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Fatty acid profile of the mutton from Tsagaan-uul breed

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Abstract
The objective of this research was to evaluate the chemical composition, muscle-to-bone ratio, fatty acid profile, and nutritional indexes (S/P, PUFA/SFA, n-6/n-3, AI, and TI) of the longissimus muscles (n=12) from pasture-raised Tsagaan-Uul breed sheep. The study focused on mutton from sheep aged 1.5, 2.5, and 3.5 years. The chemical composition of the meat varied with age. Total moisture content ranged from 56.6% to 62.2%, lipids from 19.1% to 24.9%, protein from 17.4% to 17.9%, and minerals from 0.7% to 0.8%. The muscle-to-bone ratio also increased with age, ranging from 5.2 to 6.3 kg. A total of 28 fatty acids were identified, with 50.56% being saturated fatty acids (SFA) and 49.35% unsaturated fatty acids (UFA). Among the 12 SFAs identified, palmitic acid (C16:0, 46.0%), stearic acid (C18:0, 28.4%), and butyric acid (C16:0, 11.5%) together accounted for 85.9% of the total SFA content. Seven different monounsaturated fatty acids (MUFA) were detected, with oleic acid dominating at 89.54%. Polyunsaturated fatty acids (PUFA) were dominated by linoleic acid (43.82%), α-linolenic acid (24.56%), and docosahexaenoic acid (16.64%), which made up 95.02% of the total PUFA content. The nutritional indexes, including the S/P ratio, n-6/n-3 ratio, AI, and TI, were found to be within recommended levels, except for the PUFA/SFA ratio. The observed variations in chemical composition and fatty acid profiles may be attributed to factors such as geographical location, diet, husbandry practices, and the timing of meat sampling.

Keywords: Tsagaan-Uul breed, mutton, fatty acid profile, *longissimus muscle*, nutritional indexes

Introduction
Livestock production plays a crucial role in the economic development of rural households, providing both income and savings. In many pastoral regions, herders rely on grassland resources for livestock production. However, to enhance livestock productivity, it is important to optimize herd size and composition to match pasture capacity, which can be achieved by intensifying production and reducing total livestock numbers. In several countries, particularly those that rely on pasture-based systems, male animals are often slaughtered at a young age due to the lack of economic viability in raising them. This practice allows herders to introduce younger livestock into the economy, increasing their income. Consumer preferences for mutton and its nutrient content are shaped by intrinsic factors such as fat percentage and fatty acid composition, as well as extrinsic factors like breed, age, feeding practices, and environmental conditions [1, 2, 3]. As an animal matures, its meat's biochemical composition changes due to tissue development, fat deposition, and carcass growth [2]. Several studies have shown that intramuscular fat content positively influences meat quality, particularly its flavor, tenderness, and juiciness [4, 5, 6]. Additionally, the composition of fat tissue and the fatty acid profile are crucial for meat quality, influencing attributes such as taste, aroma, texture, fat color, shelf life, and its impact on human health [6].

Polyunsaturated fatty acids (PUFAs), for instance, are essential nutrients that offer protective effects against diabetes, cardiovascular diseases, and certain cancers [7]. Research has shown that mutton quality varies depending on farming systems and pasture-based breeding [2]. Sheep raised on pastures tend to produce meat with superior nutritional quality and better taste compared to those raised on concentrate-based diets [3]. French et al. [8] noted that grass-fed sheep have higher concentrations of conjugated linoleic acid in their fat. Meat from grass-finished lambs also has a distinct flavor compared to lambs finished on concentrate-based diets [9]. In the Tsagaan-Uul sum of Khuvsgul province, the native people claim that the meat of fattened Tsagaan-Uul lambs has superior organoleptic qualities, making it tastier. This is attributed to the region's favorable environmental conditions, including the quality of pastures. Tsagaan-Uul is known for its "sweet grasses" and a natural landscape that combines forest and steppe ecosystems. The region's abundant rivers, lakes, salt marshes, and mineral-rich soils provide excellent feed and water sources for livestock. Situated at an altitude of 1,729 to 2,613 meters above sea level, the environmental conditions of the region may influence the unique characteristics of the meat from Tsagaan-Uul breed sheep. This study aims to evaluate how the age or final weight at slaughter affects the chemical composition and fatty acid profile of mutton from the Tsagaan-Uul breed. The results will provide insight into the influence of age on the meat quality of this unique breed.

Materials and methods

A total of 12 Tsagaan-Uul breed sheep, divided into three slaughter age groups (1.5, 2.5, and 3.5 years), were selected for this study. These sheep were pasture-raised in Tsagaan-Uul sum of Khuvsgul province and were part of the breeding core flock. Only well-fed sheep with medium-to-high fat content were chosen. The sheep were slaughtered using traditional methods, and the carcasses were chilled prior to sampling. Longissimus dorsi muscles were collected for chemical analysis. The analyses were conducted at the “SAMO" Food Science, Research and Production Institute, Mongolia following standardized methods as described. Moisture content was measured in triplicate using an oven set at 130°C, with samples dried for 120 minutes, according to the MNS 6477:2014 standard. Total crude fat was determined by the Soxhlet method using petroleum ether, according to MNS 3748:1984 and ISO 1443:1973. Total protein content was measured using the Kjeldahl method, in line with MNS 937:1984. Total ash content was determined using a dry ashing procedure, where the samples were incinerated in a high-temperature muffle furnace at 500°C, based on the MNS ISO 936:2003 standard. Fatty acid composition was analyzed by direct transesterification, as outlined by Rule (n=3). Fatty acids were measured using an Agilent 6890 gas chromatograph (GC-FID) with an HP–FFAP column (30m x 0.32mm x 0.25mm). The column temperature was maintained at 120°C, and the detector temperature at 250°C. The flow rates were 40 ml/min for hydrogen and 400 ml/min for oxygen, with an injection volume of 1 ml. Fatty acids were expressed as a percentage of total fatty acids, identified as fatty acid methyl esters. The saturation index (S/P), atherogenic index (AI), and thrombogenic index (TI) were calculated according to the method of Ulbricht and Southgate [11]. These indices were used to evaluate the health impact of the fatty acids present in the meat.

$$S/P = \frac{C14{:}0 + C16{:}0 + C18{:}0}{\Sigma\, MUFA + \Sigma\, PUFA}$$

$$IA\ indices = \frac{4 * C14{:}0 + C12{:}0 + C16{:}0}{\Sigma\, MUFA + \Sigma PUFA_{n\text{-}3} + \Sigma PUFA_{n\text{-}6}}$$

$$TI\ indices = \frac{C14{:}0 + C\ 16{:}0 + C18{:}0}{0.5 * MUFA + (0.5 * n\text{-}6) + (3 * n\text{-}3) + (n\text{-}3/n\text{-}6)}$$

Data analysis. All analyses were conducted using statistical procedures of Analysis of Variance (ANOVA).

Results and Discussion

The moisture, fat, protein, ash content, caloric value, and muscle-to-bone ratio of mutton were analyzed across three age groups of sheep. The muscle-to-bone ratio was found to increase with age, ranging from 5.28 to 6.33. Specifically, the muscle-to-bone ratios were 5.28±0.05 kg for young sheep, 5.80±0.05 kg for teg sheep, and 6.33±0.07 kg for three-year-old sheep. This represents an annual increase of 9.1–9.8%. These findings align with the results of studies by Perez et al. [12] and Hopkins et al. [13], which also observed that as animals age, both the fat percentage and muscle-to-bone ratio tend to increase. Slaughter age plays a critical role in the fat content and the intramuscular fat profile of carcasses. In particular, variations in the levels of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) are influenced by the age of the animal [7]. These changes in fat composition are significant as they affect both the quality of the meat and its nutritional properties.

Table 1

Proximate analysis of mutton from Tsagaan-Uul sheep compared with research results from previous studies, %

Breed	Tsagaan-Uul breed			Native breed	Southern African	Sweden, native breed
Researchers	Ariunbold et al.,			Minjigdorj et al., [14]	Sainbury and Shonfeld [15]	Willems and Kreuzer [16]
	Young /1.5 years old/	Teg /1.5 years old/	Sheep /1.5 years old/	Sheep fatten medium to high	Loin and rump	High mountain region
Moisture, %	62.20±0.49	58.87±0.44	56.60±0.48	51.8	74.0,	74.2
Total fat, %	19.12±0.47	22.86±0.54	24.97±0.97	34	8.85	2.9
Protein, %	17.95±0.04	17.46±0.39	17.61±0.53	13.4	20.7	23.1
Minerals, %	0.73±0.07	0.81±0.02	0.83±0.03	-	1.20	1.3
Calories kg, kcal	2627.8±57.1	2952.2±61.2	3500.3±42.2	3745	682	-
Muscle-to-bone ratio kg	5.28±0.05	5.80±0.05	6.33±0.07	-	-	-

Similar findings have been reported in studies examining the chemical composition of sheep loin. For instance, the moisture content was found to be 75.7%, with protein at 18.8%, crude fat at 2.7%, and ash at 1.1% [17]. Cloet et al. [18] reported a moisture content of 73.3±0.6%, protein at 22.9±0.5%, crude fat at 2.19±0.26%, and minerals at 1.07±0.07%. In their study of Dorper lambs, the moisture content was 71.1±0.5%, with protein at 23.8±0.5%, crude fat at 3.19±0.28%, and minerals at 1.10±0.07%.

Elizalde et al. [19], studying mutton from sheep raised on pastures in the dry and cold climate of Western Patagonia, Argentina, found that the moisture content was 77.7%, with crude fat at 11.9%, protein at 18.7%, and ash at 3.9%. These results indicate that the composition of meat is significantly influenced by environmental conditions and animal management practices.

Sergelen et al. [20] reported that the Sonod breed of Inner Mongolia, raised in favorable conditions, exhibited a moisture content of 76.45%, total fat of 5.82%, protein of 17.32%, and ash content ranging from 0.94% to 1.98%. These findings suggest that the total fat and caloric content of sheep meat is generally lower in warmer climates compared to those in harsher environmental conditions, highlighting the impact of geography and management practices on meat quality.

The findings of this study align with those of Minjigdorj [14], with the current research showing slightly higher moisture and protein content but lower fat and calorie content. However, compared to other researchers [17, 15, 16], this study reported lower moisture content, higher fat levels, and lower ash content. These variations may be attributed to differences in sheep production systems, breeding practices, upland habitats, extreme climate conditions, feeding strategies, husbandry technologies, and the timing or period of meat sampling.

Fatty Acid Content

A total of 26 fatty acids were identified in the mutton samples. Saturated fatty acids (SFA) made up 50.56% of the total fatty acids, while unsaturated fatty acids (UFA) accounted for 49.35%. Monounsaturated fatty acids (MUFA) represented 45.28%, and polyunsaturated fatty acids (PUFA) were 3.83%. The predominant fatty acids in the mutton were oleic acid (C18:1, 40.5%), palmitic acid (C16:0, 23.4%), and stearic acid (C18:0, 14.4%). These results are consistent with previous findings [17], where the total SFAs of Mongolian native sheep raised in the Khangai region were reported as 45.04%, with USFAs at 52.99%. For the steppe region, SFAs were identified as 50.04% and USFAs as 49.99%.

Erkigul et al. [21] identified 29 fatty acids in the loin of mutton from pasture-raised Mongolian native and Uzemchin breeds. Our results are similar to these findings, although the palmitic and oleic acid content were higher in the Tsagaan-Uul breed. Tserenkhand et al. [22] also analyzed 29 fatty acids in Mongolian sheep meat and found that 61.1% of total fatty acids were SFAs, 31.45% were MUFAs, and 7.45% were PUFAs. In their study, saturated fatty acids such as palmitic acid (C16:0, 33.03%) and stearic acid (C18:0, 17.7%) were the most predominant.

The variations observed in fatty acid composition across studies could be attributed to differences in environmental conditions, breed, diet, and management practices. These factors play a crucial role in determining the quality and nutritional value of mutton.

Table 2

The saturated fatty acid content of mutton from Tsagaan-Uul sheep, %

№	Fatty acids		Tsagaan-Uul breed	Comparison		
	Lipid Numbers	Common Name		Native breed, [22]	Uzemchin breed [21]	Australian Hemsin breed [23]
1	C4:0	Butyric	5.84±0.14	-	0.21	-
2	C6:0	Caproic	0.14±0.01	-	-	0.03
3	C10:0	Capric	0.24±0.01	0.34	0.46	0.21
4	C12:0	Lauric	0.17±0.01	0.56	0.49	0.17
5	C14:0	Myristic	3.27±0.05	4.28	2.20	3.21
6	C15:0	Pentadecanoic	0.80±0.02	0.74	0.35	0.99
7	C16:0	Palmitic	23.38±0.06	33.03	24.94	23.3
8	C17:0	Margaric	1.79±0.04	2.04	0.73	2.68
9	C18:0	Stearic	14.43±0.17	17.7	15.79	18.1
10	C20:0	Arachidic	0.09±0.01	0.29	0.12	0.12
11	C21:0	Heneicosylic	0.77±0.02	0.15	0.44	0.61
12	C24:0	Lignoceric	0.17±0.02	1.2	-	0.04
	Total SFA		**50.38±0.30**	**60.33**	**45.73**	**49.46**

A total of 12 saturated fatty acids (SFAs) were identified in the mutton samples, with palmitic acid (C16:0) accounting for 46.0%, stearic acid (C18:0) making up 28.4%, and butyric acid (C16:0) contributing 11.5%. These three SFAs together constituted 85.9% of the total SFAs.

Table 3

The monounsaturated fatty acid content of mutton from Tsagaan-Uul sheep, %

№	Fatty acids		Tsagaan-Uul breed	Comparison		
	Lipid Numbers	Common Name		Native breed, [22]	Uzemchin breed [21]	Australian Hemsin breed [23]
1	C14:1	Myristoleic	0.31±0.01	0.68	0.12	0.07
2	C15:1	Pentadecenoic cis-10	0.55±0.003	0.09	0.36	-
3	C16:1	Palmitoleic	1.39 ±0.05	1.26	1.85	1.02
4	C17:1	Heptadecenoic cis-10	1.19±0.03	0.1	0.43	-
5	C18:1	Oleic	40.54±0.25	29.3	30.28	34.87
6	C22:1	Erucic	1.17±0.10	-	-	-
7	C24:1	Nervonic	0.20 ±0.15	-	-	-
	Total MUFA		**45.28±0.25**	**31.43**	**33.04**	**35.96**

The monounsaturated fatty acid (MUFA) composition of the mutton is summarized in Table 3. Seven MUFAs were found in the muscle tissue, which collectively accounted for 45.28±0.25% of the total fatty acids. Oleic acid (C18:1) was the most abundant MUFA, making up 89.54%, while nervonic acid (C24:1) was the least, contributing just 0.44%. These findings partially align with the results of Tserenkhand et al. [22], who identified oleic acid (C18:1) as comprising 29.3% of the total fatty acids and forming 80.03% of the total MUFAs.

The flavor of mutton is closely linked to intramuscular fat (IMF) content, with oleic acid playing a significant role in enhancing the taste. Fatty acids undergo oxidation through chemical or enzymatic reactions, resulting in the formation of aldehydes, ketones, alkanes, and alcohols, which contribute to the distinct flavors of the meat [24]. As the sheep age, the characteristic "mutton" flavor intensifies, largely due to the increased fat content and the presence of short-chain and branched-chain fatty acids [25].

Table 4

The polyunsaturated fatty acid content of mutton from Tsagaan-Uul sheep, %

№	Fatty acids		Tsagaan-Uul breed	Comparison		
	Lipid Numbers	Common Name		Native breed, [22]	Uzemchin breed [21]	Australian Hemsin breed [23]
1	C18:2n9 c/t	Linoleic	1.68±0.03	2.94	2.1	2.02
2	C18:3n3	α-Linolenic	0.94±0.02	2.17	1.66	0.37
3	C20:2	Eicosadienoic	0.12±0.03	0.21	-	0.02
4	C20:4n6	Arachidonic	0.38±0.01	0.09	-	0.08
5	C22:2	Docosadienoic	0.06±0.01	0.23	0.16	-
6	C20:5m3	Eicosapentaenoic	0.16±0.04	0.01	1.63	-
7	C22:6n3	Docosahexaenoic	0.64±0.05	-	0.14	-
	Total PUFA		**3.83 ±0.09**	**5.65**	**5.69**	**2.49**
	PUFA/SFA ratio		0.08	-	-	-
	n-6/n-3		0.22	-	-	-
	Saturation index S/P		0.89	-	-	-
	Atherogenic index AI		0.77	-	-	-
	Thrombogenic index TI		1.26	-	-	-

The fatty acid profile showed that a total of 7 types of PUFAs were detected in the mutton of the Tsagaan-Uul breed, which accounted for 3.83% of the total FAs in the meat. Linoleic acid (C18:2n9 cis, 43.8%), α-linoleic acid (C18:3n3, 24.5%), and docosahexaenoic acid (C22:6n3, DHA, 16.6%) constituting 85.1% of total PUFAs (Table 4). On the contrary, docosadienoic (C22.2, 1.57%) acid was the lowest amount in total PUFAs. This observation is in good agreement with Elizalde et al.,[19], who reported that oleic acid dominated in the MUFAs, making up 58.9%, however, linoleic acid was 44.4% and α-linolenic acid was 16.8% in total PUFAs. Similarly, in the study linoleic acid (C18:2) was the predominant PUFA in the samples. This fatty acid plays an important role in generating volatile oxidation products in cooked meat [26]

Data presented here showed that the PUFA/SFA ratio was 0.08 in the mutton of the Tsagaan-Uul breed however, this ratio was below dietary recommendations of ≥0.45 [27]. The PUFA/SFA ratio is a key factor in determining the nutritional value of fatty foods [27]. PUFA/SFA ratio from male kid goats Carpathian breed was 0.23 [28]. Chen [29] reported that this ratio was from 0.16 to 1.32 for red meat.

Furthermore, the n-6/n-3 ratio was 0.22. This is consistent with the findings of Migdał [28] who also reported that the n-6/n-3 ratio was 0.1 in lamb meat. The content of n-6/n-3 PUFAs in meat is linked to human health. This nutritional index affects cardiovascular risk and other diseases and a ratio below 4.0 is considered optimal for health [30].

Present results showed that the saturation index was 0.89, the atherogenic index was 0.77, and the thrombogenic index was 1.26. This observation is in good agreement with [26]. who reported that the saturation index (S/P) ratio of fat from male kid goats Carpathian breed was 0.85, while the atherogenic index (AI) was 0.51, and the thrombogenic index (TI) was 1.52 respectively. The lower values of these indexes could indicate a reduction of possible vascular risk [31].

In conclusion, this study demonstrates that slaughter age significantly affects the chemical composition of meat and muscle-to-bone ratios in the Tsagaan-Uul breed of mutton, which increased by 9.1-9.8% annually. The findings suggest that Tsagaan-Uul mutton is rich in essential fatty acids, which are vital for human health, and possess high nutritional and biological properties. A total of 26 fatty acids were identified in the mutton, with 50.56% being saturated fatty acids and 49.35% unsaturated fatty acids. Among these, monounsaturated fatty acids comprised 45.28%, while polyunsaturated fatty acids accounted for 3.83%. The predominant fatty acids included oleic acid (40.5%), palmitic acid (C16:0, 23.4%), and stearic acid (C18:0, 14.4%). Additionally, the nutritional indices (S/P, n-6/n-3, AI, and TI) of the mutton were within recommended ranges. The observed variations in chemical and fatty acid composition can be attributed to factors such as geographical location, feeding practices, husbandry technologies, and the timing of meat sampling.

Conflict of interest

The authors declare that there is no conflict of interest.

Authors' contribution

TA writing original draft preparation, GS and ET contributed supplementary materials, review and supervision, and DD writing review and editing. All authors have read and approved the final manuscript.

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