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Determining the Impact of the CSN1S1 Gene on Physicochemical Properties of Milk among Three Goat Breeds of District Khairpur, Sindh, Pakistan

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ABSTRACT

The physicochemical characteristics of goat milk, such as acidity, citric acid level, density, fatty acid levels, freezing point, and urea content, contribute significantly to the quality of fresh milk obtained from different dairy production methods. Various environmental and genetic factors, such as health problems, lactation stage, breeding environment, feed intake, and genetic polymorphism, influence the composition of milk. Studies on the effects of CSN1S1 on the physicochemical properties (proteins, vitamins, and fat) of goat breeds' milk have been limited. This study aimed to evaluate the impact of the CSN1S1 gene on goat milk physicochemical traits. The methodology consists of three types of milk samples collected from District Khairpur, Sindh, Pakistan. The samples were sent to the Pakistan Council of Scientific and Industrial Research (PCSIR) labs in Karachi, Pakistan. All the samples were analyzed for physicochemical properties, such as fat, proteins, and vitamins (A, B2, C, D, E, and K) by PCSIR in Karachi. The AOAC 2023 method was applied in this study, and HPLC technology was employed to investigate vitamins A, B2 (riboflavin), C, D, E, and K. We employed the Gerber technique for fat determination and Kjeldahl for protein evaluation. The outcome revealed Kamori breed milk had a high fat percentage (4.50%–4.90%) by Gerber analysis but showed decreased levels of protein (2.85% and 3.60%) as compared to the standard mean value of 4.82 mg/ml. The protein was estimated by the Kjeldahl method, indicating that such alterations affect the ratio between the synthesis of fat and protein. Teddy breed milk had a higher content of fat (5.42–6.90%), according to the Gerber method, but showed lower protein contents (2.85 and 2.80%) compared to the average value of 4.82 mg/ml. The physico-chemical impact of fat content was higher (3.60%–4.40%) than the standard usual value (3.4–4.2%). In comparison to the remaining two breeds of goats, we noted a great difference. The study also determined the vitamin concentration in three breeds of goats, including Kamori, Teddy, and Gulabi. Vitamin A, B2, C, D, E, and K values were measured against the overall standard range made in other studies. The Kamori breed has a mean vitamin A concentration of 103 (µg/100g) and a vitamin B concentration of 0.13 (µg/100g). Similarly, the values are Vitamin C 1.14 (µg/100g), Vitamin D 47.34 (µg/100g), Vitamin E 0.07 (µg/100g), and Vitamin K 0.18 (µg/100g). In the Teddy breed, vitamin A was measured at 98.82 µg/100 g, while vitamin B was recorded at 0.12 µg/100 g. Likewise, the values are as follows: Vitamin C 1.28 (µg/100g), Vitamin D 20.10 (µg/100g), Vitamin E 0.04 (µg/100g), and Vitamin K 0.27 (µg/100g). In the Gulabi breed, vitamin A was measured at 88.10 (µg/100g), while vitamin B was recorded at 0.13 (µg/100g). Likewise, the values are as follows: Vitamin C 1.74 (µg/100g), Vitamin D 41.72 (µg/100g), Vitamin E 0.06 (µg/100g), and Vitamin K 0.03 (µg/100g). The vitamin values among these three breeds suggest a substantial presence of vitamin D. This study concludes that there is a substantial link between variations in the CSN1S1 gene and the Kamori goat breed, particularly regarding the percentage prevalence of fat and normal protein levels across all three breeds, as well as the significant amount of Vitamin D found in each of these breeds.

INTRODUCTION

Dairy goat farming plays a strategic role in the economies and traditions of Mediterranean countries such as France, Italy, Spain, and Greece. Recently, the role of goat milk in human nutrition has increased, owing to its favorable chemical, physical, and nutritional characteristics, which make it an effective alternative to cow milk. Goat milk contrasts with cow milk primarily on the grounds of its reduced size of fat globules, which results in greater digestibility and increased content of short- and medium-chain fatty acids, which partially account for its more vigorous taste [1]. Its characteristics qualify it for use in children and infants, for instance, in certain forms of malabsorption syndrome [2]. Goat milk is well known for its nutritional value, excellent digestibility, and healing capabilities, which make it a crucial part of human diets in the world's rural and semi-arid areas. In Pakistan, the Kamori, Teddy, and Gulabi breeds of goats are not only part of smallholder farmers' livelihoods but are also significant genetic assets to enhance milk quality and quantity. Among all the biochemical and genetic factors that decide milk composition, casein proteins are at the forefront both in terms of nutrition and technology.

One of the major genes coding casein proteins of milk is the CSN1S1 gene, which is responsible for synthesizing the alpha S1-casein (αS1-casein), one of the prominent structural and functional proteins of goat milk. The αS1-casein accounts for about 30–35% of total caseins and plays a crucial role in the formation of micelles of casein, the transport of nutrients, and the emulsification of the globules of milk fat. Genetic polymorphism in the CSN1S1 gene has been reported to result in significant variation in protein content, milk yield, and cheese-making characteristics among goat breeds [3, 4].

Goat breeds like Kamori, Teddy, and Gulabi can have unique CSN1S1 allelic variants, which not only affect the amount and quality of milk protein but also fat-soluble vitamins like A, D, E, and K. All these vitamins are vital to human health and tend to be employed as indicators of the nutritional value of milk. It is important to understand how the CSN1S1 gene influences the physicochemical characteristics of milk in these goats to ensure selective breeding and genetic enhancement and boost the economic sustainability of goat milk production.

The physicochemical additives such as acidity, citric acid, density, free fatty acid (FFA), freezing point degree (FPD), and urea concentrations are critical parameters to identify the impact of various dairy processing operations on the quality of fresh milk [5]. The parameters attain product quality and profitability and processability based on the technological nature of milk for the dairy industry [6]. The storage time and temperature are closely related to the level of FFA, which also alters the storage time. Alternatively, milk acidity is applied to detect the development of the bacteria in fermentation during the cheese or yogurt manufacturing process [7]. The effect on the technological process turns the physicochemical characteristics of milk into a critical standard for the dairy industry. The milk composition is affected by numerous environmental and genetic factors like health issues, lactation stage, breeding, feed intake, or genetic polymorphism [8]. The CSN1S1 gene, whose eighteen alleles have been revealed to date, is connected with variable levels of alpha S1-casein (αS1-CN) milk protein. It was shown that the polymorphisms of this gene influence not only the casein content but also the structural and nutritional properties and technological qualities of goat milk [9].

The teddy bear is a strong animal. They are well adapted to their native areas. Teddy goats primarily raised for meat with certain CSN1S1 variants could still produce milk with desirable properties, such as higher protein or fat content. The Kamori goat is a popular and beautiful breed. It is a milk goat breed that is found in the Sindh Province of Pakistan. Gulabi Goats Known for their dual-purpose use (milk and meat), Gulabi goats with advantageous variants in these genes could see improvements in both milk yield and quality, making them more valuable for dairy production.

MATERIALS AND METHODS

Three types of milk samples were collected from different regions of District Khairpur, Sindh, Pakistan. Milk from Kamori, Teddy, and Gulabi breeds. Samples were transported to the Pakistan Council of Scientific and Industrial Research (PCSIR) laboratories complex in Karachi, Pakistan. All collected samples were analyzed for physicochemical properties, including fats, proteins, and vitamins (A, B2, C, D, E, and K) from PCSIR, Karachi. Analysis of fats was done by the Gerber method. Analysis of protein was done by the Kjeldahl method. The AOAC (Association of Official Analytical Chemists) 2023 methods for analyzing vitamins A, B2 (riboflavin), C, D, E, and K [10-11].

RESULTS

The results of the present study are mentioned in 06 tables in total, along with their detailed description for all three goat breeds, namely the Kamri goat breed, the Teddy goat breed, and the Gulabi goat breed, for all the samples of each breed. The results are also compared with the other studies and standard values available in literature. The results are described in mean value and standard errors for each breed. The milk from the Kamori sample K1 exhibited a fat content of 4.50%, which is above the typical range of 3.4–4.2% [10, 11], indicating enhanced lipid synthesis, possibly influenced by the active CSN1S1 gene. However, the protein content was relatively low (2.85%), falling below the average values cited in literature (3.4–4.82 mg/ml), which may suggest a weaker expression of αS1-casein or the presence of a low-expressing allele.

Vitamin A level was 103.10 μg/100 g, which is lower than the values reported by Park (185 μg/100 g) and Voulsinas (191 μg/100 g), suggesting modest β-carotene conversion. The vitamin D concentration (47.34 μg/100 g) was significantly higher than the standard global range (0.6–2.8 μg/kg), highlighting the strong vitamin D storage or synthesis capacity in Kamori milk. Vitamins B2, C, E, and K were found in small but consistent amounts, reflecting a balanced micronutrient profile as shown in Table 1.

Table 1

Mean and Standard Errors for the Effect of the CSN1S1 Gene on the physicochemical Properties of the Kamori Breed

Sample. 1	Breed	Gene	Parameters Examined	Reported values	Average Standard range	Y.W.Park *et al* (2007)	Voulsinas *et al.* (1992)
K1	Kamori	CSN1S1	Total Fat (%)	*4.50	3.4-4.2%	3.8	3.44

K1	Kamori	CSN1S1	Total Protein (%)	2.85	4.82mg/mL	3.4	3.35
K1	Kamori	CSN1S1	Vitamin A (µg/100g)	103.10	0.79± 0.08	185	191
K1	Kamori	CSN1S1	Vitamin B2 (µg/100g)	0.13	0.337mg	0.21	0.18
K1	Kamori	CSN1S1	Vitamin C (µg/100g)	1.14	1.3mg	1.29	1.5
K1	Kamori	CSN1S1	Vitamin D (µg/100g)	*47.34	0.6–2.8 µg/kg	2.3	2.4
K1	Kamori	CSN1S1	Vitamin E (µg/100g)	0.07	0.79±0.08mg/kg	1.5	0.10
K1	Kamori	CSN1S1	Vitamin K (µg/100g)	0.18	0.03µg	0.31	0.34
			Mean±SD	22.7329±36.416			

On the contrary, results of the Kamori K2 milk exhibited the highest fat content among all samples (4.90%), reflecting superior milk fat synthesis, potentially due to favorable CSN1S1 allele expression. The protein content was 3.60%, which is better than K1 and closer to standard values, indicating some degree of casein production activity. The vitamin A content (106.25 µg/100g) remained lower than expected from international references, but slightly higher than in K1. Vitamin D levels peaked at 55.82 µg/100g, the highest recorded in this study, pointing to excellent vitamin D retention or synthesis, which may be attributed to genetic and environmental factors (e.g., sunlight exposure). Vitamins B2 and C were within acceptable ranges, while vitamin K (0.24 µg/100g) showed a beneficial level for bone health as written under Table 2.

Table 2

Mean and Standard Errors for the Effect of the CSN1S1 Gene on Physicochemical Properties of the Kamori Breed

Sample. 2	Breed	Gene	Parameters Examined	Reported values	Average Standard range	Chandan *et al.* (1992)	Szymanowska and Lipecka (1997)
K2	Kamori	CSN1S1	Total Fat (%)	*4.90	3.4-4.2%	4.0	4.1
K2	Kamori	CSN1S1	Total Protein (%)	3.60	4.82mg/mL	3.2	2.9
K2	Kamori	CSN1S1	Vitamin A (µg/100g)	106.25	0.79± 0.08	185	190
K2	Kamori	CSN1S1	Vitamin B2 (µg/100g)	0.13	0.337mg	0.14	0.04
K2	Kamori	CSN1S1	Vitamin C (µg/100g)	1.39	1.3mg	1.50	2.1
K2	Kamori	CSN1S1	Vitamin D (µg/100g)	*55.82	0.6–2.8 µg/kg	0.06	2.4
K2	Kamori	CSN1S1	Vitamin E (µg/100g)	0.06	0.79±0.08mk/kg	0.20	0.24
K2	Kamori	CSN1S1	Vitamin K (µg/100g)	0.24	0.03µg	0.05	0.34
			Mean±SD	21.6925±39.0627			

The results of the Teddy goat breed are symbolized as Teddy sample T1 showed a fat content of 3.50%, which aligns with standard values and previous findings by [13]. The protein content (2.85%) was notably low, suggesting limited casein synthesis due to possible CSN1S1 gene mutations or deletions.

Vitamin A (98.82 µg/100g) was modest, and vitamin D (20.10 µg/100g), while higher than the global average, was significantly lower than Kamori samples, indicating lower capacity for vitamin D incorporation. Vitamin K was relatively high (0.27 µg/100g), which is notable as this vitamin supports bone metabolism and clotting. Vitamin E (0.04 µg/100g) was among the lowest, pointing to weak lipid-soluble antioxidant properties in this sample, as given in Table 3.

Table 3

Mean and Standard Errors for the Effect of the CSN1S1 Gene on the Physicochemical Properties of the Teddy Breed

Sample. 3	Breed	Gene	Parameters Examined	Reported values	Average Standard range	Graf *et al.* (1970)	Mba *et al.* (1975)
T1	Teddy	CSN1S1	Total Fat (%)	3.50	3.4-4.2%	3.92	3.41
T1	Teddy	CSN1S1	Total Protein (%)	2.85	4.82mg/mL	2.9	3.07
T1	Teddy	CSN1S1	Vitamin A (µg/100g)	98.82	0.79± 0.08	185	172
T1	Teddy	CSN1S1	Vitamin B2 (µg/100g)	0.12	0.337mg	0.08	0.04
T1	Teddy	CSN1S1	Vitamin C (µg/100g)	1.28	1.3mg	1.20	1.15
T1	Teddy	CSN1S1	Vitamin D (µg/100g)	*20.10	0.6–2.8 µg/kg	2.9	2.30
T1	Teddy	CSN1S1	Vitamin E (µg/100g)	0.04	0.79±0.08mk/kg	0.68	0.09
T1	Teddy	CSN1S1	Vitamin K (µg/100g)	0.27	0.03µg	0.31	0.29
			Mean±SD	21.11167±35.39589			

Results of the Teddy sample T2 had the highest fat content across all samples (5.42%), suggesting exceptional lipid metabolism. However, the protein level remained low (2.80%), reflecting inconsistent CSN1S1 gene activity or alternative post-transcriptional regulation mechanisms.

Surprisingly, vitamin A (54.14 µg/100g) was the lowest of all samples, highlighting poor β-carotene metabolism despite high fat. Vitamin D (18.42 µg/100g), though above the global average, remained significantly below Kamori and Gulabi, suggesting suboptimal retention. However, vitamin K (0.34 µg/100g) was the highest observed, indicating the breed's potential for producing bone-supportive milk, despite deficiencies in other areas, as shown in Table 04.

Table 4

Mean and Standard Errors for the Effect of the CSN1S1 Gene on the Physicochemical Properties of the Teddy Breed

Sample. 4	Breed	Gene	Parameters Examined	Reported values	Average Standard range	Akinsoyinu *et al.* (1977)	Ranawana and Kellaway *et al.* (1977)
T2	Teddy	CSN1S1	Total Fat (%)	5.42	3.4-4.2%	6.90	3.39
T2	Teddy	CSN1S1	Total Protein (%)	2.80	4.82mg/mL	3.91	4.93

T2	Teddy	CSN1S1	Vitamin A (µg/100g)	54.14	0.79± 0.08	4.49	159
T2	Teddy	CSN1S1	Vitamin B2 (µg/100g)	0.12	0.337mg	0.18	0.17
T2	Teddy	CSN1S1	Vitamin C (µg/100g)	1.32	1.3mg	2.0	1.39
T2	Teddy	CSN1S1	Vitamin D (µg/100g)	*18.42	0.6–2.8 µg/kg	2.4	16.24
T2	Teddy	CSN1S1	Vitamin E (µg/100g)	0.08	0.79±0.08mk/kg	0.10	0.8
T2	Teddy	CSN1S1	Vitamin K (µg/100g)	0.34	0.03µg	0.32	0.29
			Mean±SD	10.33±18.73065			

The results of the Gulabi goat breed are mentioned as Gulabi G1 presented a fat content of 3.60%, aligning with the standard range and confirming a moderate fat-yielding capacity. The protein content (2.20%) was the lowest among all samples, indicating a potentially weak CSN1S1 gene expression, possibly due to a deletion or low-expressing allele. In terms of vitamins, G1 excelled in vitamin C (1.74 µg/100 g), which supports antioxidant functions and immune health. Vitamin D (41.72 µg/100g) was considerably high, showing that Gulabi goats are also capable of producing vitamin D-rich milk, although slightly below Kamori. Vitamin K (0.31 µg/100g) was among the highest, making Gulabi milk potentially beneficial for osteocalcin activation and coagulation, as shown in Table 5.

Table 5

Mean and Standard Errors for the Effect of the CSN1S1 Gene on Physicochemical Properties of the Gulabi Breed

Sample. 5	Breed	Gene	Parameters Examined	Reported values	Average Standard range	Jenness (1980)	El-Zayat *et al.* (1984)
G1	Gulabi	CSN1S1	Total Fat (%)	3.60	3.4-4.2%	7.76	4.40
G1	Gulabi	CSN1S1	Total Protein (%)	2.20	4.82mg/mL	4.71	3.35
G1	Gulabi	CSN1S1	Vitamin A (µg/100g)	88.10	0.79± 0.08	80.09	24.09
G1	Gulabi	CSN1S1	Vitamin B2 (µg/100g)	0.13	0.337mg	0.17	0.15
G1	Gulabi	CSN1S1	Vitamin C (µg/100g)	1.74	1.3mg	2.1	2.2
G1	Gulabi	CSN1S1	Vitamin D (µg/100g)	*41.72	0.6–2.8 µg/kg	24.2	22.3
G1	Gulabi	CSN1S1	Vitamin E (µg/100g)	0.06	0.79±0.08mk/kg	0.17	0.09
G1	Gulabi	CSN1S1	Vitamin K (µg/100g)	0.31	0.03µg	0.34	0.30
			Mean±SD	17.2325±31.95407			

Whereas the results of the fat content as Sample G2 showed better fat content (4.40%) than G1 and also outperformed Teddy and Kamori samples in some micronutrient areas. However, protein content (2.28%) remained low, consistent with G1, pointing to consistent CSN1S1 gene limitation in Gulabi goats. On the other hand, Vitamin A (98.14 µg/100g) was among the better values, rivaling Kamori and significantly surpassing Teddy. Vitamin D (33.27 µg/100g) was also high, although lower than K2 and G1, confirming the breed's moderate-to-high capability for vitamin D retention. Vitamin C (1.42 µg/100g) was substantial, supporting antioxidant functions, while vitamin K (0.29 µg/100g) reinforced Gulabi's potential for nutraceutical and functional dairy use are given in Table 06.

Table 6

Mean and Standard Errors for the Effect of the CSN1S1 Gene on Physicochemical Properties of the Gulabi Breed

Sample. 6	Breed	Gene	Parameters Examined	Reported values	Average Standard range	Jenness (1980)	El-Zayat *et al.* (1984)
G2	Gulabi	CSN1S1	Total Fat (%)	4.40	3.4-4.2%	3.42	4.06
G2	Gulabi	CSN1S1	Total Protein (%)	2.28	4.82mg/mL	3.76	2.92
G2	Gulabi	CSN1S1	Vitamin A (µg/100g)	98.14	0.79± 0.08	185	159
G2	Gulabi	CSN1S1	Vitamin B2 (µg/100g)	0.14	0.337mg	0.16	0.17
G2	Gulabi	CSN1S1	Vitamin C (µg/100g)	1.42	1.3mg	1.40	1.05
G2	Gulabi	CSN1S1	Vitamin D (µg/100g)	*33.27	0.6–2.8 µg/kg	30.20	22.2
G2	Gulabi	CSN1S1	Vitamin E (µg/100g)	0.05	0.79±0.08mk/kg	0.08	0.06
G2	Gulabi	CSN1S1	Vitamin K (µg/100g)	0.29	0.03µg	0.30	0.25
			Mean±SD	17.49875±34.4661			

Figure 1

Biochemistry of Kamori, Teddy, and Gulabi Milk

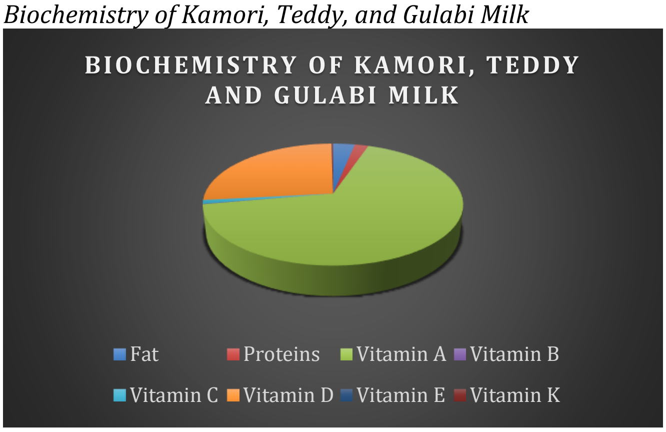

Figure 1 represents the "Biochemistry of Kamori, Teddy and Gulabi Milk," which provides a visual summary of the major biochemical components present in the milk of three indigenous goat breeds. It highlights that Vitamin A constitutes the largest proportion, indicating its dominant presence in goat milk. Vitamin A is essential for vision, immune function, and epithelial cell maintenance, making it a key nutritional asset. The second most abundant component is Vitamin D, which plays a crucial role in calcium absorption and bone health. Proteins and fat also contribute notable portions, reflecting the nutritional richness of goat milk in terms of essential amino acids and digestible lipids. Minor segments of the chart represent Vitamins B, C, E, and K, which, although present in smaller amounts, collectively support metabolic processes, antioxidant defense, and blood coagulation. Overall, the chart emphasizes that goat milk from Kamori, Teddy, and Gulabi breeds is not only rich in fat and protein but also a valuable source of fat-soluble vitamins, especially A and D, enhancing its nutritional and therapeutic importance.

DISCUSSION

Goat milk serves as a crucial nutritional resource in many parts of the world, particularly in South Asia, due to its digestibility, micronutrient content, and suitability for individuals with cow milk intolerance. The current study explores and compares milk composition (fat, protein, and vitamins A, B2, C, D, E, and K) among three breeds of Sindh, Pakistan: Kamori, Teddy, and Gulabi, while linking variations to known casein and metabolic gene expressions, the CSN1S1 gene. Kamori samples (K1: 4.50%, K2: 4.90%) consistently showed higher fat percentages than the reference standard range of 3.4–4.2% reported by [5, 11]. This aligns with Kamori's status as a milk-rich breed and possibly reflects strong expression of AGPAT6, which enhances lipid synthesis [3].

Teddy's samples showed significant variability. T2 exhibited exceptionally high fat (5.42%), surpassing even Kamori, while T1 recorded a lower 3.50%, within the standard range. The disparity may be due to individual metabolic efficiency. Gulabi samples (G1: 3.60%, G2: 4.40%) showed moderate to high fat, confirming a well-balanced milk profile. This trend is consistent with regional studies [14] that reported Gulabi as a dual-purpose breed with moderate fat levels. All breeds recorded lower-than-expected protein values compared to the standard 4.82 mg/ml. Kamori samples (K1: 2.85%, K2: 3.60%) still performed better than Teddy and Gulabi. The increased protein in K2 hints at stronger CSN1S1 gene activity, responsible for αS1-casein production [15].

Teddy samples (T1: 2.85%, T2: 2.80%) were lower in protein despite T2's high fat, indicating potential null alleles or down-regulated CSN1S1 expression consistent with findings by [16], who emphasized breed-specific genetic effects on casein expression.

Gulabi showed the lowest protein levels (G1: 2.20%, G2: 2.28%). This suggests significant gene deletion or non-functional CSN1S1 variants, which is a concern for protein-based dairy processing. Kamori milk had moderately high vitamin A levels, with K1 at 103.10 µg/100g and K2 at 106.25 µg/100g; however, these values are still lower than the global averages of 185–191 µg/100g cited by [17]. Teddy and Gulabi generally had lower levels, with T2 showing the lowest value (54.14 µg/100g) despite high fat, suggesting inefficient β-carotene to retinol conversion, possibly breed-specific [18].

Gulabi (G2: 98.14 µg/100g) fared better than T1 and T2, reflecting moderate conversion efficiency, possibly influenced by dietary intake or enzyme variations [19].

Vitamin B2 levels in all breeds were below the average reference value of 0.337 mg/100 g [5]. Kamori (0.13 µg/100g) and Gulabi (up to 0.14 µg/100g) outperformed Teddy (0.12 µg/100g), consistent with historical data from [13] showing lower riboflavin levels in Teddy milk. The difference may reflect breed-specific riboflavin metabolism. Gulabi showed superior antioxidant potential, with G1 (1.74 µg/100g) and G2 (1.42 µg/100g) exceeding the reference (1.3 mg/100g) reported by **[17]**. Kamori and Teddy were within or slightly below the standard. This supports literature suggesting that milk vitamin C varies more with feed and oxidative stress status than genetics [4], although some breed dependency is evident.

Vitamin D values among Kamori were exceptionally high (K1: 47.34 µg/100g, K2: 55.82 µg/100g), far exceeding global references (0.6–2.8 µg/kg) [20]. Gulabi also had robust levels (G1: 41.72 µg/100g, G2: 33.27 µg/100g), while Teddy recorded lower values. These results suggest effective endogenous synthesis or dietary supplementation among Kamori and Gulabi. Such high concentrations are nutritionally beneficial, especially for regions facing vitamin D deficiency. Vitamin E levels were low across all breeds (Kamori: 0.06–0.07 µg/100g; Teddy: 0.04–0.08 µg/100g; Gulabi: 0.05–0.06 µg/100g) compared to the standard (~0.79 mg/kg) [5]. These findings suggest breed limitations in tocopherol secretion or conversion. Environmental factors and lipid digestion efficiency may also play roles [21].

Vitamin K was highest in Teddy (T2: 0.34 µg/100g) and Gulabi (up to 0.31 µg/100g), exceeding the average global level (~0.03 µg/100g) [22]. Kamori showed moderate levels. The high K content is nutritionally significant, particularly for bone and cardiovascular health, and may indicate effective metabolic pathways for menaquinone and phylloquinone synthesis in Teddy and Gulabi goats.

CONCLUSION

The physicochemical analysis of this study concludes that there is a substantial link between CSN1S1 gene variations and the Kamori goat breed concerning the higher percentage prevalence of fat. All three goat breeds, Kamori, Teddy, and Gulabi, exhibit normal protein levels. This study also concludes that a significant amount of vitamin D is present in all three breeds examined as compared to all other vitamins examined (A, B, C, E, and K).

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