for raw analysis and the other for cooking treatment. Perirenal fat samples were similarly trimmed to remove extraneous tissues and impurities. All samples were stored at 4 °C for approximately 24 h post-mortem to allow completion of rigor mortis and stabilization of physicochemical properties prior to further processing.

A total of nine animals were included in the study. From each animal, one representative subsample per tissue type was prepared for both raw and cooked treatments. This design yielded 9 raw muscle samples, 9 cooked muscle samples, 9 raw adipose samples, and 9 cooked adipose samples (n = 36 total samples).

Cooking Procedure

Thermal processing was conducted using a thermostatically controlled water bath. Muscle and adipose tissue samples were individually vacuum-packaged in heat-stable polyethylene bags to minimize moisture loss and oxidative exposure during cooking.

Samples were cooked until the internal core temperature reached 71 °C, which was monitored using a calibrated thermocouple probe inserted into the geometric center of each sample. After cooking, samples were immediately cooled to room temperature under laboratory conditions, vacuum-packaged, and stored at −20 °C until lipid extraction and fatty acid analysis.

Lipid Extraction and Gas Chromatography Analysis

Total lipids were extracted according to the Folch extraction method using a chloroform–methanol mixture (2:1, v/v). Approximately 5 g of homogenized tissue was mixed with the solvent system and homogenized thoroughly. After filtration, 0.9 % NaCl solution was added to facilitate phase separation. Following centrifugation, the lower chloroform phase containing total lipids was collected. Methyl nonadecanoate (C19:0) was added as an internal standard to allow quantitative determination of fatty acid concentrations.

Extracted lipids were converted to fatty acid methyl esters (FAME) using boron trifluoride–methanol (BF_3–methanol) reagent. The reaction mixture was heated under controlled conditions to ensure complete transesterification of triglycerides and free fatty acids. FAME were subsequently extracted with hexane and dried under nitrogen prior to chromatographic analysis.

FAME were analyzed using a gas chromatograph (7890B, Agilent Technologies, Santa Clara, CA, USA) equipped with a fused-silica capillary column (SP™-2560, Supelco; 100 m × 0.25 mm × 0.20 µm film thickness) specifically designed for fatty acid methyl ester separation. Chromatographic conditions were as follows: injector temperature 240 °C, detector temperature 260 °C, helium as the carrier gas, and a 10:1 split ratio. The oven temperature program was: initial temperature 60 °C, increased at 20 °C min^{-1} to 170 °C, followed by 5 °C min^{-1} to 220 °C, and finally 2 °C min^{-1} to 240 °C. Fatty acids were identified by comparing sample retention times with those of authentic FAME standards (Supelco 37 Component FAME Mix, C4–C24). Importantly, geometric (cis/trans) and positional isomers were not chromatographically resolved under the analytical conditions used. Therefore, when multiple isomeric forms were present, peak areas representing these isomers were integrated together and reported as combined totals. Consequently, reported MUFA and PUFA values represent aggregated fatty acid classes rather than individual isomeric species. Quantification was performed relative to the internal standard (C19:0) using peak-area ratios to determine the concentration and proportional distribution of each fatty acid.

Fatty acid grouping and nutritional indices

Fatty acids analyzed included myristic (C14:0), myristoleic (C14:1), palmitic (C16:0), palmitoleic (C16:1), margaric (C17:0), heptadecenoic (C17:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), and arachidic (C20:0). Isomers were not separated and were included in their respective totals.

Fatty acids were combined to calculate total saturated (Equation 1), monounsaturated (Equation 2), and polyunsaturated fatty acids (Equation 3) as follow:

$$SFA = C14{:}0 + C16{:}0 + C17{:}0 + C18{:}0 + C20{:}0 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$MUFA = C14{:}1 + C16{:}1 + C17{:}1 + C18{:}1 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

$$PUFA = C18{:}2 + C18 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The desaturation index (DI), representing the addition of a double bond (Equation 4), and the elongation index (EI), representing the conversion of 16 to 18 carbon fatty acids (Equation 5), were calculated:

$$DI = 100 \times \frac{[C16{:}1]+[C18{:}1]}{[C16{:}1]+[C16{:}0]+[C18{:}1]+[C18{:}0]} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$EI = 100 \times \frac{[C18{:}0]}{[C16{:}0]} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Statistical analysis

All statistical analyses were performed using Python (version 3.12). A two-way analysis of variance (ANOVA) was conducted to assess the main effects of tissue type (muscle vs. adipose), cooking treatment (raw vs. cooked), and their interaction on fatty acid composition and derived indices. When significant main or interaction effects were identified ($p < 0.05$), multiple comparisons were performed using Tukey's honestly significant difference (HSD) post hoc test to determine pairwise differences between groups. Results are presented as mean values, and the standard error (SE) is reported in a separate column in the tables.

Results

Effects of Tissue Type, Cooking Treatment, and Their Interaction on Fatty Acid Composition

Two-way ANOVA demonstrated a significant main effect of tissue type on total fat content ($p < 0.001$), with adipose tissue (68.66%) exhibiting substantially higher lipid levels than muscle (5.82%) (Table 1). Cooking treatment did not significantly affect total fat ($p = 0.21$), and no significant Type × Treatment interaction was detected ($p = 0.49$).

Table 1: Fatty acid composition (g/100 g total lipid) of meat and fat portions in raw and cooked conditions and their interaction effects (Type × Treatment).

Traits	Meat	Fat	Raw	Cooked	SE	*p(Type)*	*p(Treatment)*	*p(Type × Treatment)*
Total Fat	5.82[b]	68.66[a]	32.61	41.87	10.02	0	0.21	0.49
Saturated Fatty Acid	41.01[a]	40.31[a]	38.39	42.93	0.84	0.4	0	0.02
Myristic Acid	2.1[b]	2.96[a]	2.44	2.62	0.16	0	0.36	0.66
Palmitic Acid	26.23[a]	23.8[a]	23.94	26.09	0.75	0.09	0.12	0.34
Stearic Acid	12.35[a]	13.36[a]	11.75	13.95	0.66	0.44	0.12	0.53
Arachidic Acid	0.24[a]	0.17[a]	0.20	0.21	0.02	0.06	0.55	0.97
Lignoceric Acid	0.09[a]	0.02[a]	0.07	0.05	0.02	0.11	0.61	0.6
Unsaturated Fatty Acid	58.99[a]	59.69[a]	61.61	57.07	0.84	0.4	0	0.02
Monounsaturated Fatty Acid	53.66[b]	46.97[a]	51.97	48.66	1.22	0	0.01	0.16
Myristoleic Acid	0.18[a]	0.32[a]	0.26	0.24	0.08	0.43	0.94	0.71
Palmitoleic Acid	4.84[a]	3.37[a]	4.29	3.91	0.51	0.2	0.73	0.84
Oleic Acid	48.44[b]	42.67[a]	47.01	44.10	1.17	0	0.07	0.29
Eicosenoic Acid	0.21[b]	0.61[a]	0.41	0.41	0.07	0	0.95	0.52
Polyunsaturated Fatty Acid	5.33[b]	12.72[a]	9.64	8.41	1.29	0	0.43	0.65
Linoleic Acid	4.54[b]	11.87[a]	8.71	7.71	1.27	0	0.49	0.63
Linolenic Acid	0.27[b]	0.81[a]	0.63	0.45	0.09	0	0.07	0.77
Arachidonic Acid	0.51[b]	0.04[a]	0.30	0.26	0.1	0.02	0.8139	0.8529

Values are expressed as mean. SE indicates Standard Error. Different superscripts (a, b) within the same row indicate significant differences *($p < 0.05$)*. *p(Type)*: comparison between meat and fat; *p(Treatment)*: comparison between raw and cooked samples; *p(Type × Treatment)*: interaction between type and treatment.

Total saturated fatty acids (SFA) were not influenced by tissue type ($p = 0.40$) but were significantly affected by cooking treatment ($p < 0.001$), increasing from 38.39% in raw samples to 42.93% in cooked samples. A significant Type × Treatment interaction was observed ($p = 0.02$).

Total unsaturated fatty acids (UFA) were likewise unaffected by tissue type ($p = 0.40$) but were significantly reduced following cooking (61.61% vs. 57.07% for raw and cooked samples, respectively; $p < 0.001$). The interaction between tissue type and treatment was significant ($p = 0.02$).

Among individual SFA, myristic acid (C14:0) showed a significant effect of tissue type ($p < 0.001$), with higher values in adipose tissue (2.96%) than in muscle (2.10%). No significant effects of treatment ($p = 0.36$) or interaction ($p = 0.66$) were detected. Palmitic (C16:0), stearic (C18:0), arachidic (C20:0), and lignoceric (C24:0) acids were not significantly affected by tissue type, cooking treatment, or their interaction ($p > 0.05$).

Total monounsaturated fatty acids (MUFA) were significantly influenced by tissue type ($p < 0.001$) and cooking treatment ($p = 0.01$). MUFA proportions were higher in muscle (53.66%) than in adipose tissue (46.97%) and decreased after cooking (51.97% vs. 48.66% for raw and cooked samples, respectively). The interaction effect was not significant ($p = 0.16$).

Oleic acid (C18:1), the predominant fatty acid, was significantly affected by tissue type ($p < 0.001$), with higher proportions in muscle (48.44%) than in adipose tissue (42.67%). Neither cooking treatment ($p = 0.07$) nor the interaction term ($p = 0.29$) reached statistical significance.

Eicosenoic acid (C20:1) differed significantly between tissue types ($p < 0.001$), being higher in adipose tissue (0.61%) than in muscle (0.21%), whereas treatment ($p = 0.95$) and interaction ($p = 0.52$) effects were not significant. Myristoleic (C14:1) and palmitoleic (C16:1) acids were not significantly influenced by either main effects or their interaction ($p > 0.05$).

Total polyunsaturated fatty acids (PUFA) were significantly affected by tissue type ($p < 0.001$), with higher proportions in adipose tissue (12.72%) compared to muscle (5.33%). Cooking treatment ($p = 0.43$) and the interaction term ($p = 0.65$) were not significant.

Linoleic acid (C18:2) and linolenic acid (C18:3) both exhibited significant tissue-type effects ($p < 0.001$), with higher concentrations in adipose tissue than in muscle. Treatment and interaction effects were not significant ($p > 0.05$).

Arachidonic acid (C20:4) showed a significant tissue-type effect ($p = 0.02$), with higher levels in muscle (0.51%) than in adipose tissue (0.04%). No significant treatment ($p = 0.81$) or interaction ($p = 0.85$) effects were observed.

Fatty Acid Ratios and Nutritional Indices

Cooking treatment altered lipid quality indices in both tissues (Table 2). The SFA/UFA ratio increased following cooking in muscle (0.66 to 0.73) and adipose tissue (0.57 to 0.78). Conversely, the PUFA/SFA ratio decreased in both tissues, with a more pronounced reduction in adipose tissue (0.40 to 0.27) than in muscle (0.14 to 0.12). The n-6/n-3 ratio decreased in muscle (15.00 to 9.54) but increased in adipose tissue (13.73 to 15.79). The MUFA/PUFA ratio increased after cooking in both muscle (9.76 to 10.43) and adipose tissue (3.47 to 3.79).

Table 2: Fatty acid ratio between raw versus cooked beef and fat

Ratio	Meat		Fat	
	Raw	Cooked	Raw	Cooked
SFA/UFA	0.66	0.73	0.57	0.78
PUFA/SFA	0.14	0.12	0.40	0.27
n-6/n-3	15	9.54	13.73	15.79
MUFA/PUFA	9.76	10.43	3.47	3.79

Desaturation and Elongation Indices

The desaturation index (DI) decreased following cooking in both tissues, with a greater reduction observed in adipose tissue (59.30 to 51.97) than in muscle (59.30 to 57.01) (Table 3). The elongation index (EI) remained relatively stable across treatments. Muscle exhibited minimal change (66.26 to 66.08), while adipose tissue showed a slight decrease (69.95 to 69.01).

Table 3: Calculation of Desaturation Index (DI) and Elongation Index (EI) of fatty acids in raw versus cooked beef and fat

Traits	Meat		Fat	
	Raw	Cooked	Raw	Cooked
DI	59.30	57.01	59.30	51.97
EI	66.26	66.08	69.95	69.01

Ranking and Relative Abundance of Major Fatty Acids

Across all treatments, oleic acid (C18:1) was the most abundant fatty acid in both tissues, followed by palmitic (C16:0) and stearic (C18:0) acids (Table 4). Cooking resulted in minor changes in ranking among secondary fatty acids; however, the hierarchical dominance of major fatty acids remained unchanged. Long-chain saturated fatty acids, including arachidic and lignoceric acids, remained below 0.5% of total lipids across treatments.

Table 4: Ranking and Relative Abundance of Major Fatty Acids in Raw and Cooked Beef and Fat

Fatty acids	Raw beef meat ranking		Cooked beef meat ranking		Raw beef fat ranking		Cooked beef fat ranking	
	%	Ranking	%	Ranking	%	Ranking	%	Ranking
Oleic Acid (C18:1)	49.09	1	47.78	1	45.20	1	40.41	1
Palmitic Acid (C16:0)	25.79	2	26.68	2	21.31	2	25.51	2
Stearic Acid (C18:0)	11.66	3	13.04	3	13.28	3	11.02	4
Palmitolic Acid (C16:1)	5.14	4	4.53	4	12.12	4	14.87	3
Linoleic Acid (C18:2)	4.70	5	4.39	5	3.51	5	3.29	5
Myristic Acid (C14:0)	2.51	6	2.15	6	2.58	6	3.09	6
Arachidonic Acid (C20:4)	0.55	7	0.48	7	0.97	7	0.70	7
Linolenic Acid (C18:3)	0.35	8	0.19	11	0.63	8	0.57	8
Eicosenoic Acid (C20:1)	0.27	9	0.31	9	0.48	9	0.42	9
Myristoleic Acid (C14:1)	0.23	10	0.42	8	0.16	10	0.18	10
Arachidic Acid (C20:0)	0.23	10	0.24	10	0.04	11	0.03	11
Lignoceric Acid (C24:0)	0.17	11	0.11	12	0.01	12	0.02	12

Correlation Analysis of Fatty Acid Profiles

A strong inverse correlation was observed between total SFA and total UFA ($r = -1.00$), reflecting their compositional relationship (Figure 1).

Oleic acid was positively correlated with eicosenoic acid ($r = 0.54$) and negatively correlated with total PUFA ($r = -0.61$). Linoleic and linolenic acids were positively correlated ($r = 0.76$). Arachidonic acid showed positive correlations with lignoceric acid ($r = 0.95$) and total fat content ($r = 0.70$).

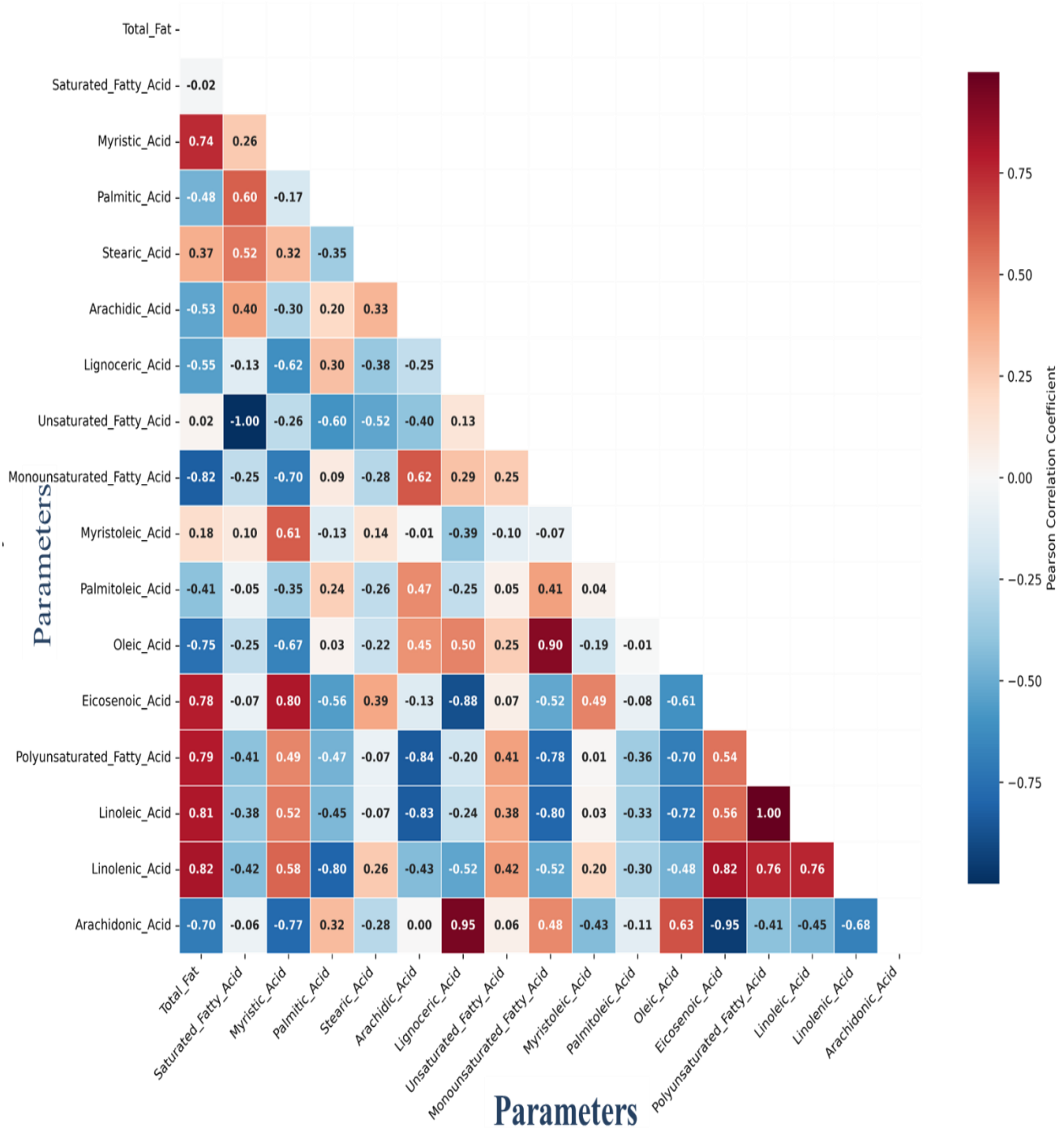

Figure 1: Correlation Analysis of Fatty Acid Profiles.

Overall Impact of Cooking on Lipid Composition

Across replications, cooking increased SFA proportions while reducing MUFA and PUFA proportions (Figure 2). These compositional shifts were more evident in adipose tissue than in muscle. The overall fatty acid profile remained MUFA-dominant across all treatments.

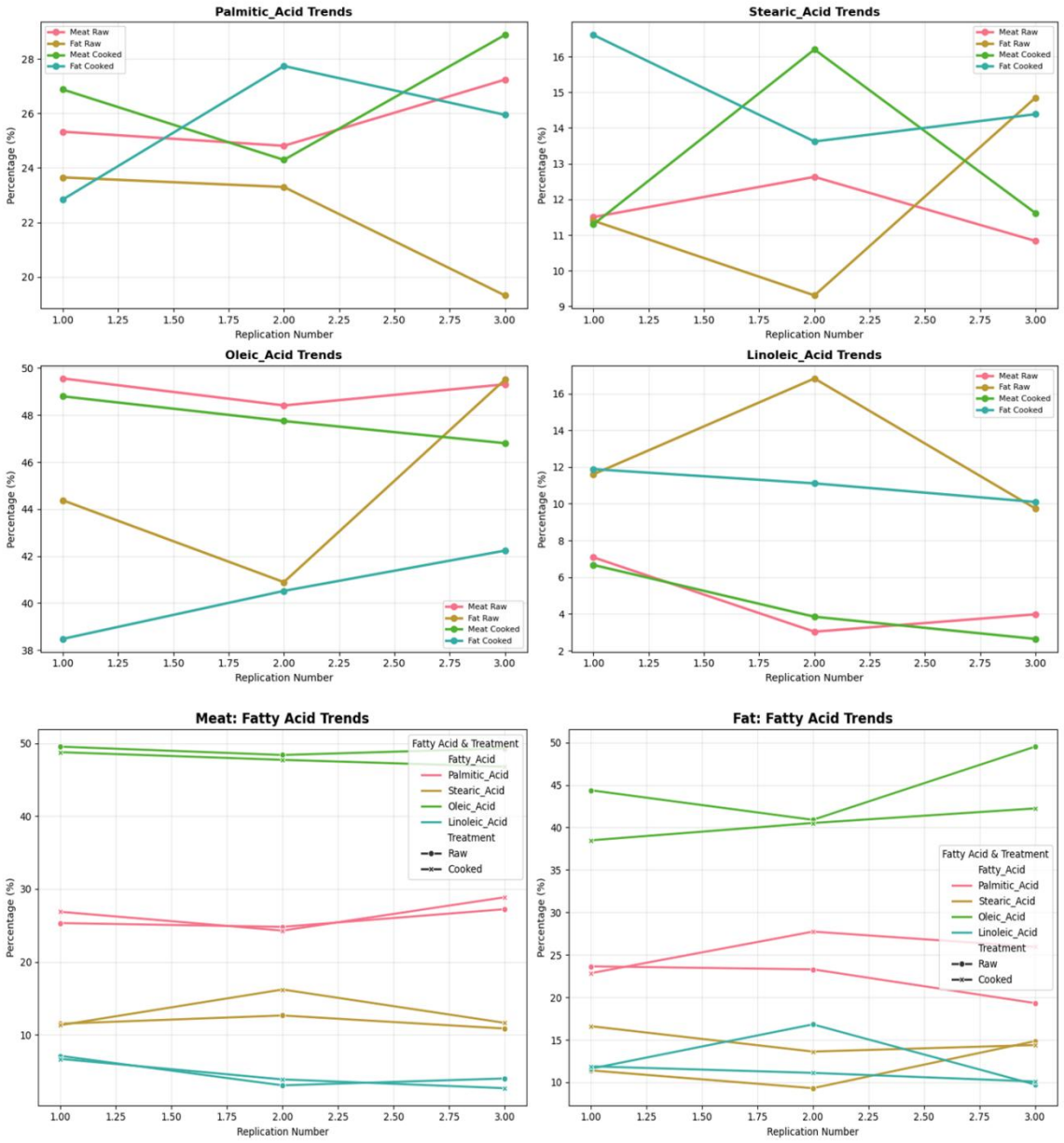

Figure 2: Cooking-Induced Variations in Fatty Acid Composition of Meat and Fat Tissues across Experimental Replications.

Discussion

Tissue-Specific Lipid Deposition Patterns in Indigenous Cattle

The present study demonstrates that tissue type exerts a stronger influence on fatty acid composition than thermal processing, confirming the central role of biological lipid deposition mechanisms in determining beef lipid quality (Bartoň et al., 2021; Murshed et al., 2014). As expected, adipose tissue contained markedly higher total lipid levels than muscle, reflecting its physiological function as a primary triglyceride storage depot (Du et al., 2022).

Although total SFA and UFA proportions were statistically similar between tissues, distinct differences emerged at the individual fatty acid level (Costa et al., 2020). Muscle exhibited significantly higher MUFA proportions (Chen et al., 2022), particularly oleic acid (C18:1), whereas adipose tissue contained greater total PUFA, especially linoleic and linolenic acids (Urrutia et al., 2020). These findings align with the differential lipid class distribution between tissues. Muscle lipids comprise both structural phospholipids and neutral lipids, whereas adipose tissue is dominated by triacylglycerols (Zhang et al., 2025; Cui et al., 2024).

The higher arachidonic acid (C20:4) concentration in muscle further supports this structural distinction (Rule et al., 2022). Arachidonic acid is preferentially incorporated into membrane phospholipids, where it contributes to membrane fluidity and serves as a precursor for bioactive eicosanoids (Weiny et al., 2022). Conversely, its minimal presence in adipose tissue reflects limited incorporation into storage lipids (Kalkman et al., 2021).

The relatively high MUFA content, particularly oleic acid dominance across tissues (Smith, 2024), suggests favorable stearoyl-CoA desaturase (SCD) activity in indigenous cattle (Rodriguez et al., 2024). Such a profile is often associated with improved

oxidative stability and sensory properties, and may reflect adaptation to forage-based feeding systems typical of indigenous production in Bangladesh (Islam et al., 2014).

Influence of Cooking on Fatty Acid Stability

Thermal processing induced moderate but consistent changes in fatty acid composition, characterized by an increase in the relative proportion of saturated fatty acids and a reduction in unsaturated fatty acids (Gruffat et al., 2021).

These shifts are commonly attributed to preferential degradation of unsaturated fatty acids during heating, as double bonds present in MUFA and PUFA are more susceptible to oxidative reactions than the single bonds found in saturated fatty acids (Dragoev, 2024; Rasinska et al., 2019).

Among the unsaturated fatty acids, PUFA are particularly vulnerable to lipid peroxidation due to their multiple double bonds. Consequently, thermal exposure during cooking can lead to partial degradation or structural modification of PUFA, resulting in an apparent increase in the relative proportion of SFA (Marović et al., 2024; Mortensen et al., 2024). Despite these changes, oleic acid remained the dominant fatty acid across all treatments, indicating relatively greater thermal stability compared with polyunsaturated fatty acids (Zhu et al., 2022).

Interaction between Tissue Matrix and Thermal Processing

Significant Type × Treatment interactions were limited to total SFA and UFA, indicating that the response to cooking is matrix-dependent. Adipose tissue exhibited relatively larger shifts in fatty acid proportions following heat treatment (Dinh et al., 2021).

This differential response may be explained by lipid microstructure. In muscle, lipids are embedded within protein–phospholipid complexes that may confer partial protection against oxidative attack (Zou et al., 2022). In contrast, adipose tissue lipids are organized into large triglyceride droplets with less structural protection, potentially facilitating oxidative reactions during heating (Guo et al., 2023).

Despite these matrix-specific responses, the hierarchical ranking of major fatty acids remained unchanged after cooking. Oleic, palmitic, and stearic acids consistently dominated the lipid profile, indicating preservation of fundamental fatty acid structure under the applied cooking conditions (Mwangi et al., 2021).

Nutritional Lipid Indices and Health Implications

Cooking increased the SFA/UFA ratio and decreased the PUFA/SFA ratio in both tissues, changes often interpreted as less favorable from a cardiovascular perspective. However, the magnitude of change was moderate (Liu et al., 2020).

Notably, the n-6/n-3 ratio decreased substantially in muscle but increased slightly in adipose tissue. This divergence suggests tissue-specific oxidative sensitivity of omega-3 fatty acids. The reduction of n-6/n-3 in muscle may reflect selective degradation patterns or proportional concentration effects resulting from moisture loss during cooking (Bielawiec et al., 2021).

The increase in MUFA/PUFA ratio across tissues further supports preferential loss of PUFA during heating. From a nutritional standpoint, the preservation of high MUFA levels particularly oleic acid is favorable, as MUFA intake has been associated with improved lipid metabolism and reduced cardiovascular risk (Sheashea et al., 2021).

Importantly, despite measurable thermal effects, the overall lipid profile of indigenous beef remained MUFA-dominant after cooking, suggesting that typical culinary preparation does not fundamentally diminish its nutritional lipid quality (Dagne et al., 2021).

Correlation Structure and Compositional Data Considerations

The observed near-perfect inverse correlation between total SFA and UFA reflects the compositional constraint inherent to proportional fatty acid data. Because fatty acids are expressed as percentages of total lipid, increases in one fraction necessarily reduce others. Thus, this relationship should be interpreted as a mathematical consequence of data closure rather than direct biological antagonism (Bristy et al., 2025; Bello et al., 2021).

Positive correlations between linoleic and linolenic acids indicate coordinated deposition of essential fatty acids, likely influenced by dietary intake (Schettini et al., 2022). The strong association between arachidonic acid and lignoceric acid may reflect shared elongation or membrane incorporation pathways, although further metabolic investigation would be required to confirm this (Wang et al., 2021).

The relatively stable elongation index (EI) across treatments supports the understanding that elongation processes occur in vivo and are not modified post-mortem by cooking. In contrast, the decline in DI reflects post-mortem thermal modification of unsaturated bonds rather than enzymatic regulation (Ndereyimana et al., 2024).

Implications for Indigenous Cattle and Regional Beef Quality

Indigenous cattle in Bangladesh are typically reared under extensive systems with forage-based diets (Alam et al., 2024; Islam et al., 2022). The fatty acid profile observed in this study, characterized by high MUFA and moderate PUFA levels, may reflect such feeding systems and slower growth rates relative to commercial crossbreeds (Ponnampalam et al., 2024).

The retention of a MUFA-rich profile following cooking suggests that indigenous beef maintains lipid quality under common domestic preparation conditions. Given the limited data available on the lipid characteristics of native Bangladeshi cattle, these findings provide foundational evidence supporting the nutritional value of locally produced beef.

Study Limitations and Future Perspectives

Several limitations should be acknowledged. First, animals were obtained from retail markets, and detailed information regarding feeding regime, and genetic background was not available. These factors may influence fatty acid composition and introduce biological variability. Second, lipid oxidation products were not directly measured, limiting mechanistic interpretation of thermal degradation processes.

Future studies incorporating controlled feeding trials, oxidative stability measurements, and sensory evaluation would provide a more comprehensive understanding of lipid quality in indigenous cattle.

Conclusion

This study evaluated the fatty acid composition and lipid nutritional indices of raw and cooked ribeye muscle and perirenal adipose tissue from indigenous cattle in Bangladesh. Tissue type was the primary determinant of lipid characteristics, with adipose tissue containing higher total fat and PUFA, whereas muscle exhibited higher MUFA levels, particularly oleic acid. Cooking caused moderate shifts in fatty acid composition, increasing the relative proportion of saturated fatty acids while reducing unsaturated fatty acids, likely due to thermal oxidation. Despite these changes, the overall fatty acid profile remained MUFA-dominant and the ranking of major fatty acids was preserved. These findings indicate that typical cooking conditions do not substantially compromise the nutritional lipid quality of indigenous beef and provide baseline information supporting its value as a nutritionally important local protein source.

Funding

This research was supported by Bangladesh Agricultural University Research System (BAURES), Award No: 2024/119/BAU and Ministry of Science and Technology, Government of the People's Republic of Bangladesh (MOST), Award No: 2022/121/MoST.

Data availability

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

CRediT authorship contribution statement

Rawnak Jahan: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Dip Ghosh**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Raad Al Deen**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Masuma Habib:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing; **Md. Mukhlesur Rahman:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing; **Md. Shawkat Ali:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing; **Md. Abul Hashem:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Conflicting Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Approval

Samples were obtained from commercial slaughterhouses; therefore, no animal experimentation was conducted.

References

Alam S, Krupnik TJ, Sharmin S, Islam MA, Groot JC. 2024. Alternative cropping and feeding options to enhance sustainability of mixed crop-livestock farms in Bangladesh. NJAS: Impact in Agricultural and Life Sciences, 96(1), 2290046. https://doi.org/10.1080/27685241.2023.2290046

Bartoň L, Bureš D, Řehák D, Kott T, Makovický P. 2021. Tissue-specific fatty acid composition, cellularity, and gene expression in diverse cattle breeds. Animal, 15(1), 100025. https://doi.org/10.1016/j.animal.2020.100025

Bello U, Adamu H, Faizan M, Ourimi M, Alzoubi RA, Jallow A, Siddiqui MN, Abdul Jameel AG. 2026. Advancing Biodiesel Quality Assessment Using Machine Learning Algorithms: A Mini-Review on Oxidative Stability Prediction and Models Benchmarking. Energy Fuels. https://doi.org/10.1021/acs.energyfuels.5c06424

Bhat ZF, Morton JD, Bekhit AEDA, Kumar S, Bhat HF. 2021. Thermal processing implications on the digestibility of meat, fish and seafood proteins. Comprehensive Reviews in Food Science and Food Safety, 20(5), 4511–4548. https://doi.org/10.1111/1541-4337.12802

Bielawiec P, Harasim-Symbor E, Sztolsztener K, Konstantynowicz-Nowicka K, Chabowski A. 2021. Attenuation of oxidative stress and inflammatory response by chronic cannabidiol administration is associated with improved n-6/n-3 PUFA ratio in the white and red skeletal muscle in a rat model of high-fat diet-induced obesity. Nutrients, 13(5), 1603. https://doi.org/10.3390/nu13051603

Bristy KK, Ghosh D, Hashem MA. 2025. NIRS and machine learning algorithms as a non-invasive technique to discriminate and classify cooked broiler and duck meat. Applied Food Research, 5(1), 100984. https://doi.org/10.1016/j.afres.2025.100984

Carneiro MMY, de Tonissi RH, de Goes B, Barros BCB, de Oliveira RT, Fernandes ARM, dos Santos Picanço Y. 2021. Fatty acids profile, atherogenic and thrombogenic health lipid indices in the meat of lambs that received canola grain. Brazilian Journal of Veterinary Research and Animal Science, 58, e178023. https://doi.org/10.11606/issn.1678-4456.bjvras.2021.178023

Chen D, Wang X, Guo Q, Deng H, Luo J, Yi K, Sun A, Chen K, Shen Q. 2022. Muscle fatty acids, meat flavor compounds and sensory characteristics of Xiangxi yellow cattle in comparison to Aberdeen Angus. Animals, 12(9), 1161. https://doi.org/10.3390/ani12091161

Costa C, Rizzieri R, Melo G, Müller L, Estevan D, Pacheco R, Millen D, Pereira A, Zanatta M, Cappellozza B, Cervieri R. 2020. Effects of fatty acid profile of supplements on intake, performance, carcass traits, meat characteristics, and meat sensorial analysis of feedlot Bos indicus bulls offered a high-concentrate diet. Translational Animal Science, 4(3), txaa142. https://doi.org/10.1093/tas/txaa142

Cui S, Wang Y, Zhou Z, Zhang YY, Huang XH, Zhou DY, Qin L. 2024. A comprehensive evaluation of lipid profiles and nutritional quality in different animal source muscle tissues. Food Bioscience, 59, 103947. https://doi.org/10.1016/j.fbio.2024.103947

Dagne T, Mummed Y, Kurtu M, Leta M, O'Quinn T, Vipham J. 2021. Proximate Composition and Fatty Acid Profile of Beef from Arsi, Borana and Harar Cattle Breeds in Oromia National Regional State, Ethiopia. Open Journal of Animal Sciences, 11(2), 139–156. https://doi.org/10.4236/ojas.2021.112011

Dinh TT, To KV, Schilling MW. 2021. Fatty acid composition of meat animals as flavor precursors. Meat and Muscle Biology, 5(1), 12251. https://doi.org/10.22175/mmb.12251

Domínguez R, Pateiro M, Gagaoua M, Barba FJ, Zhang W, Lorenzo JM. 2019. A comprehensive review on lipid oxidation in meat and meat products. Antioxidants, 8(10), 429. https://doi.org/10.3390/antiox8100429
Dragoev SG. 2024. Lipid peroxidation in muscle foods: Impact on quality, safety and human health. Foods, 13(5), 797. https://doi.org/10.3390/foods13050797
Du L, Chang T, An B, Liang M, Deng T, Li K, Gao H. 2022. Transcriptomics and lipid metabolomics analysis of subcutaneous, visceral, and abdominal adipose tissues of beef cattle. Genes, 14(1), 37. https://doi.org/10.3390/genes14010037
Goluch Z, Eng PD. 2021. The protein and fat quality of thigh muscles from Polish goose varieties. Poultry Science, 100(5), 101015. https://doi.org/10.1016/j.psj.2021.01.015
Gruffat D, Bauchart D, Thomas A, Parafita E, Durand D. 2021. Fatty acid composition and oxidation in beef muscles as affected by ageing times and cooking methods. Food Chemistry, 343, 128476. https://doi.org/10.1016/j.foodchem.2020.128476
Guo P, Yao X, Jin X, Xv X, Zhang J, Li Q, Yan C, Li X, Kim N. 2023. Interference with DGAT gene inhibited TAG accumulation and lipid droplet synthesis in bovine preadipocytes. Animals, 13(13), 2223. https://doi.org/10.3390/ani13132223
Islam MA, Alam MK, Islam MN, Khan MA, Ekeberg D, Rukke EO, Vegarud GE. 2014. Principal milk components in buffalo, holstein cross, indigenous cattle and red chittagong cattle from Bangladesh. Asian-Australasian Journal of Animal Sciences, 27(6), 886. https://doi.org/10.5713/ajas.2013.13586
Islam MS, Hossain MM, Akhter S, Al Noman MA, Goswami PK, Hashem MA. 2022. Indigenous beef cattle production scenario in Bangladesh. Meat Research, 2(4), 29. https://doi.org/10.55002/mr.2.4.29
Islam S, Islam MS, Islam MS, Alam MH, Azad MAK, Hossain MM. 2021. Effects of indigenous cattle age on their beef quality. Journal of Agriculture, Food and Environment, 2(1), 1–5. http://doi.org/10.47440/JAFE.2021.2101
Kalkman HO, Hersberger M, Walitza S, Berger GE. 2021. Disentangling the molecular mechanisms of the antidepressant activity of omega-3 polyunsaturated fatty acid: a comprehensive review of the literature. International Journal of Molecular Sciences, 22(9), 4393. https://doi.org/10.3390/ijms22094393
Khalid W, Maggiolino A, Kour J, Arshad MS, Aslam N, Afzal MF, Korma SA. 2023. Dynamic alterations in protein, sensory, chemical, and oxidative properties occurring in meat during thermal and non-thermal processing techniques: A comprehensive review. Frontiers in Nutrition, 9, 1057457. https://doi.org/10.3389/fnut.2022.1057457
Lidgard B, Fretts AM, Zelnick LR, van Westing AC, Geleijnse JM, Steur M, Samieri C, Helmer C, Le Goff M, Chen YY, Chien KL. 2026. Circulating saturated fatty acids and incident chronic kidney disease: a meta-analysis of de-novo prospective cohort investigations. American Journal of Clinical Nutrition, 101138. https://doi.org/10.1016/j.ajcnut.2025.101138
Liu T, Wu JP, Lei ZM, Zhang M, Gong XY, Cheng SR, Liang Y, Wang JF. 2020. Fatty acid profile of muscles from crossbred Angus-Simmental, Wagyu-Simmental, and Chinese Simmental cattles. Food Science of Animal Resources, 40(4), 563. https://doi.org/10.5851/kosfa.2020.e33
Marović R, Badanjak Sabolović M, Brnčić M, Ninčević Grassino A, Kljak K, Voća S, Karlović S, Rimac Brnčić S. 2024. The nutritional potential of avocado by-products: A focus on fatty acid content and drying processes. Foods, 13(13), 2003. https://doi.org/10.3390/foods13132003
Mititelu M, Lupuliasa D, Neacșu SM, Olteanu G, Busnatu ȘS, Mihai A, Scafa-Udriște A. 2024. Polyunsaturated fatty acids and human health: a key to modern nutritional balance in association with polyphenolic compounds from food sources. Foods, 14(1), 46. https://doi.org/10.3390/foods14010046
Momot M, Nogalski Z, Pogorzelska-Przybyłek P, Sobczuk-Szul M. 2020. Influence of genotype and slaughter age on the content of selected minerals and fatty acids in the longissimus thoracis muscle of crossbred bulls. Animals, 10(11), 2004. https://doi.org/10.3390/ani10112004
Mortensen EG, Fuerniss HF, Legako JF, Thompson LD, Woerner DR. 2024. Nutrient analysis of raw and cooked USDA prime beef cuts. Nutrients, 16(17), 2912. https://doi.org/10.3390/nu16172912
Murshed HM, Sarker MA, Rahman SM, Hashem MA. 2014. Comparison of carcass and meat quality of Black Bengal goat and Indigenous sheep of Bangladesh. Journal of Meat Science and Technology, 2(3), 63–67.
Mwangi FW, Blignaut DJ, Charmley E, Gardiner CP, Malau-Aduli BS, Kinobe RT, Malau-Aduli AE. 2021. Lipid metabolism, carcass characteristics and Longissimus dorsi muscle fatty acid composition of tropical crossbred beef cattle in response to Desmanthus spp. forage backgrounding. Metabolites, 11(12), 804. https://doi.org/10.3390/metabo11120804
Ndereyimana A, Contò M, Chiariotti A, Renzi G, Failla S. 2024. Beef Carcasses Aged at Mild Temperature to Improve Sustainability of Meat Production. Sustainability, 16(22), 9907. https://doi.org/10.3390/su16229907
Ponnampalam EN, Priyashantha H, Vidanarachchi JK, Kiani A, Holman BW. 2024. Effects of nutritional factors on fat content, fatty acid composition, and sensorial properties of meat and milk from domesticated ruminants: An overview. Animals, 14(6), 840. https://doi.org/10.3390/ani14060840
Rahman MA, Chowdhury R, Islam KMS. 2024. Performance and nutritional status of Holstein crossbred cows in a selected area of Bangladesh under the existing farming system. Journal of Advanced Veterinary and Animal Research, 11(3), 686. http://doi.org/10.5455/javar.2024.k818
Rasinska E, Rutkowska J, Czarniecka-Skubina E, Tambor K. 2019. Effects of cooking methods on changes in fatty acids contents, lipid oxidation and volatile compounds of rabbit meat. LWT, 110, 64–70. https://doi.org/10.1016/j.lwt.2019.04.067
Rodriguez EE, Hamblen H, Leal-Gutierrez JD, Carr C, Scheffler T, Scheffler JM, Mateescu RG. 2024. Exploring the impact of fatty acid composition on carcass and meat quality in Bos taurus indicus influenced cattle. Journal of Animal Science, 102, skae306. https://doi.org/10.1093/jas/skae306
Rule DC, Melson EA, Alexander BM, Brown TE. 2022. Dietary fatty acid composition impacts the fatty acid profiles of different regions of the bovine brain. Animals, 12(19), 2696. https://doi.org/10.3390/ani12192696
Sakowski T, Grodkowski G, Gołębiewski M, Slósarz J, Kostusiak P, Solarczyk P, Puppel K. 2022. Genetic and environmental determinants of beef quality—a review. Frontiers in Veterinary Science, 9, 819605. https://doi.org/10.3389/fvets.2022.819605
Samad MA. 2020. A six-decade review: research on cattle production, management and dairy products in Bangladesh. Journal of Veterinary Medical and One Health Research, 2(2), 183–404. https://doi.org/10.36111/jvmohr.2020.2(2).0021
Schettini GP, Peripolli E, Alexandre PA, Dos Santos WB, da Silva Neto JB, Pereira AS, de Albuquerque LG, Curi RA, Baldi F. 2022. Transcriptomic profile of longissimus thoracis associated with fatty acid content in Nellore beef cattle. Animal Genetics, 53(2), 264–280. https://doi.org/10.1111/age.13199
Sheashea M, Xiao J, Farag MA. 2021. MUFA in metabolic syndrome and associated risk factors: is MUFA the opposite side of the PUFA coin?. Food & Function, 12(24), 12221–12234. https://doi.org/10.1039/D1FO00979F
Sherratt SC, Libby P, Budoff MJ, Bhatt DL, Mason RP. 2023. Role of omega-3 fatty acids in cardiovascular disease: the debate continues. Current Atherosclerosis Reports, 25(1), 1–17. https://doi.org/10.1007/s11883-022-01075-x
Smith SB. 2024. Oleic acid concentration in bovine adipose tissues: impact on human health, sensory attributes, and genetic regulation. Frontiers in Animal Science, 5, 1332861. https://doi.org/10.3389/fanim.2024.1332861
Urrutia O, Mendizabal JA, Alfonso L, Soret B, Insausti K, Arana A. 2020. Adipose tissue modification through feeding strategies and their implication on adipogenesis and adipose tissue metabolism in ruminants. International Journal of Molecular Sciences, 21(9), 3183. https://doi.org/10.3390/ijms21093183

Wang B, Wu L, Chen J, Dong L, Chen C, Wen Z, Wang DW. 2021. Metabolism pathways of arachidonic acids: mechanisms and potential therapeutic targets. Signal transduction and targeted therapy, 6(1), 94. https://doi.org/10.1038/s41392-020-00443-w

Weiny JA, Boeglin WE, Calcutt MW, Stec DF, Brash AR. 2022. Monolayer autoxidation of arachidonic acid to epoxyeicosatrienoic acids as a model of their potential formation in cell membranes. Journal of Lipid Research, 63(1), 100159. https://doi.org/10.1016/j.jlr.2021.100159

Zhang M, Bai H, Wang W, Zhao Y, Yang W, Liu J, Zhang Y, Jiao P. 2025. Impact of dietary lysophospholipids supplementation on growth performance, meat quality, and lipid metabolism in finishing bulls fed diets varying in fatty acid saturation. Journal of Animal Science and Biotechnology, 16(1), 7. https://doi.org/10.1186/s40104-024-01138-w

Zhu M, Zhang J, Jiao L, Ma C, Kang Z, Ma H. 2022. Effects of freezing methods and frozen storage on physicochemical, oxidative properties and protein denaturation of porcine longissimus dorsi. LWT, 153, 112529. https://doi.org/10.1016/j.lwt.2021.112529

Zou B, Yu Q, Shao L, Sun Y, Li X, Dai R. 2022. Alteration of mitochondrial lipidome and its potential effect on apoptosis, mitochondrial reactive oxygen species production, and muscle oxidation in beef during early postmortem. Journal of Agricultural and Food Chemistry, 70(26), 8064–8074. https://doi.org/10.1021/acs.jafc.2c02519