RESEARCH ARTICLE

Modulation of Metabolic and Oxidative Stress Biomarkers and Cortisol by Dietary *Tinospora cordifolia* Supplementation in Twin-Bearing Periparturient Surti Goats

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Abstract

The present study evaluated the effects of dietary supplementation of *Tinospora cordifolia* (Guduchi) on metabolic indices, oxidative stress biomarkers and cortisol concentration in twin-bearing periparturient Surti goats. Twelve clinically healthy advanced pregnant Surti goats carrying twin fetuses were randomly allocated into two groups (n=6 each). The control group received a routine diet, whereas, the treatment group received the routine diet supplemented with *Tinospora cordifolia* stem powder at 6% of the total concentrate mixture from 30 days before to 30 days after kidding. Blood samples were collected at regular intervals from day −30 prepartum to day +30 postpartum for analyses of metabolic and oxidative stress biomarkers and cortisol. *Tinospora cordifolia* supplementation significantly ($p<0.05$) increased blood glucose, serum albumin, calcium, superoxide dismutase (SOD) and glutathione peroxidase (GPx) activities, with reduced AST, malondialdehyde (MDA) and cortisol concentrations during critical stages of the periparturient period. Although serum total protein, ALT and creatinine did not differ significantly between the groups and supplemented goats consistently exhibited numerically favourable values. The findings demonstrate that *Tinospora cordifolia* supplementation may improve metabolic adaptation, strengthen antioxidant defence and alleviate oxidative and endocrine stress during the periparturient period, suggesting its potential as a natural phytogenic feed additive for enhancing the health and physiological resilience of transition dairy goats.

Key words: Antioxidant defense, Cortisol, Metabolic adaptation, Tinospora cordifolia, Twin-bearing Surti goats.

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Introduction

The dairy goat industry has experienced substantial growth over the past five decades, with global milk production increased more than twofold (Pulina *et al*., 2018). As milk yield has increased, maintaining optimal metabolic health during the periparturient period has become increasingly important for sustaining productivity, milk quality and overall animal welfare (Matthews, 2016). Similar to high-producing dairy cows, dairy goats undergo profound physiological and metabolic adaptations during the transition from late gestation to early lactation, making them highly susceptible to negative energy balance (NEB) (Simões and Gutiérrez, 2018).

The periparturient period, encompassing the final weeks of pregnancy and the onset of lactation, represents a critical phase characterized by a marked increase in nutrient and energy requirements to support rapid fetal growth, parturition and the initiation of milk synthesis. However, dry matter intake (DMI) frequently declines during this period and often fails to meet these escalating nutritional demands, resulting in a pronounced negative energy balance (Huang *et al*., 2023). These metabolic and nutritional challenges are further intensified in twin-bearing goats because of the greater nutrient demand associated with the development of multiple fetuses and the subsequent onset of lactation. To compensate for this energy deficit, extensive mobilization of adipose tissue reserves occurs, leading to enhanced lipid metabolism and increased production of reactive oxygen species (ROS). Excessive accumulation of ROS disturbs the balance between oxidant generation and the endogenous antioxidant defence system, culminating in oxidative stress and cellular damage (Kumar *et al*., 2011). This oxidative imbalance, together with the heightened metabolic demands of late gestation and early lactation,

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compromises immune function and predisposes dairy goats to production-related metabolic disorders, including ketosis and hypocalcaemia, and haemato-biochemical alterations ultimately impairing health, productivity and reproductive performance (Huang *et al*., 2023; Eeswar *et al*., 2026; Suthar *et al.,* 2026).

In recent years, phytogenic feed additives have gained considerable attention as natural nutritional interventions for improving animal health, metabolic efficiency and productivity. *Tinospora cordifolia*, commonly known as Guduchi (Giloy or Gado), is one of the most extensively studied medicinal plants owing to its diverse pharmacological properties (Mittal *et al*., 2014). Its stems and leaves are rich sources of bioactive phytoconstituents such as tinosporine, tinosporide, tinosporaside, cordifolide, cordifol, tinosporidine, columbin, heptacosanol and β-sitosterol which contribute to its pharmacological activities (Mehra *et al*., 2013). *Tinospora cordifolia* possesses potent antioxidant, anti-inflammatory, adaptogenic and hepatoprotective properties. It enhances endogenous antioxidant defence, modulates glucose and protein metabolism, improves hepatic function and attenuates stress-induced endocrine responses, including cortisol secretion (Sinha *et al*., 2004). These biological properties suggest that dietary supplementation with *Tinospora cordifolia* may improve metabolic adaptation, antioxidant status and physiological resilience during the periparturient period. However, despite its well-documented pharmacological potential, evidence regarding the effects of *Tinospora cordifolia* supplementation on metabolic adaptation and oxidative stress in twin-bearing periparturient goats remains scarce (Eeswar *et al*. 2026). Therefore, the present study was undertaken to evaluate the modulatory effects of dietary *Tinospora cordifolia* supplementation on metabolic and oxidative stress biomarkers in twin-bearing periparturient Surti goats.

Materials and Methods

Experimental Animals and Management

A total of 12 clinically healthy advanced pregnant Surti goats carrying twin fetuses were selected for the present study from the flock maintained at the Pashupalan Sanshodhan Kendra, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Ramna Muvada, Gujarat, India. Twin pregnancy was confirmed by transabdominal ultrasonographic examination (USG) prior to the commencement of the experiment to ensure uniformity in the experimental animals. All selected goats were managed under identical husbandry conditions throughout the study. The experimental protocol was reviewed and approved by the Institutional Animal Ethics Committee (IAEC) of the College of Veterinary Science and Animal Husbandry, Kamdhenu University (Approval No. F. No. 483/VPB/2025). All experimental procedures were carried out in accordance with the institutional guidelines for the ethical care and use of animals in research.

The goats (n=12) were randomly assigned into two equal experimental groups (n=6 each). Goats in Group I (Control) were fed the standard routine diet formulated to meet their nutritional requirements during the transition period. Goats in Group II (Treatment) received the same routine diet, but supplemented with *Tinospora cordifolia* stem powder at the rate of 6% of the total concentrate mixture. The dietary supplementation was initiated 30 days before the expected kidding date and continued until 30 days postpartum. Throughout the experimental period, all animals were maintained under uniform housing, feeding and management practices, with unrestricted access to clean drinking water and routine veterinary care to minimize the influence of non-experimental variables.

Blood Collection and Sample Processing

Blood samples were collected aseptically from all experimental animals at predetermined intervals, *i.e.,* on days −30, −20, −10 and −5 relative to kidding, on the day of kidding (day 0) and on days +5, +10, +20 and +30 postpartum. The prepartum sampling schedule was established based on the expected kidding date calculated from the breeding records. As the actual kidding date varied by approximately ±5 days among individual animals, the sampling schedule was adjusted accordingly to ensure collection at the designated physiological stages.

Approximately 3 mL of blood was collected aseptically from the jugular vein of each goat into clot activator vacutainer tubes for serum separation. The samples were allowed to clot at room temperature and subsequently centrifuged at 3,000 rpm for 15 min. The separated serum was carefully aliquoted into sterile microcentrifuge tubes and stored at −20°C until subsequent biochemical and enzyme-linked immunosorbent assay (ELISA) analyses.

Estimation of Metabolic Profile and Oxidative Markers

Serum analysis was performed to evaluate key indicators of energy and protein metabolism, liver and kidney function, including glucose, total protein, albumin, creatinine, calcium, AST & ALT activity using commercially available diagnostic reagent kits according to the manufacturers' protocols on an automated serum analyzer (BS-120, Mindray). Serum SOD, GPx, MDA and cortisol concentrations were determined using commercially available Puregene™ enzyme-linked immunosorbent assay (ELISA) kits according to the manufacturers' protocols.

Statistical Analysis

The experimental data were analysed using statistical software. Between group comparison at each sampling interval was performed using the independent samples *t*-test, while changes across different sampling periods within each experimental group were analysed by one-way analysis of variance. All statistical analyses were performed according to the procedures described by Snedecor and Cochran (2014).

Results and Discussion

The blood glucose concentration exhibited a progressive decline from the prepartum period, reaching the lowest level on the day of kidding, followed by a gradual increase during the postpartum period up to day +30 in both groups. Blood glucose concentration differed significantly ($p<0.05$) between the two groups on the day of kidding and on days +5 and +20 postpartum, with consistently higher values recorded in the *treatment group* compared with the control group at these sampling intervals. The comparatively higher blood glucose concentration observed in the supplemented group during the periparturient period may be attributed to the adaptogenic and metabolic modulatory properties of *Tinospora cordifolia*, which might have enhanced energy metabolism, improved nutrient utilization and alleviated transition-associated metabolic stress. The findings of the present study were in agreement with the findings reported by Soni *et al.* (2022) in healthy Gaddi goats.

The serum total protein concentration remained relatively stable throughout the experimental period in both groups, with only minor fluctuations observed from the prepartum to the postpartum period. Although the *treatment* group exhibited numerically higher total protein concentrations throughout the study, the differences were not statistically significant, suggesting that supplementation had no marked influence on circulating total protein levels under the conditions of the present investigation. These findings were in close agreement with those reported by Soares *et al.* (2018) in periparturient crossbred goats.

The serum albumin concentration exhibited a declining trend from the prepartum period to the day of kidding, followed by gradual fluctuations during the postpartum period in both groups. Intergroup comparison revealed a significant ($p<0.05$) difference only on the day of kidding, with higher albumin concentration observed in the *treatment* group compared with the control group, whereas the differences at the remaining sampling intervals were statistically non-significant. The comparatively higher albumin concentration observed in the treatment group on the day of kidding suggests that *Tinospora cordifolia* supplementation may have supported hepatic protein synthesis and improved metabolic adaptation during the period of maximum physiological stress through its antioxidant and adaptogenic properties. The above findings closely aligned with those reported by Jayaganthan *et al.* (2013) in Muzaffarnagari rams.

The serum alanine aminotransferase (ALT) activity exhibited only minor fluctuations throughout the experimental period in both the control and *treatment* groups, with no consistent trend from the prepartum to the postpartum period. Despite the absence of statistically significant differences between the groups, the treatment group consistently exhibited numerically lower ALT activity throughout most of the experimental period. This trend may indicate a beneficial effect of *Tinospora cordifolia* on hepatic function, which could be attributed to its well-documented hepatoprotective and antioxidant properties that help preserve hepatocellular integrity during the metabolic stress of the periparturient period. The findings corresponded closely with those reported by Soni *et al*. (2022) in male Gaddi goats supplemented with *Tinospora cordifolia*.

The serum aspartate aminotransferase (AST) activity exhibited a progressive increase from the prepartum period, reaching peak levels around the day of kidding, followed by a gradual decline during the postpartum period in both the control and treatment groups. Between group comparison indicated significantly ($p<0.05$) lower AST activity in the *treatment* group on day −5, the day of kidding and day +20 postpartum, whereas, the differences at the remaining sampling intervals were statistically non-significant. The comparatively lower AST activity in the treatment group suggests that *Tinospora cordifolia* may have alleviated periparturient tissue damage by preserving the integrity of hepatocytes and skeletal muscle cells through its antioxidant and membrane-stabilizing properties, thereby reducing the leakage of intracellular AST into the circulation. These findings were in agreement with those of Jayaganthan *et al*. (2013) with *Tinospora cordifolia* supplementation in Muzaffarnagari rams.

The serum creatinine concentration exhibited only minor fluctuations throughout the experimental period in both the control and treatment groups, with no consistent trend from the prepartum to the postpartum period. Intergroup comparison revealed no significant differences in creatinine concentration between the two groups at any stage of the experiment. While the differences in serum creatinine concentration were statistically non-significant, the lower values consistently recorded in the *treatment* group may reflect improved renal adaptation to the physiological demands of the periparturient period. Such an effect is likely attributable to the herb's nephroprotective potential,

Table 1: Mean ± SE values of metabolic indices, oxidative stress biomarkers and cortisol concentration in periparturient twin-bearing Surti goats of control and treatment (*Tinospora cordifolia* supplemented) groups

Parameters	Group	Days peripartum								
		-30	-20	-10	-5	0	5	10	20	30
Glucose (mg/dL)	Control	67.50^{ac}±2.01	65.00^{abc}±3.36	61.33^{ab}±2.04	60.00^{a}±2.16	58.50^{b}±1.84	60.67^{ab}±2.06	69.83^{bcd}±2.70	71.00^{cd}±2.02	77.83^{d}±4.83
	Treatment	69.83^{ac}±2.55	72.00^{cd}±2.35	67.17^{abc}±3.38	66.00^{ab}±1.88	62.17^{b}±1.26*	65.00^{ab}±2.53*	67.33^{abc}±1.74	74.33^{cd}±2.51*	77.83^{d}±1.96
Total protein (g/dL)	Control	6.04±0.32	6.00±0.26	6.36±0.19	6.30±0.20	6.05±0.17	6.35±0.22	6.44±0.21	6.60±0.17	6.29±0.29
	Treatment	6.61±0.30	6.78±0.63	6.83±0.21	6.27±0.65	6.85±0.15	7.20±0.30	7.26±0.23	7.09±0.20	6.91±0.21
Albumin (g/dL)	Control	3.17±0.12	3.10±0.33	3.21±0.40	2.63±0.28	2.61±0.20	2.81±0.15	2.52±0.31	3.30±0.34	2.92±0.51
	Treatment	3.23±0.18	3.44±0.13	3.31±0.12	2.93±0.17	3.19±0.21	2.86±0.17	2.92±0.31	3.03±0.21	2.97±0.27
ALT (U/L)	Control	12.22±1.33	11.58± 0.39	12.35± 1.38	14.15± 1.00	14.87± 0.99	12.62± 0.59	13.00± 0.82	12.25± 1.22	12.82± 1.45
	Treatment	11.64± 0.68	10.87± 0.69	11.27± 0.61	11.59± 0.59	13.26± 0.91	12.16± 0.42	12.46± 0.72	12.18± 0.61	11.52± 0.52
AST (U/L)	Control	218^{a}±15.69	321^{bc}±36.59	333^{c}±45.69	387^{c}±28.75	389^{c}±32.01	307^{abc}±22.68	234^{ab}±16.68	313^{abc}±28.07	297^{abc}±37.32
	Treatment	184^{a}±14.48	267^{cd}±17.01	258^{bcd}±22.39	267^{cd}±20.31*	290^{d}±17.35*	278^{cd}±24.26	225^{abc}±13.54	200^{ab}±20.66*	206^{ab}±18.33
Creatinine (mg/dL)	Control	1.29±0.22	1.25±0.16	1.18±0.13	1.04±0.14	1.33±0.13	1.03±0.15	1.06±0.14	1.06±0.13	0.89±0.11
	Treatment	1.07±0.14	1.15±0.17	1.07±0.15	0.96±0.10	1.15±0.15	0.94±0.09	0.97±0.16	1.04±0.16	0.77±0.14
Calcium (mg/dL)	Control	8.86±0.54	10.15±0.78	10.54±0.93	10.84±0.32	9.31±0.54	8.76±0.63	8.92±0.34	8.66±0.53	8.94±0.24
	Treatment	9.97^{a}±0.42	10.58^{a}±0.48	11.66^{a}±0.31	12.40^{b}±0.37	11.37^{a}±0.53	10.66^{a}±1.03	10.01^{a}±0.88	11.93^{a}±0.55	10.71^{a}±0.94
SOD (U/mL)	Control	1.19±0.08	1.22±0.09	1.17±0.08	1.12±0.10	1.19±0.11	1.27±0.09	1.24±0.15	1.12±0.03	1.18±0.09
	Treatment	1.15±0.10	1.23±0.19	1.30±0.16*	1.21±0.12*	1.23±0.12*	1.26±0.22	1.28±0.09	1.25±0.16*	1.30±0.03*
GPx (nmol/min/ mL)	Control	28.40^{ab}±4.43	24.55^{a}±3.49	24.80^{a}±4.76	23.24^{a}±2.87	18.41^{a}±3.05	23.07^{a}±2.56	24.78^{a}±0.82	18.03^{a}±2.52	20.75^{a}±2.46
	Treatment	23.35^{ab}±1.15	23.57^{ab}±1.90	24.37^{ab}±1.23	37.57^{d}±2.19*	32.10^{d}±1.83*	26.62^{a}±3.20	26.67^{abc}±1.39	22.53^{abc}±1.61*	29.15^{cd}±3.48
MDA (µmol/mg protein)	Control	1.31^{a}±0.09	1.66^{abcd}±0.21	1.72^{abcd}±0.20	1.97^{cd}±0.19	2.24^{d}±0.09	1.80^{bcd}±0.17	1.59^{abc}±0.05	1.18^{a}±0.12	1.26^{ab}±0.06
	Treatment	1.26^{ab}±0.06	1.43^{abc}±0.10	1.50^{bcd}±0.15	1.66^{cd}±0.14*	1.83^{d}±0.08*	1.62^{bcd}±0.09	1.23^{ab}±0.08	1.03^{a}±0.15*	1.10^{a}±0.04
Cortisol (ng/mL)	Control	7.68^{ab}±0.60	9.14^{bcd}±0.48	10.70^{d}±0.62	9.70^{cd}±0.35	12.66^{e}±0.57	9.32^{cd}±0.54	9.75^{cd}±0.23	8.79^{abc}±0.51	8.37^{a}±0.65
	Treatment	7.13^{a}±0.34	8.74^{abc}±0.59	9.61^{bc}±0.67	9.31^{bc}±0.73	10.14^{c}±0.61*	9.40^{bc}±0.36	8.17^{ab}±0.28*	8.42^{abc}±0.50	7.25^{a}±0.28*

Values with different superscript (a, b, c, d) within the row differ significantly ($p<0.05$); * represents the significance between two groups within a column for a particular parameter at $p<0.05$.

mediated through its antioxidant activity and its ability to preserve renal cellular homeostasis. The findings of the study were consistent with those reported by Samui *et al*. (2023) in pregnant Black Bengal goats around parturition.

The serum calcium concentration exhibited a gradual increase during the prepartum period, followed by a decline around the time of kidding and during the early postpartum period in both the control and treatment groups. Significant ($p<0.05$) intergroup differences in serum calcium concentration were observed on day −5, the day of kidding and day +20 postpartum, with higher values recorded in the treatment group than in the control group. However, no significant differences were detected at the remaining sampling intervals. The comparatively higher serum calcium concentration observed in the treatment group suggests that *Tinospora cordifolia* supplementation may have supported calcium homeostasis by improving mineral metabolism and enhancing physiological adaptation to the increased calcium requirements during the transition period. The findings of the present study were in accordance with those reported by Tharwat *et al*. (2015) in goats during the three weeks preceding and following parturition.

The serum superoxide dismutase (SOD) activity remained relatively stable throughout the experimental period in both the control and treatment groups, with only minor fluctuations observed from the prepartum to the postpartum period. Significant ($p<0.05$) intergroup differences in SOD activity were observed on day −10, day −5, the day of kidding, day +20 and day +30 postpartum, with higher values recorded in the treatment group than in the control group. However, SOD activity remained comparable between the groups at the remaining sampling intervals. The comparatively higher SOD activity observed in the treatment group suggests that *Tinospora cordifolia* enhanced the antioxidant defence system during the periparturient period. This beneficial effect may be attributed to its potent antioxidant phytoconstituents, which are known to scavenge reactive oxygen species, enhance endogenous antioxidant enzyme activity and alleviate oxidative stress associated with late gestation, parturition and early lactation. These findings were in accordance with those reported by Jayaganthan *et al*. (2013) in Muzaffarnagari rams.

The glutathione peroxidase (GPx) activity exhibited moderate fluctuations throughout the experimental period in both the control and treatment groups. GPx activity was significantly ($p<0.05$) elevated in the *treatment* group compared with the control group on day −5, the day of kidding and day +20 postpartum, while the remaining sampling intervals showed no significant intergroup differences. The elevated GPx activity observed in the *treatment* group indicates an enhanced antioxidant defence capacity during the periparturient period. This response may be attributed to the bioactive phytoconstituents of *Tinospora cordifolia*, which are known to augment endogenous antioxidant enzyme systems, promote the neutralization of hydrogen peroxide and lipid hydroperoxides and thereby minimize oxidative stress-induced cellular damage. The outcomes of the present study were in close agreement with those reported by Soni *et al.* (2022) in male Gaddi goats.

The malondialdehyde (MDA) concentration exhibited a progressive increase from the prepartum period, reaching peak levels on the day of kidding, followed by a gradual decline during the postpartum period in both the control and treatment groups. Between-group analysis demonstrated significantly ($p<0.05$) lower MDA concentrations in the *Tinospora cordifolia*-supplemented group on day −5, the day of kidding, day +10 and day +30 postpartum, whereas MDA concentrations remained comparable between the groups at the remaining sampling intervals. The significantly lower MDA concentration observed in the *treatment* group suggests that supplementation effectively mitigated oxidative stress during the periparturient period. This response may be attributed to the diverse bioactive phytoconstituents of *Tinospora cordifolia*, which possess potent free radical-scavenging and antioxidant properties capable of suppressing lipid peroxidation and preserving cellular membrane integrity. The attenuation of MDA accumulation further indicates that *Tinospora cordifolia* strengthened the endogenous antioxidant defence system, thereby limiting oxidative damage and promoting improved physiological adaptation to the metabolic challenges associated with the transition period. The findings of the present study closely aligned with those reported by Manat *et al.* (2017) in Surti goats.

The serum cortisol concentration exhibited a progressive increase from the prepartum period, reaching peak levels on the day of kidding, followed by a gradual decline during the postpartum period in both the control and treatment groups. Between-group analysis demonstrated significantly ($p<0.05$) reduced serum cortisol concentrations in the treatment group on the day of kidding and on days +10 and +30 postpartum. In contrast, cortisol concentrations did not differ significantly between the groups during the remaining sampling intervals. The comparatively lower cortisol concentrations observed in the treatment group suggest that *Tinospora cordifolia* supplementation may have attenuated the endocrine stress response during the periparturient period. This beneficial effect could be attributed to the well-established adaptogenic, antioxidant and anti-stress properties of *Tinospora cordifolia*, which may help regulate hypothalamic–pituitary–adrenal axis activity.

These observations were in agreement with those reported by Soni *et al.* (2022) in male Gaddi goats supplemented with *Tinospora cordifolia*.

Conclusion

The dietary supplementation of *Tinospora cordifolia* stem powder @ 6 % of concentrate mixture during the periparturient period improved metabolic adaptation, antioxidant status and stress resilience in twin-bearing Surti goats. Supplemented goats exhibited better glucose homeostasis, numerically higher total protein and albumin concentrations, higher serum calcium concentrations, lower AST activity while maintaining normal ALT and creatinine concentrations, indicating improved hepatic and renal function. Furthermore, supplementation enhanced the antioxidant defence system by increasing SOD and GPx activities and reducing MDA concentrations, while lower cortisol levels suggested attenuation of transition-associated stress. Overall, these findings indicate that *Tinospora cordifolia* is a promising natural phytogenic feed supplement for improving metabolic health, antioxidant capacity and physiological adaptation during the transition period in dairy goats.

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References

Eeswar, N. S. V. S. S., Suthar, D. N., Chavda, S. A., Pathan, M. M., Madhira, S. P., & Chaudhary, J. C. (2026). Effect of *Tinospora cordifolia* on haematological parameters in twin-bearing periparturient Surti goats. *Indian Journal of Veterinary Sciences and Biotechnology, 22*(5), 177–179.

Huang, Y., Kong, Y., Li, B., Zhao, C., Loor, J. J., Tan, P., & Wang, J. (2023). Effects of perinatal stress on the metabolites and lipids in plasma of dairy goats. *Stress Biology, 3*(1), 11.

Jayaganthan, P., Perumal, P., Balamurugan, T. C., Verma, R. P., Singh, L. P., Pattanaik, A. K., & Kataria, M. (2013). Effects of *Tinospora cordifolia* supplementation on semen quality and hormonal profile in rams. *Animal Reproduction Science, 140*(1–2), 47–53.

Kumar, M., Jindal, R., & Nayyar, S. (2011). Influence of heat stress on antioxidant status in Beetal goats. *Indian Journal of Small Ruminants, 17*(2), 178–181.

Manat, T. D., Chaudhary, S. S., Singh, V. K., Patel, S. B., & Tyagi, K. K. (2017). Oxidative stress profile during postpartum period in Surti goats. *Indian Journal of Animal Research, 51*(5), 837–840.

Matthews, J. G. (2016). *Diseases of the goat*. John Wiley & Sons.

Mehra, R., Naved, T., Arora, M., & Madan, S. (2013). Standardization and evaluation of formulation parameters of *Tinospora cordifolia* tablet. *Journal of Advanced Pharmacy Education & Research, 3*(4), 440–449.

Mittal, J., Sharma, M. M., & Batra, A. (2014). *Tinospora cordifolia*, a multipurpose medicinal plant—A. *Journal of Medicinal Plants, 2*(2), 32–47.

Pulina, G., Milán, M. J., Lavín, M. P., Theodoridis, A., Morin, E., Capote, J., Thomas, D. L., Francesconi, A. H. D., & Caja, G. (2018). Invited review: Current production trends, farm structures, and economics of the dairy sheep and goat sectors. *Journal of Dairy Science, 101*(8), 6715–6729.

Samui, T., Ghosh, P. R., Das, P. K., Banerjee, D., Naskar, S., Bag, S., & Mukherjee, J. (2023). Alterations in the haemato-biochemical, endocrine and *in vitro* immune competence of leukocytes in Black Bengal does (*Capra hircus*) during periparturient period. *Indian Journal of Animal Health, 62*(2), 222–227.

Simões, J., & Gutiérrez, C. (2018). Nutritional and metabolic disorders in dairy goats. In *Sustainable goat production in adverse environments: Volume I: Welfare, health and breeding* (Vol. 1, pp. 177–194). Springer International Publishing.

Sinha, K., Mishra, N. P., Singh, J., & Khanuja, S. P. S. (2004). *Tinospora cordifolia* (Guduchi), a reservoir plant for therapeutic applications: A review. *Indian Journal of Traditional Knowledge, 3*(3), 257–270.

Snedecor, G. W., & Cochran, W. G. (2014). *Statistical methods* (8th ed.). The Iowa State University Press.

Soares, G. S. L., Souto, R. J. C., Cajueiro, J. F. P., Afonso, J. A. B., Rego, R. O., Macêdo, A. T. M., & Mendonça, C. L. (2018). Adaptive changes in blood biochemical profile of dairy goats during the period of transition. *Revue de Médecine Vétérinaire, 169*, 65–75.

Soni, P. K., Bhar, R., & Kumar, K. (2022). *Tinospora cordifolia* stem powder effects on antistress and blood biochemical parameters in heat stressed Gaddi goats. *Agricultural Science Digest—A Research Journal, 42*(5), 649–653.

Suthar, D. N., Chavda, S. A., Eeswar, N. S. V. S. S., Pathan, M. M., Madhira, S. P., & Chaudhary, J. C. (2026). Modulatory effects of *Tinospora cordifolia* supplementation on haematological and biochemical indices in periparturient crossbred cows. *Indian Journal of Veterinary Sciences and Biotechnology, 22*(6), 8–13.

Tharwat, M., Ali, A., & Al-Sobayil, F. (2015). Hematological and biochemical profiles in goats during the transition period. *Comparative Clinical Pathology, 24*(1), 1–7.