



Health status, antioxidants and milk quality of goats reared under stall-fed and free range grazing system

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ABSTRACT

The present study was conducted to determine health status and milk quality of goats reared under stall fed and free range grazing system. The research areas reported higher THI throughout the summer. Respiration rate (RR) and heart rate (HR) was significantly higher during summer in both the groups. Both groups had significantly increased neutrophils and eosinophils during the summer and increased Hb, PCV, and lymphocyte during the winter. Stall fed goats had significantly higher MDA during summer. The free range group had significantly higher levels of SOD and GSH in the summer and winter, respectively. Vitamins C and E levels declined during the summer. In both the groups, summer levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and plasma alkaline phosphatase (ALP) were significantly higher but remained within the reference range. During the summer, both groups of goats showed a significant decrease in plasma glucose, triglycerides, and cholesterol. Total proteins (TP) and Albumin both significantly declined during the winter in both the groups. Total immunoglobulins significantly increased during the winter in the free range group. Throughout the winter and the summer, respectively, the fat percentage increased in the milk of the stall-fed and free-range groups. Moreover, solid not fat (SNF) significantly declined in stall fed group during the winter. Also, there was no discernible difference in the amount of milk proteins between the groups; however, during the summer, it was discovered that stall-fed goats had more of them. The milk lactose significantly increased in both the groups in the time of summer though the increase was remarkable in stall fed goats. The present study indicated that stall fed and free range reared goats in winter and summer exhibit physiological variation in their health state, milk production, and composition.

Keywords: Beetal goats, Free range, Milk quality, Seasons, Stall-fed

With 148.88 million goats, India ranks as the second-largest goat producer in the world. Goat productivity, however, is quite low in the current traditional production method (Kumar 2007). India is the world's top producer of goat milk with a production of 6.09 million tonnes, while it is the second-largest producer of meat with a production of 504-501 tonnes (FAO 2018). The 20th Livestock Census shows that goats make up 27.80% of all livestock in the nation and bring in ₹38,590 crores annually to the national economy. According to BAHS 2019, the contribution of goats to India's overall milk and meat output was 3% and 13.53%, respectively.

There are more goats being raised for milk as a result of rising demand. Due to smaller fat globules in goat milk, which are extremely comparable to those in human milk, it is easily digested and has health-promoting qualities (Choudhary *et al.* 2018). Beetal is one of the most popular Indian goat breed, raised mostly for milk and meat (Madan *et al.* 2020). Goats have been seen to survive on a variety of

shrubs and to browse on the leaves and pods of numerous plants. Although, goats have traditionally been raised primarily for their meat, they are now being raised for their milk. Since ancient times, goat milk has been used for its therapeutic properties. According to reports, factors influencing milk's chemical composition include species, breeds, lactation stage, animal age, health, nutrition, and season (Malissiova *et al.* 2015, Mohsin *et al.* 2019). Goats have historically been raised in India using a system of free-range grazing, which is still used in the high Himalayan region and the dry regions of central India. Due to its low input requirements and excellent return, this technique was chosen by small and marginal farmers. However, the lack of grazing pasture has forced farmers to adopt the stall-fed technique of animal husbandry.

When compared to free-range goats, which graze on a variety of plants that may be rich in antioxidants and bioactive components, well-managed stall-fed goats typically, receive a balanced diet that may be monotonous in quality and composition. So, the aforementioned raising techniques can undoubtedly contribute to goat health, milk yield, and quality. In order to compare the production and quality of goat milk from two distinct raising systems, it

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is crucial to evaluate its features. As mentioned before goat milk content fluctuates owing to several variables, seasons could be one of the factors which might alter its composition. There is a paucity of thorough research on the health of goats and the quality of their milk in relation to production methods in the summer and winter. The current study was planned to ascertain the impact of two distinct raising methods and seasonal fluctuations on physiological, biochemical, antioxidant, and milk production performance of lactating beetal goats under stall fed and free range grazing systems.

MATERIALS AND METHODS

The experiment was carried out at the Goat Research Farm, Livestock Farm Complex, College of Veterinary Science, Ludhiana (Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab). Experimental procedures using beetal lactating goats and kids in this study have been conducted as per IAEC guidelines and approval obtained as per memo No. IAEC/2020/81-110 Proposal no. GADVASU/2020/IAEC/54/01 dated 24.08.2020.

Experimental design: Twenty adult lactating goats were selected from Goat Research Farm, Livestock Farm Complex, GADVASU and from villages near Ludhiana. The experimental design followed in present study is:

Lactating goats Group 1: n=10, stall fed at Goat farm;

Group 2: n=10, grazing at villages near Ludhiana;

Similar age group and close parity (more than 1 year);

Summer (June-August) 2021; Winter (November-January) 2020; Milk, Thrice at monthly interval.

Blood samples: 5 ml blood sample was collected from all the selected goats. Blood collected was used for analysing haematological and biochemical parameters. Heparinized blood was centrifuged at 3000 r.p.m. for 15 min to separate plasma which was used for the estimation of glucose, cholesterol, triglycerides, various diagnostic enzymes, total proteins, albumin and total immunoglobulins. Erythrocytic pellet was used for preparation of hemolysate to estimate enzymatic and non-enzymatic antioxidants, viz. SOD, glutathione and vitamin E, etc.

Haematological parameters: The total erythrocyte count (TEC), total leukocyte count (TLC), hemoglobin and PCV was measured using standard protocols.

Blood biochemical constituents: The estimation of diagnostic enzymes, Alanine Transaminase (ALT), Aspartate Transaminase (AST), Alkaline Phosphatase (ALP) and biochemical parameters, total bilirubin, glucose, total proteins, albumin, total cholesterol, triglycerides, urea and creatinine were done using kits obtained from BPC Biosed (SRL, Rome, Italy) in the fully automatic biochemistry analyzer (Global 240 BPC Biosed). Total immunoglobulins were estimated in plasma as per Oser (1965).

Antioxidants: Antioxidants such as Superoxide Dismutase (SOD), Reduced Glutathione (GSH), Vitamin C, Vitamin E and lipid peroxidation indicator, MDA, in

hemolysate were determined by standard protocols (Sahoo *et al.* 2020)

Physiological parameters: Rectal temperature (RT), Rectal temperature of the selected goats was measured with the help of digital rectal thermometer. Respiration rate (RR) was recorded by the FLANK method. Heart rate (HR) was recorded by auscultation between 4/5 intercostals space with stethoscope.

Milk: Milk samples (50 mL) were collected in glass containers from the selected animals during summer (June-August) and winter (November-January) seasons. Fat, SNF, protein and lactose were estimated from the milk samples by Lacto Scan Milk Analyzer.

Statistical analysis: Statistical analysis of data was done by general linear model using SPSS (ver. 26). Comparison of group means was done by Tukey's post hoc test. Results were expressed as Mean±S.E. and significant difference ($P<0.05$) between days, origin and season was analyzed.

RESULTS AND DISCUSSION

Environmental parameters: As per the recommendations of National Weather Service Centre Region (NWSCR), the Temperature-Humidity Index (THI) value of more than 75 indicated an alert condition; the THI value between 79 and 83 was considered as dangerous for livestock especially for animals reared in confinement and THI value above 84 indicated an emergency situation. The recorded THI varied from 61.51 to 69.96 in stall fed and 62.54 to 68.59 in free range grazing locations during winter season. During summer, THI ranged from 73.32 to 80 in stall-fed and from 73.24 to 79.92 in free range during the study period (Fig. 1). The findings were found to be similar to another study who also observed (Tej *et al.* 2018) higher temperature and THI during summer as compared to winter season. The increase in THI indicates that both temperature and humidity are rising, which could lead to heat stress in farm animals. Heat stress occurs when the animal's body is unable to dissipate heat effectively, and this can have several detrimental effects like reduced feed intake, decreased weight gain, lower milk production, reduced fertility, increased susceptibility to diseases and respiratory distress. The heat stress is higher in pre-monsoon and monsoon season as compared to post-monsoon season.

Physiological parameters: Physiological parameters of

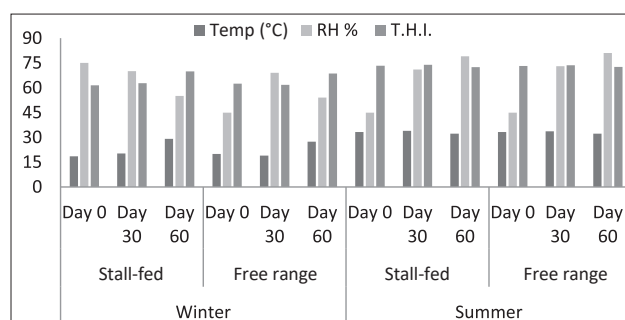


Fig. 1. Temperature, humidity and THI on different days of sampling in winter and summer.

Table 1. Physiological parameters of lactating goats under stall fed and free range grazing system (Mean±S.E.)

Parameter	Winter			Summer		
	Stall fed	Free range	Mean	Stall fed	Free range	Mean
Rectal Temp.	39.12±0.06 ^A	39.02±0.06 ^A	39.41±0.06 ^B	39.07±0.04 ^A	39.50±0.06 ^B	39.46±0.04 ^B
Resp. Rate	20.80±0.61 ^{Aa}	24.70±0.61 ^{Ab}	22.75±0.43 ^A	55.60±0.61 ^{Ba}	54.20±0.61 ^{Bb}	55.40±0.43 ^B
Heart Rate	20.00±2.44 ^A	122.10±2.44 ^A	5.35±1.72 ^B	121.05±1.72 ^A	156.80±2.44 ^{Ba}	133.90±2.44 ^{Bb}

lactating goats determined during different environment conditions and rearing systems revealed significant ($P<0.05$) elevation in respiration rate (RR) and heart rate (HR) during summer in both the groups (Table 1). However, no significant ($P<0.05$) variation in vital parameters (RT, RR and HR) was reported between the stall fed and free range groups during any of the seasons. Similar findings were reported in previous studies (Shinde *et al.* 2002, Banerjee *et al.* 2015a, Devendra 1989) who also reported significant ($P<0.05$) increase in the physiological parameters during summer. The findings of Appleman and Delouche (1958) revealed decreased rectal temperature and respiration rate during fall in environmental temperature. Elevation in environmental temperature affects the homeostasis of the animals which is influenced by hypothalamus. To maintain the thermo-neutrality in the body excessive heat is lost through skin as sweating and respiratory evaporation. Stimulation of the respiratory system causes increase in RR and HR. Increased blood flow from core to surface causes excessive heat loss via both sensible and insensible ways (Sarangi, 2007).

Haematological parameters: The haematological examination of lactating goats during summer and winter being reared in free range and stall fed systems reported significant ($P<0.05$) increase in haemoglobin and PCV during winter season. When compared between the two groups stall fed goats exhibited significantly ($P<0.05$) higher values (Table 2). The TLC in both the groups was found to be significantly ($P<0.05$) reduced in summer than winter. However, no significant ($P<0.05$) change was detected between the groups. Similar to Hb and PCV the Lymphocyte count was also found to be significantly higher during winter in both the groups. The primary immune cells such as neutrophils and eosinophils were also reported to be significantly ($P<0.05$) higher in both the groups during summer. However, the comparison between the groups revealed no significant ($P<0.05$) seasonal variation. The elevated monocytes were reported in both

the groups during summer, however, free range group exhibited higher monocytes as compared to stall-fed.

The previous studies have reported contradictory findings to the present study. Aengwanich *et al.* (2011), Hassan *et al.* (2013) Tej *et al.* (2018), reported no significant seasonal variation in haematological parameters. The present study revealed seasonal variation in few of the haematological parameters. These results are in agreement with the findings of Kumar and Pachauri (2000), AL-Saeed *et al.* (2009), Mirzadeh *et al.* (2010) and Banerjee *et al.* (2015a), who reported significant ($P<0.05$) decrease in TLC, Hb and PCV in summer as compared to winter. However, present findings are in agreement with the results of Banerjee *et al.* (2015a) who also reported significant ($P<0.05$) decrease in lymphocytes and increase in neutrophils during summer. Current results indicates variation in haematological parameters particularly in immune cells. The variation was pronounced during summer which could be related to stressful conditions. The immunity of the lactating goats during summer could be severely compromised. Though both the groups have shown comparable blood picture stall fed goats had better haemoglobin indices which could be attributed to better nutrition provided to the goats.

Antioxidant parameters: To determine extent of lipid peroxidation and free radical scavenging activity of goats malondialdehyde (MDA), superoxide dismutase (SOD) and reduced glutathione (GSH) were estimated. Lipid peroxidation occurred due to oxidative stress was indicated by variation in MDA. The present findings does not reveals significant ($P<0.05$) seasonal variation in erythrocytic MDA. However, stall fed goats were found to have significantly higher MDA during summer ($P<0.05$) (Fig. 2). Erythrocytic SOD was found to be significantly ($P<0.05$) higher during summer in the free range group. Whole blood GSH was relatively found to be higher during winter but decreased during summer in the free range group. Heat stress caused oxidative stress in goats which

Table 2. Haematological parameters of lactating goats under stall fed and free range grazing system (Mean ±S.E.)

Parameter	Winter			Summer		
	Stall fed	Free range	Mean	Stall fed	Free range	Mean
Hb(g/ dL)	8.99±0.42 ^B	12.90±0.42 ^{Aa}	11.02±0.29 ^A	9.14±0.42	8.38±0.42	8.69±0.29 ^B
PCV (%)	37.40±1.28 ^{Aa}	26.10±1.28 ^b	31.75±0.90 ^A	26.50±0.28 ^{Ba}	23.40±1.28 ^b	24.95±0.90 ^B
TLC	11.94±0.21 ^A	11.89±0.21 ^A	11.91±0.14 ^A	9.30±0.21 ^B	9.31±0.21 ^B	9.31±0.14 ^B
Lym (%)	65.90±1.06 ^A	65.10±1.06 ^A	65.50±0.75 ^A	58.20±1.06 ^B	58.80±1.06 ^B	58.50±0.75 ^B
Neuto (%)	32.90±1.12 ^A	33.80±1.12 ^A	33.35±0.79 ^A	38.80±1.12 ^B	38.20±1.12 ^B	38.50±0.79 ^B
Eosino(%)	0.90±0.27 ^A	0.70±0.27 ^A	0.80±0.19 ^A	38.80±1.12 ^B	38.20±1.12 ^B	38.50±0.79 ^B
Mono (%)	0.30±0.17	0.40±0.17	0.35±0.12 ^A	0.80±0.17	0.90±0.17	0.85±0.12 ^B

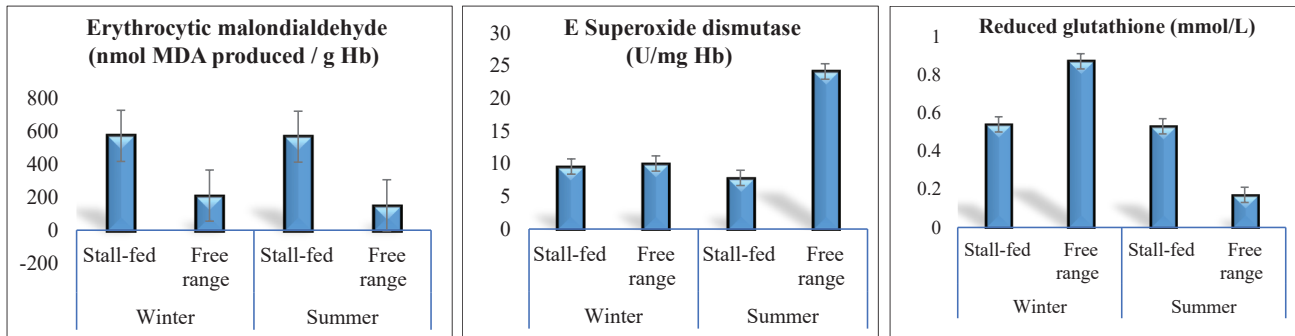


Fig. 2. Erythrocytic malondialdehyde (per g Hb), Superoxide dismutase (U/mg Hb) and Reduced glutathione (mmol/L) in lactating goats under stall fed and free range grazing system (Mean±S.E.).

resulted in higher production of reactive oxygen species (Chigerwe *et al.* 2013). SOD, catalase, GSH-Px being the major defence system against ROS which operates at cellular level (Gutteridge 1995). GSH-Px is involved in the reduction of H_2O_2 to H_2O and thus combats oxidative stress (Jaeschke 1990). Present findings have indicated that goat reared in any system were definitely exposed to stress during summer as indicated by elevation in MDA level during summer which might have been due to excessive lipid peroxidation. Moreover, it was evident from the findings that ROS production significantly increases during summer as SOD and GSH were also found to be elevated to combat free radicals. Due to heat stress goats might remain off feed or reluctant to move into sun for browsing in free range system and stall fed goats might suffer due to unavailability of nutritious diet and confinement.

Non-enzymatic antioxidants, Vitamin C and E, determined in both the groups, during winter and summer revealed no significant ($P < 0.05$) difference among seasons or groups, however, these vitamins were found to be decreased during summer (Fig. 3). Free range reared goats exhibited higher levels than that of stall fed. Present results are in agreement with the findings of Padilla *et al.* (2006), Sahin *et al.* (2003) and Calamari *et al.* (1999) that recorded decrease in vitamin concentrations during summer. Similar study was out by Trout *et al.* (1998) that reported no change in vitamin E concentration due to heat stress. Elevation

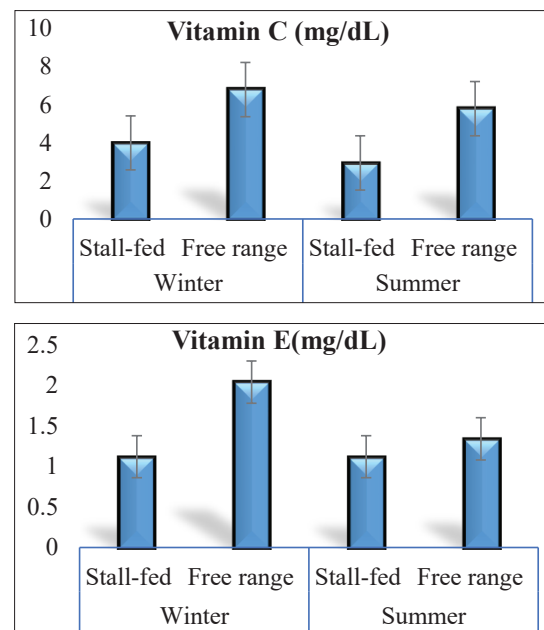


Fig. 3. Vitamin C (mg/dL) and E (mg/dL) in blood plasma of lactating goats under stall fed and free range grazing system (Mean ± S.E.).

in the antioxidant vitamins in the free range reared goats could be attributed to the browsing varieties of plants which could be rich in vitamins. In contrary, stall fed goats were given routine diets.

Table 3. Biochemical parameters of lactating goats under stall fed and free range grazing system (Mean±S.E.)

Parameter	Winter			Summer		
	Stall fed	Free range	Mean	Stall fed	Free range	Mean
Glucose (mg/dL)	61.26±3.91 ^A	55.36±3.91 ^A	58.31±2.76 ^A	39.96±3.91 ^B	39.98±3.91 ^B	39.97±2.76 ^B
Cholesterol (mg/dL)	109.69±9.02 ^{Aa}	70.11±9.02 ^b	89.90±6.38 ^A	56.12±9.02	52.86±9.02	54.49±6.38 ^B
Triglycerides (mg/dL)	44.71±6.35 ^A	35.40±6.35 ^A	40.05±4.49 ^A	11.71±6.35 ^B	10.48±6.35 ^B	11.09±4.49 ^B
Total proteins (g/dL)	9.15±0.71 ^a	4.69±0.71 ^{Ab}	6.92±0.50 ^A	9.32±0.71	9.41±0.71 ^B	9.36±0.50 ^B
Albumin (g/dL) (mg/dL)	2.62±0.59	2.10±0.59 ^A	2.36±0.42 ^A	3.87±0.59	3.62±0.59 ^B	3.75±0.42 ^B
Total Igs (U/L)	1.91±0.13 ^{Aa}	4.28±0.13 ^{Ab}	3.10±0.09 ^A	2.67±0.13 ^B	2.79±0.13 ^B	2.73±0.09 ^B
AST (U/L)	70.95±6.02 ^A	80.55±6.02 ^A	75.75±4.26 ^A	96.03±6.02 ^B	109.89±6.02 ^B	102.96±4.26 ^B
ALT (U/L)	24.04±1.13 ^a	16.81±1.13 ^{Ab}	20.44±0.80	22.64±1.13	20.10±1.13 ^B	21.37±0.80
Bilirubin (mg/dL)	0.12±0.02	0.13±0.02	0.13±0.02	0.17±0.02	0.14±0.02	0.16±0.02
ALKP (U/L)	141.01±29.85	105.00±29.85 ^A	123.01±21.11	120.64±29.85 ^a	222.30±29.	85 ^{Bb} .47±21.11
Urea (mg/dL)	16.44±0.74 ^{Aa}	13.00±0.74 ^b	14.72±0.53 ^A	13.18±0.74 ^B	12.87±0.74	13.02±0.53 ^B
Creatinine (mg/dL)	0.42±0.06 ^A	0.29±0.06 ^A	0.36±0.04 ^A	1.42±0.06 ^{Ba}	0.80±0.06 ^{Bb}	1.11±0.04 ^B

Biochemical parameters: The health status of both the groups during winter and summer was assessed by estimating biochemical parameters which could depict the functioning of vital organs related to metabolism. Aspartate aminotransferase (AST) was found to be significantly ($P<0.05$) higher during summer in both the groups, however, comparison between the groups revealed higher levels in free range reared goats but the values remained within the reference range. Conversely, alanine aminotransferase (ALT) was reportedly elevated but within the reference range in stall fed goats as compared to free range reared goats between the groups and seasons (Table 3). Plasma bilirubin indicated no significant change between the groups and seasons.

Plasma alkaline phosphatase (ALP) was found to be significantly ($P<0.05$) elevated during summer and pronounced increase was observed during summer in free range group. Present findings are similar to the results of Banerjee *et al.* (2015), Rasouli *et al.* (2004) and Kataria *et al.* (1993) who also reported higher ALT and AST levels in summer as compared to winter. The increase was attributed to heat adaptation (Nazifi *et al.* 1999). Acid phosphatase and alkaline phosphatase (ALP) are key enzymes associated with the metabolic activities in animals which could be attributed to a metabolic shift in the animals (Chaidanya *et al.* 2015). The alterations of the enzyme could be attributed to the heat stress magnitude as well as the individual differences (Chaidanya *et al.* 2015)). Blood urea and creatinine in both the groups were found to be within the reference range in between the groups and seasons, however, significantly ($P<0.05$) higher level of urea was found during winter in all the groups. Stall fed goats exhibited higher level as compared to the free range group. Plasma creatinine was found to be significantly ($P<0.05$) higher during summer in both the groups but stall fed group showed significantly higher levels during summer. Contrary to present findings, previous studies Rowlands *et al.* (1979), Rasouli *et al.* (2004), Kour *et al.* (2017) have reported significantly ($P<0.05$) higher BUN during summer. They attributed the increased BUN level during heat exposure to excess utilization of amino acids *via* protein mobilization (Sreedhar *et al.* 2013). Increase in blood urea but within the reference range could be affected due to dietary protein supplementation.

Assessment of energy metabolites have revealed that plasma glucose, triglycerides and cholesterol were found to be significantly decreased ($P<0.05$) in both the groups during summer. Comparison between the groups indicated significant decrease in aforementioned parameters in free range reared goats during summer. The gross plasma protein composition also indicated significant variation. The comparison between the seasons revealed significant drop in the total proteins (TP) content during winter. The stall fed goats exhibited significantly ($P<0.05$) higher level than free range group during winter (Table 3). The major component of plasma proteins, albumin also followed the same trend as TP. Significant ($P<0.05$) increase in albumin

was reported during summer in the in free range group as compared to winter. Total immunoglobulins as an indicator of humoral response were found to be significantly ($P<0.05$) higher in free range group, however, its level significantly declined during summer. Previous studies also reported similar findings as observed by Kour *et al.* (2017), Rasouli *et al.* (2004) and Shrikhande *et al.* (2008) who found significantly ($P<0.05$) higher levels of total protein and albumin during summer and declined levels of glucose and cholesterol during winter. El-Nouty *et al.* (1990) also reported significant ($P<0.05$) elevation in total proteins, albumin and globulins during summer. Similar observations were recorded in other species (Rasouli *et al.* 2004; Shrikhande *et al.* 2008). While few of the studies have-not reported any significant ($P<0.05$) effect on the total protein level in goat and sheep (Abdalla *et al.* 2009). One of the physiological reasons responsible for significant increase in plasma protein components during summer is loss of extracellular fluid during exposure to heat.

The decrease in blood glucose might be due to reduced feed intake during heat stress (Kataria *et al.* 2002) and due to higher glucose oxidation as reported by other previous studies (Collier *et al.* 2008). Sejian and Srivastava (2010) also found significantly ($P<0.05$) increased glucose level after thermal exposure. Contrary to present results few of the research findings as reported by Marai *et al.* (1995) and Habeeb *et al.* (1996) have revealed significantly higher ($P<0.05$) cholesterol level during winter. The decrease in cholesterol concentration in summer might be due to the decreased acetate concentration, which is the precursor for the synthesis of cholesterol (Ocak *et al.* 2009, Darcan 2000). Plasma cholesterol concentrations were also reduced during stress (Press *et al.* 1993). The decrease in the cholesterol could be attributed to heat stress induced accelerated fat catabolism (Alameen and Abdelatif 2012) and increased lipid mobilization (Abeni *et al.* 2007).

Milk parameters: As feeding regime and dietary intake in goats is quite variable during different seasons, the difference could be remarkable if the goats are reared in two different systems. Free range grazers being dynamic get the opportunity to graze on varieties of plants, on the other hand stall fed goats though might be fed formulated balanced diet but their diet is quite repetitive. So, dietary nutrient intake by the goats is reflected in the quality of their milk. The determination of composition of milk collected from goats reared in stall fed and free range grazing systems was carried out (Fig. 4). The estimated fat percentage in milk during winter was found to be higher in stall fed goats but the same was found to be higher in free range group during summer. Solid not fat (SNF) was found to be significantly ($P<0.05$) lower in stall fed group during winter season in contrast was higher during summer. However, no significant changes were detected between the seasons ($P<0.05$). The estimated proteins in the milk revealed no significant difference between the groups during winter, however, the milk protein content in stall fed goats was found to be increased during summer.

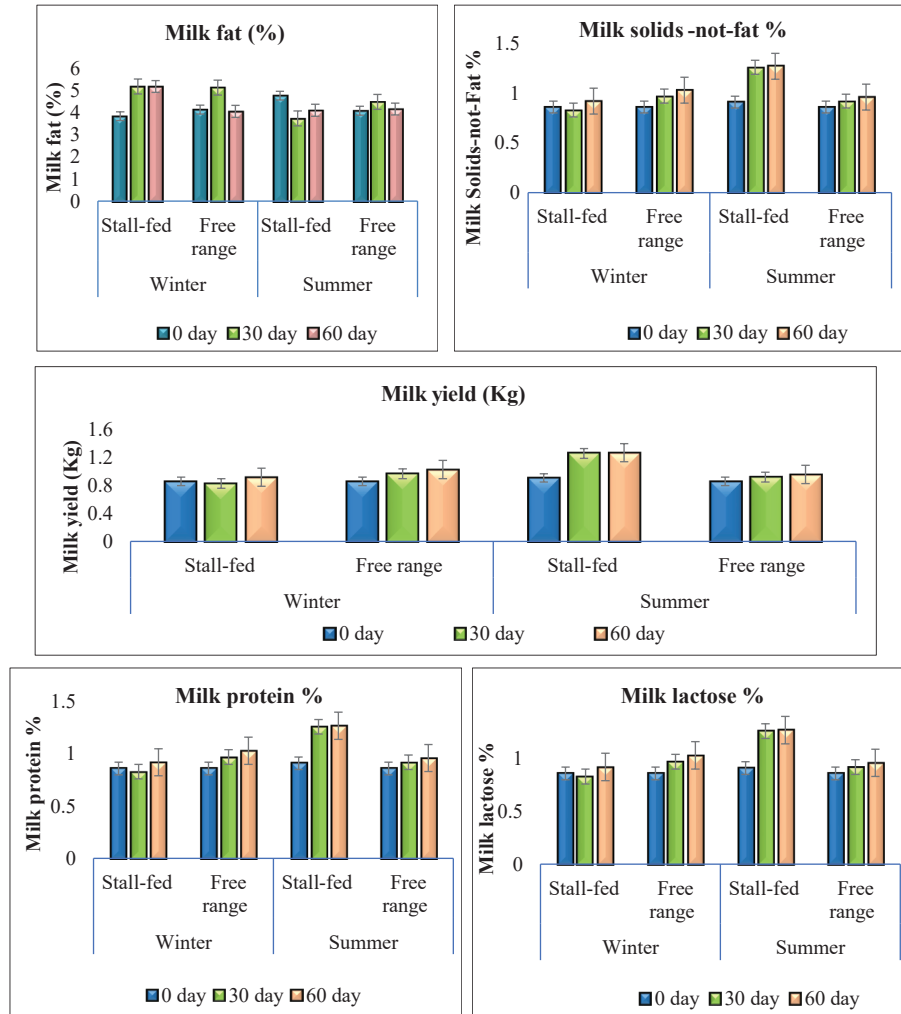


Fig. 4. Milk fat %, Milk solids-not-fat %, Milk protein %, Milk lactose % and Milk yield (kg) in lactating goats under stall fed and free range grazing system (Mean±S.E.).

The comparison between the seasons regarding milk sugar, lactose, revealed significant increase during summer though the increase was remarkable in stall fed goats. Milk yield in both the groups during winter was reported to be non-significant ($P < 0.05$), however, milk yield during summer in free range group was relatively low. Similar studies conducted previously in other species like cows revealed decreased milk fat during summer (Jensen *et al.* 1991). Ng-Kwai-Hang *et al.* (1985) and Lindmark-Månsson *et al.* (2003) found decline in protein content during summer as high air temperatures has negative effect on dairy cow environment (Sharma *et al.* 1983, Broucek *et al.* 2006). Kljajevic *et al.* (2018) reported negative correlation between THI and goat milk parameters which indicated goats were susceptible to heat stress, thus, resulted in a decline in physio-chemical properties.

Similar findings were reported in previous studies of Goetsch *et al.* (2011), Mayer and Fiechter (2012) and Kljajevic *et al.* (2018), in which they reported significantly ($P < 0.05$) lower protein and milk fat during months of June and July and a similar trend of variation was also reported for cow milk, fat content with respect to season (Chen *et*

al. 2014). Few other studies reported positive correlation between milk yield and heat production. Their research findings indicated that higher yielding animals were more prone to heat stress than lower yielding animals (Marco Jiménez *et al.* 2017). So the seasonal influence might have affected the doe milk production which likely resulted in transient hypogalactia. On the contrary, Hamzaoui *et al.* (2013) reported no significant ($P < 0.05$) decrease in milk yield in heat stressed lactating goats. This could be attributed to the fact that some degree of body muscle degradation under heat stress and the resultant amino acids could be utilized for gluconeogenesis which might have sufficed the need of energy requirement for milk production during summer (Wheelock *et al.* 2010). Apart from suppressed energy production during heat stress chronic hypogalactia could result from depressed mammary gland development, indicating that heat stress might affect lactation independent of reduced feed intake (Renquist 2019). Few other studies also indicated that heat stress during the stages of mammary gland development, before and immediately after parturition, affect milk production

(Tao *et al.* 2011). During heat stress mammary blood flow also decreases which limits milk yield (Delamaire and Guinard-Flament 2006). Present results were in agreement with the findings of Hamzaoui *et al.* (2012) and Salama *et al.* (2014), who have revealed that heat-stressed goats produced milk with lesser proteins due to lower mammary synthesis of milk protein (Bernabucci *et al.* 2002a). This might be due to decreased protein intake and increased sweat secretion which might have limited availability of amino acids for milk protein synthesis (Joshi *et al.* 1968).

Correlation Studies: Rectal temperature, respiration rate, heart rate, neutrophil, reduced glutathione, creatinine and milk lactose were found to be positively correlated with THI at $P < 0.01$ while monocyte, plasma aspartate aminotransferase, plasma alkaline phosphatase and albumin were found to be positively correlated with THI at $P < 0.05$. THI had negative correlation with hemoglobin, PCV, lymphocyte, cholesterol, milk protein and body weight at $P < 0.01$.

The present findings were in accordance with the findings of Adriani and Mushawwir (2020), Mengwei *et al.* (2020), Khan *et al.* (2021), Abera *et al.* (2021) who reported positive correlation of physiological parameters with high THI. Significant ($P < 0.05$) positive correlation between albumin and ALP was noted by Khan *et al.* (2021). Cholesterol was also found negatively correlated with THI by Pandey *et al.* (2012), Sejian *et al.* (2014), Macias-Cruz *et al.* (2016), Khan *et al.* (2021). Negative correlation of lymphocytes with THI was reported by Adriani and Mushawwir (2020). Bhan *et al.* (2013) found negative correlation of THI with haematological parameters. Abera *et al.* (2021) and Nabenishi and Yamazaki (2017) observed negative correlation between T.H.I. and growth parameters (body weight).

In conclusion, the present study examined the health

Table 4. Correlation between T.H.I. and different parameters

Parameter	Pearson Correlation	
	0.05 (*)	0.01 (**)
Rectal temperature		0.407
Respiration rate		0.426
Heart rate		0.313
Haemoglobin		-0.355
PCV		-0.285
Lymphocyte		-0.469
Neutrophil		0.48
Monocyte	0.161	
Reduced glutathione		0.238
Plasma aspartate aminotransferase	0.176	
Plasma Alkaline phosphatase	0.203	
Plasma Creatinine		0.257
Plasma Total Cholesterol		-0.305
Albumin	0.19	
Milk Protein		-0.301
Milk Lactose		0.371
Body Weight		-0.295

status and milk quality of goats reared under stall-fed and free-range grazing systems during the winter and summer seasons. The results revealed significant physiological variations in response to seasonal changes and management practices. During the summer, both groups of goats experienced higher levels of physiological stress, as evidenced by increased respiration rate (RR) and heart rate (HR). They also exhibited higher levels of neutrophils and eosinophils, indicating an immune response to the challenging environmental conditions. Stall-fed goats showed higher levels of malondialdehyde (MDA), suggesting increased oxidative stress during hot weather. On the other hand, the free-range group demonstrated higher levels of superoxide dismutase (SOD) and reduced glutathione (GSH), indicating better antioxidant defense mechanisms during the respective seasons. Vitamins C and E levels declined during the summer, possibly due to increased utilization to counter oxidative stress. However, both groups of goats remained within the reference range for the enzyme levels (AST, ALT, and ALP), indicating that they were still in normal health despite seasonal changes. During the winter, both groups exhibited adaptive responses, including increased haemoglobin (Hb), packed cell volume (PCV), and lymphocytes. Total immunoglobulins significantly increased during the winter in the free-range group, suggesting an enhanced immune response during the colder season. Regarding milk quality, the fat percentage in the milk increased in both groups during the winter and summer, while solid-not-fat (SNF) declined in stall-fed goats during the winter. Stall-fed goats also had higher milk protein levels during the summer compared to the free-range group.

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