Effect of Tinospora cordifolia supplementation on haematological, biochemical, antioxidant and stress indices during the periparturient period in twin-bearing Surti goats

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Effect of *Tinospora cordifolia* supplementation on haematological, biochemical, antioxidant and stress indices during the periparturient period in twin-bearing Surti goats

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Abstract:

Twelve clinically healthy pregnant twin-bearing Surti goats were randomly allotted into two groups (n=6 each): control and *Tinospora cordifolia* supplemented. Blood samples were collected at days −30, −20, −10 and −5 before kidding, on the day of kidding (0) and days +5, +10, +20 and +30 after kidding to evaluate haematological, biochemical, antioxidant and stress indices during the periparturient period. Erythrocytic parameters showed physiological peri-parturient variations without significant differences between groups. However, supplemented goats exhibited significantly ($p<0.05$) higher total leukocyte, neutrophil and lymphocyte counts, along with a significantly lower neutrophil-to-lymphocyte ratio around kidding, indicating improved immune competence and reduced stress response. Serum glucose, albumin and calcium concentrations were significantly ($p<0.05$) higher, whereas AST activity was significantly ($p<0.05$) lower in supplemented goats, suggesting improved metabolic and hepatic status. Antioxidant enzymes SOD and GPx were significantly ($p<0.05$) elevated during late gestation and early lactation, while serum MDA concentrations were significantly lower on days −5, 0, +10 and +30, indicating reduced lipid peroxidation. Serum cortisol concentrations peaked on the day of kidding in both groups but remained significantly ($p<0.05$) lower in supplemented goats on day 0, +10 and +30, suggesting attenuation of parturition-induced stress. Overall, *Tinospora cordifolia* supplementation improved immune response, metabolic adaptation, antioxidant defense and stress resilience during the periparturient period, highlighting its potential as a natural phytogenic supplement in transition goats.

Keywords: Antioxidant status, Haematology, Periparturient goats, Stress physiology, Surti goats, *Tinospora cordifolia*

Introduction

The transition period, spanning from three weeks prepartum to three weeks postpartum, represents a particularly critical phase for both production and health. During this period, animals frequently experience pronounced negative energy balance accompanied by reduced serum or plasma concentrations of essential minerals and vitamins, indicative of compromised metabolic and health status (Goff, 2006). Early lactation is therefore associated with impaired immune competence and increased disease susceptibility, primarily driven by the imbalance between energy requirements and energy availability (Sordillo, 2016). In this context, the exploration of effective nutritional and therapeutic interventions to support metabolic and immune function during the transition period is of considerable interest. Traditional veterinary medicinal plants, widely used by indigenous communities, represent a valuable yet under-documented resource in this regard. Concurrently, modern medicine continues to seek novel bioactive agents to replace or complement fewer effective therapies (Pattanayak *et al*., 2016). Among these, *Tinospora cordifolia* (Giloy), also known as *Guduchi*, occupies a prominent position in "*Ayurvedic Materia Medica*" and is classified as a '*Rasayana*' owing to its rejuvenating and immunomodulatory properties. The therapeutic potential of this plant is extensively documented in classical Ayurvedic texts, including the *Charaka Samhita* and *Sushruta Samhita*, supporting its relevance as a natural intervention for improving health and productivity during physiologically demanding periods (Bhattacharyya and Bhattacharya, 2013). Keeping these beneficiary properties into consideration, the present study was planned to investigate the effect of *Tinospora cordifolia* supplementation on haematological parameters in twin-bearing periparturient surti goats.

Material and methods

A total of twelve clinically healthy advanced pregnant Surti goats carrying twin foetuses were selected for the study and maintained at the Kamdhenu University, Pashupalan Sanshodhan Kendra, College of Veterinary Science and Animal Husbandry, Ramna Muvada, Gujarat, India. Twin pregnancy was confirmed by ultrasonographic examination (USG).

The selected animals were randomly allotted into two equal groups comprising six goats each. Group I served as the control and received basal diet, whereas Group II served as the treatment group and was supplemented with *Tinospora cordifolia* stem powder at the rate of 6% of the total concentrate mixture. Supplementation was provided from 30 days before kidding to 30 days after kidding. All animals were maintained under uniform housing, feeding and management conditions throughout the experimental period.

Blood samples were collected at regular intervals on days −30, −20, −10 and −5 before kidding, on the day of kidding (0) and on days +5, +10, +20 and +30 after kidding. Approximately 2 mL of blood was collected from the jugular vein in EDTA vacutainers for haematological analysis, while 3 mL of blood was collected in clot activator tubes for serum biochemical, antioxidant and cortisol estimations. Serum was separated by centrifugation and stored at −20 °C until analysis.

Haematological parameters including total erythrocyte count (TEC; $\times 10^6/\mu L$), haemoglobin concentration (Hb; g/dL), packed cell volume (PCV; %), total leukocyte count (TLC; $\times 10^3/\mu L$), lymphocyte count ($\times 10^3/\mu L$), neutrophil count ($\times 10^3/\mu L$) and neutrophil-to-lymphocyte (N:L) ratio were analysed using an automated haematology analyser following standard laboratory procedures.

Serum biochemical parameters including glucose (mg/dL; Catalog No.: GLUS0240PS), total protein (g/dL; TPRG0100PS), albumin (g/dL; ALBG0100PS), alanine aminotransferase (ALT, U/L; ALTG0050PS), aspartate aminotransferase (AST, U/L; ASTG0050PS), creatinine (mg/dL; CRTG0100PS) and calcium (mg/dL; CALG0100PS) were analysed using standard commercial diagnostic kits. Antioxidant and stress indices including superoxide dismutase (SOD; U/mL; Catalog No.: 706002), glutathione peroxidase (GPx; nmol/min/mL; Catalog No.: 703102), malondialdehyde (MDA; µmol/mg protein; Catalog No.: 10009055) and cortisol hormone (ng/mL; Catalog No.: 1109576) were estimated using commercially available ELISA kits.

The data obtained were statistically analysed using independent (unpaired) sample t-test and one-way analysis of variance (ANOVA) according to the procedures described by Snedecor and Cochran (2014).

Results

Total erythrocyte count, haemoglobin and packed cell volume increased toward kidding in both groups with peaking on the day of kidding and declining postpartum; however, between-group differences were non-significant (p>0.05) throughout experimental period. Total leukocyte count and neutrophil counts showed a periparturient rise, with significantly (p<0.05) higher TLC and neutrophils in *Tinospora cordifolia* supplemented goats on day 0 and day +5. Lymphocyte counts declined at kidding in controls but remained comparatively higher in supplemented goats, with significant (p<0.05) differences on day 0 and day +5. The neutrophil-to-lymphocyte ratio increased at kidding in both groups but was significantly (p<0.05) lower in the supplemented group on the day of kidding. The values of different haematological parameters are presented in Table 1 and 2. The graphical representations for the values of haematological parameters are presented in figure 1 to 7.

Serum glucose declined toward kidding in both groups, reaching the lowest value on day 0, followed by a postpartum increase**;** supplemented goats showed significantly (p<0.05) higher glucose levels on day 0, day +5 and day +20. Total protein and albumin showed peri-parturient fluctuations without significant day-wise variation; however, albumin was significantly (p<0.05) higher in supplemented goats on the day of kidding. ALT activity remained stable and non-significant between groups. AST activity peaked around kidding in both groups, but *Tinospora cordifolia* supplementation significantly (p<0.05) reduced AST levels on day −5, day 0 and day +20. Serum creatinine showed no significant variation between groups. Serum calcium declined around kidding, but supplemented goats maintained significantly (p<0.05) higher calcium levels on day −5, day 0 and day +20. The values of different biochemical parameters are presented in Table 3 and 4. The graphical representations for the values of biochemical parameters are presented in figure 8 to 14.

The treatment group exhibited significantly higher SOD activity than the control group from late gestation through the post-kidding period, with marked ($p<0.05$) elevations on days −10, −5, 0, +20 and +30, while the control group showed only minor, non-significant fluctuations. GPx activity declined toward kidding in control group, whereas treatment group maintained significantly ($p<0.05$) higher GPx levels, with peak values observed during the immediate pre-kidding and kidding period (days −5, 0 and +20). Serum MDA concentrations increased toward kidding in both groups; however, treatment group showed significantly ($p<0.05$) lower MDA levels on days −5, 0, +10 and +30 compared to the control group, indicating reduced lipid peroxidation and improved antioxidant status during the periparturient period. The values of different antioxidant enzyme profile are presented in Table 5. The graphical representations for the values of antioxidant parameters are presented in figure 15 to 17.

Serum cortisol concentrations showed marked periparturient variations in both groups. In control group, cortisol levels increased significantly ($p<0.05$) from day −30 to peak on the day of kidding, reflecting heightened physiological stress and although values declined post-kidding, they remained higher than pre-kidding levels. In contrast, treatment group exhibited consistently lower cortisol concentrations throughout the study, with significantly ($p<0.05$) reduced values on the day of kidding, day +10 and day +30 compared to the control group. Moreover, treatment group showed a more gradual periparturient rise and faster post-kidding normalization of cortisol levels, indicating an attenuated stress response. The values of cortisol hormone are presented in Table 5. The graphical representation for the values of cortisol hormone is presented in figure 18.

Table 1: Mean ± S.E. for the hematological parameters (TEC, Hb and PCV) of supplemented and non-supplemented periparturient Surti Goats.

		-30	-20	-10	-5	0	5	10	20	30
TEC ($10^6/\mu l$)	**GROUP - I (Control)**	13.72± ^{a} 0.67	13.54± ^{ab} 1.12	14.63± ^{ab} 0.42	14.12± ^{bc} 1.39	17.29± ^{c} 0.93	13.53± ^{ab} 1.15	13.13± ^{ab} 1.43	11.23± ^{ab} 1.11	12.19± ^{ab} 1.71
	GROUP – II (Supplemented)	12.86± 0.82 ^{a}	14.08± 0.42 ^{ab}	13.18± 1.06 ^{ab}	16.18± 1.10 ^{bc}	17.20± 1.28 ^{c}	13.71± 0.79 ^{ab}	13.21± 1.24 ^{ab}	13.06± 1.00 ^{ab}	13.65± 0.84 ^{ab}
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Hb (g/dl)	**GROUP - I (Control)**	8.93± 0.22 ^{a}	8.78± 0.25 ^{a}	9.23± 0.26 ^{a}	8.87± 0.23 ^{a}	11.27± 0.48 ^{b}	9.30± 0.41 ^{a}	9.07± 0.39 ^{a}	9.48± 0.41 ^{a}	9.23± 0.41 ^{a}
	GROUP – II (Supplemented)	8.83± 0.38 ^{a}	9.56± 0.41 ^{a}	8.97± 0.62 ^{a}	10.12± 0.40 ^{b}	11.52± 0.52 ^{b}	9.87± 0.47 ^{a}	9.10± 0.38 ^{a}	9.20± 0.65 ^{a}	9.25± 0.55 ^{a}
PCV (%)		NS	NS	NS	*	NS	NS	NS	NS	NS
	GROUP - I (Control)	22.83± 1.08 ^{a}	22.33± 0.49 ^{a}	24.17± 0.95 ^{ab}	26.33± 1.05 ^{bc}	28.33± 0.76 ^{c}	24.00± 1.21 ^{ab}	23.50± 0.76 ^{ab}	22.33± 1.12 ^{a}	22.00± 1.06 ^{a}
	GROUP – II (Supplemented)	22.67± 1.23 ^{a}	23.67± 0.88 ^{ab}	24.17± 1.19 ^{ab}	26.83± 1.72 ^{bc}	27.83± 1.08 ^{c}	24.83± 1.35 ^{ab}	23.83± 0.60 ^{ab}	23.67± 0.42 ^{a}	22.67± 0.88 ^{a}
		NS	NS	NS	NS	NS	NS	NS	NS	NS

Values with different superscripts differed significantly within raws. NS- non-significant and * represents the significance ($p<0.05$) between two groups within a column.

Table 2: Mean ± S.E. for the hematological parameters (TLC, Neutrophil count, Lymphocyte count and N:L ratio) of supplemented and non-supplemented periparturient Surti Goats.

		-30	-20	-10	-5	0	5	10	20	30
TLC (10^3/µl)	GROUP - I (Control)	6.72± ^{ab} 0.33	8.57± ^{ab} 0.90	11.67± ^{bc} 1.95	10.37± ^{c} 1.71	12.37± ^{c} 1.01	12.71± ^{d} 1.55	11.05± ^{abc} 2.33	8.21± ^{a} 1.08	7.13± ^{ab} 1.24
	GROUP – II (Supplemented)	7.045± 1.13 ^{ab}	7.36± 0.75 ^{ab}	10.56± 1.72 ^{bc}	11.98± 1.70 ^{c}	17.84± 1.94 ^{d}	9.78± 1.46 ^{abc}	9.26± 1.43 ^{abc}	5.73± 0.52 ^{a}	6.47± 0.26 ^{ab}
		NS	NS	NS	NS	*	*	NS	NS	NS
Neutrophils (10^3/µl)	GROUP - I (Control)	3.70± ^{a} 0.43	4.93± ^{ab} 0.57	6.53± ^{c} 1.92	6.70± ^{bc} 0.42	7.44± ^{c} 0.36	6.78± ^{c} 0.41	5.15± ^{bc} 2.51	3.85± ^{a} 0.32	3.75± ^{a} 1.28
	GROUP – II (Supplemented)	3.93± 0.51 ^{a}	4.75± 0.22 ^{ab}	6.70± 0.47 ^{c}	7.78± 0.39 ^{d}	8.37± 0.59 ^{d}	8.38± 0.24 ^{d}	6.15± 1.05 ^{bc}	4.14± 0.31 ^{a}	3.46± 0.22 ^{a}
		NS	NS	NS	*	*	*	NS	NS	NS
Lymphocytes (10^3/µl)	GROUP - I (Control)	5.27± 0.55 ^{a}	4.53± 0.20 ^{a}	4.47± 0.49 ^{a}	4.25± 0.55 ^{a}	3.50± 0.39 ^{b}	3.96± 0.49 ^{b}	5.30± 0.58 ^{a}	5.05± 1.12 ^{a}	4.74± 1.10 ^{a}
	GROUP – II (Supplemented)	5.73± 0.40 ^{a}	5.48± 0.51 ^{a}	5.10± 0.37 ^{a}	5.09± 0.60 ^{a}	5.16± 0.75 ^{a}	6.15± 0.87 ^{a}	5.87± 0.63 ^{a}	5.72± 0.51 ^{a}	5.74± 0.42 ^{a}
		NS	NS	NS	NS	*	*	NS	NS	NS
N:L ratio	GROUP - I (Control)	0.73± ^{a} 0.10	1.11± ^{a} 0.15	1.48± ^{abc} 0.25	1.73± ^{abc} 0.61	2.63± ^{d} 0.15	1.81± ^{bc} 0.74	0.91± ^{ab} 0.44	1.14± ^{a} 0.41	1.35± ^{a} 0.83
	GROUP – II (Supplemented)	0.68± 0.07 ^{a}	0.90± 0.09 ^{a}	1.33± 0.10 ^{abc}	1.47± 0.31 ^{abc}	2.10± 0.14 ^{c}	1.95± 0.47 ^{bc}	1.16± 0.28 ^{ab}	0.76± 0.10 ^{a}	0.62± 0.06 ^{a}
		NS	NS	NS	NS	*	NS	NS	NS	NS

Values with different superscripts differed significantly within raws. NS- non-significant and * represents the significance (p<0.05) between two groups within a column.

Table 3: Mean ± S.E. for the biochemical parameters (Glucose, Total protein, Albumin and ALT) of supplemented and non-supplemented periparturient Surti Goats.

		-30	**-20**	**-10**	**-5**	**0**	**5**	**10**	**20**	**30**
Glucose (mg/dl)	**GROUP - I (Control)**	67.50± 2.01 ^{ac}	65.00± 3.36 ^{abc}	61.33± 2.04 ^{ab}	60.00± 2.16 ^{a}	58.50± 1.84 ^{b}	60.67± 2.06 ^{ab}	69.83± 2.70 ^{bcd}	71.00± 2.02 ^{bc}	77.83± 4.83 ^{d}
	GROUP - II (Supplemented)	69.83± 2.55 ^{ac}	72.00± 2.35 ^{cd}	67.17± 3.38 ^{abc}	66.00± 1.88 ^{ab}	62.17± 1.26 ^{c}	65.00± 2.53 ^{cd}	67.33± 1.74 ^{abc}	74.33± 2.51 ^{d}	77.83± 1.96 ^{d}
		NS	NS	NS	NS	*	*	NS	*	NS
Total Protein (g/dl)	**GROUP - I (Control)**	6.04± ^{ab} 0.32	6.00± ^{ab} 0.26	6.36± ^{ab} 0.19	6.30± ^{ab} 0.20	6.05± ^{ab} 0.17	6.35± ^{ab} 0.22	6.44± ^{ab} 0.21	6.60± ^{a} 0.17	6.29± ^{ab} 0.29
	GROUP - II (Supplemented)	6.61± ^{b} 0.30	6.78± ^{ab} 0.63	6.83± ^{ab} 0.21	6.27± ^{b} 0.65	6.85± ^{a} 0.15	7.20± ^{a} 0.30	7.26± ^{a} 0.23	7.09± ^{a} 0.20	6.91± ^{a} 0.21
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Albumin (g/dl)	**GROUP - I (Control)**	3.17± ^{ab} 0.12	3.10± ^{ab} 0.33	3.21± ^{a} 0.40	2.63± ^{bc} 0.28	2.61± ^{bc} 0.20	2.81± ^{b} 0.15	2.52± ^{c} 0.31	3.30± ^{a} 0.34	2.92± ^{b} 0.51
	GROUP - II (Supplemented)	3.23± ^{bc} 0.18	3.44± ^{a} 0.13	3.31± ^{ab} 0.12	2.93± ^{bc} 0.17	3.19± ^{a} 0.21	2.86± ^{bc} 0.17	2.92± ^{bc} 0.31	3.03± ^{ab} 0.21	2.97± ^{bc} 0.27
		NS	NS	NS	NS	*	NS	NS	NS	NS
ALT (U/L)	**GROUP - I (Control)**	12.22± ^{bc} 1.33	11.58± ^{c} 039	12.35± ^{bc} 1.38	14.15± ^{c} 1.00	14.87± ^{a} 0.99	12.62± ^{bc} 0.59	13.00± ^{b} 0.82	12.25± ^{bc} 1.22	12.82± ^{bc} 1.45
	GROUP - II (Supplemented)	11.64± ^{bc} 0.68	10.87± ^{c} 0.69	11.27± ^{bc} 0.61	11.59± ^{bc} 0.59	13.26± ^{a} 0.91	12.16± ^{bc} 0.42	12.46± ^{bc} 0.72	12.18± ^{bc} 0.61	11.52± ^{c} 0.52
		NS	NS	NS	NS	NS	NS	NS	NS	NS

Values with different superscripts differed significantly within raws. NS- non-significant and * represents the significance (p<0.05) between two groups within a column.

Table 4: Mean ± S.E. for the biochemical parameters (AST, Creatinine and Calcium) of supplemented and non-supplemented periparturient Surti Goats.

		-30	-20	-10	-5	0	5	10	20	30
AST (U/L)	**GROUP - I (Control)**	218.50± 15.69 ^{a}	321.50± 36.59 ^{bc}	333.67± 45.69 ^{c}	387.17± 28.75 ^{c}	389.50± 32.01 ^{c}	307.83± 22.68 ^{abc}	234.50± 16.68 ^{ab}	313.50± 28.07 ^{bcd}	297.50± 37.32 ^{abc}
	GROUP - II (Supplemented)	184.50± 14.48 ^{a}	267.33± 17.01 ^{cd}	258.33± 22.39 ^{bcd}	267.83± 20.31 ^{d}	290.83± 17.35 ^{d}	278.67± 24.26 ^{cd}	225.00± 13.54 ^{abc}	200.17± 20.66 ^{a}	206.50± 18.33 ^{ab}
		NS	NS	NS	*	*	NS	NS	*	NS
Creatinine (mg/dl)	**GROUP - I (Control)**	1.29± ^{ab} 0.22	1.25± ^{ab} 0.16	1.18± ^{a} 0.13	1.04± ^{a} 0.14	1.33± ^{abc} 0.13	1.03± ^{a} 0.15	1.06± ^{a} 0.14	1.06± ^{a} 0.13	0.89± ^{a} 0.11
	GROUP - II (Supplemented)	1.07± ^{a} 0.14	1.15± ^{a} 0.17	1.07± ^{a} 0.15	0.96± ^{a} 0.10	1.15± ^{a} 0.15	0.94± ^{a} 0.09	0.97± ^{a} 0.16	1.04± ^{a} 0.16	0.77± ^{a} 0.14
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Calcium (mg/dl)	**GROUP - I (Control)**	8.86± ^{a} 0.54	10.15± ^{a} 0.78	10.54± ^{a} 0.93	10.84± ^{a} 0.32	9.31± ^{b} 0.54	8.76± ^{a} 0.63	8.92± ^{a} 0.34	8.66± ^{b} 0.53	8.94± ^{a} 0.24
	GROUP - II (Supplemented)	9.97± 0.42 ^{a}	10.58± 0.48 ^{a}	11.66± 0.31 ^{a}	12.40± 0.37 ^{b}	11.37± 0.53 ^{a}	10.66± 1.03 ^{a}	10.01± 0.88 ^{a}	11.93± 0.55 ^{a}	10.71± 0.94 ^{a}
		NS	NS	NS	*	*	NS	NS	*	NS

Values with different superscripts differed significantly within raws. NS- non-significant and * represents the significance (p<0.05) between two groups within a column.

Table 5: Mean ±S.E. of antioxidant parameters (SOD, GPx and MDA) and cortisol of supplemented and non-supplemented periparturient Surti Goats.

		-30	-20	-10	-5	0	5	10	20	30
SOD (U/ml)	**GROUP - I (Control)**	1.19±^{ab} 0.08	1.22±^{ab} 0.09	1.17±^{a} 0.08	1.12±^{a} 0.10	1.19±^{a} 0.11	1.27±^{ab} 0.09	1.24±^{a} 0.15	1.12±^{a} 0.03	1.18±^{a} 0.09
	GROUP - II (Supplemented)	1.15±^{a} 0.10	1.23±^{ab} 0.19	1.30±^{bc} 0.16	1.21±^{bc} 0.12	1.23±^{bc} 0.12	1.26±^{a} 0.22	1.28±^{ab} 0.09	1.25±^{bc} 0.16	1.30±^{bc} 0.03
		NS	NS	*	*	*	NS	NS	*	*
GPx (nmol/min/ml)	**GROUP - I (Control)**	28.40±^{a} 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
	GROUP - II (Supplemented)	23.35± 1.15^{ab}	23.57± 1.90^{ab}	24.37± 1.23^{ab}	37.57± 2.19^{d}	32.10± 1.83^{d}	26.62± 3.20^{a}	26.67± 1.39^{abc}	22.53± 1.61^{bc}	29.15± 3.48^{ab}
		NS	NS	NS	*	*	NS	NS	*	NS
MDA (µmol/mg protein)	**GROUP - I (Control)**	1.31± 0.09^{a}	1.66± 0.21^{abcd}	1.72± 0.20^{abcd}	1.97± 0.19^{cd}	2.24± 0.09^{d}	1.80± 0.17^{bcd}	1.59± 0.05^{abc}	1.18± 0.12^{a}	1.26± 0.06^{b}
	GROUP - II (Supplemented)	1.26± 0.06^{ab}	1.43± 0.10^{abc}	1.50± 0.15^{bcd}	1.66± 0.14^{b}	1.83± 0.08^{b}	1.62± 0.09^{bcd}	1.23± 0.08^{d}	1.03± 0.15^{a}	1.10± 0.04^{a}
		NS	NS	NS	*	*	NS	*	NS	*
Cortisol (ng/ml)	**GROUP - I (Control)**	7.68± 0.60^{ab}	9.14± 0.48^{bcd}	10.70± 0.62^{b}	9.70± 0.35^{cd}	12.66± 0.57^{d}	9.32± 0.54^{cd}	9.75± 0.23^{cd}	8.79± 0.51^{abc}	8.37± 0.65^{a}
	GROUP - II (Supplemented)	7.13± 0.34^{a}	8.74± 0.59^{abc}	9.61± 0.67^{bc}	9.31± 0.73^{bc}	10.14± 0.61^{c}	9.40± 0.36^{bc}	8.17± 0.28^{ab}	8.42± 0.50^{abc}	7.25± 0.28^{bc}
		NS	NS	NS	NS	*	NS	*	NS	*

Values with different superscripts differed significantly within raws. NS- non-significant and * represents the significance ($p < 0.05$) between two groups within a column.

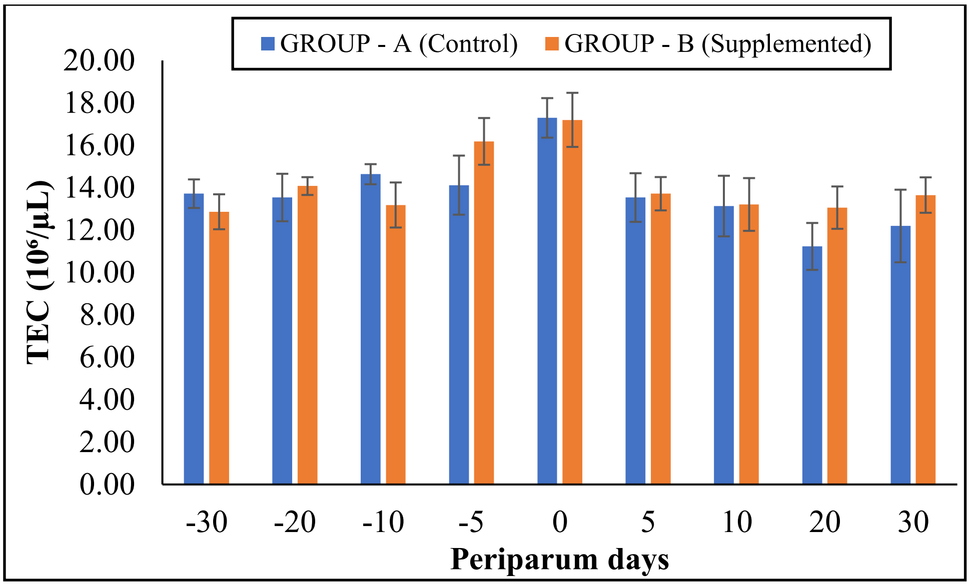

Figure 1: Effect of *Tinospora cordifolia* supplementation on TEC ($10^6/\mu L$) in twin fetus bearing periparturient Surti goats.

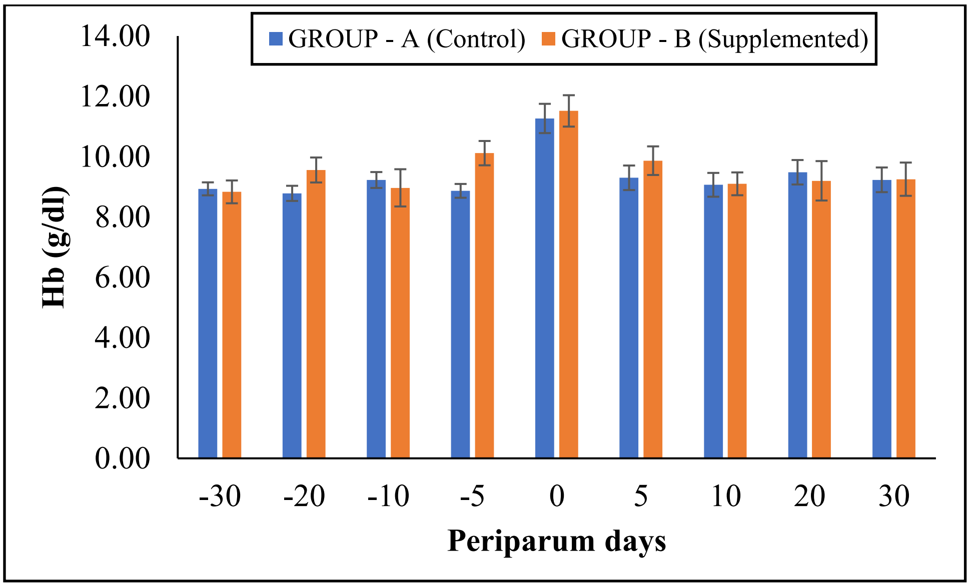

Figure 2: Effect of *Tinospora cordifolia* supplementation on Hb (g/dl) in twin fetus bearing periparturient Surti goats.

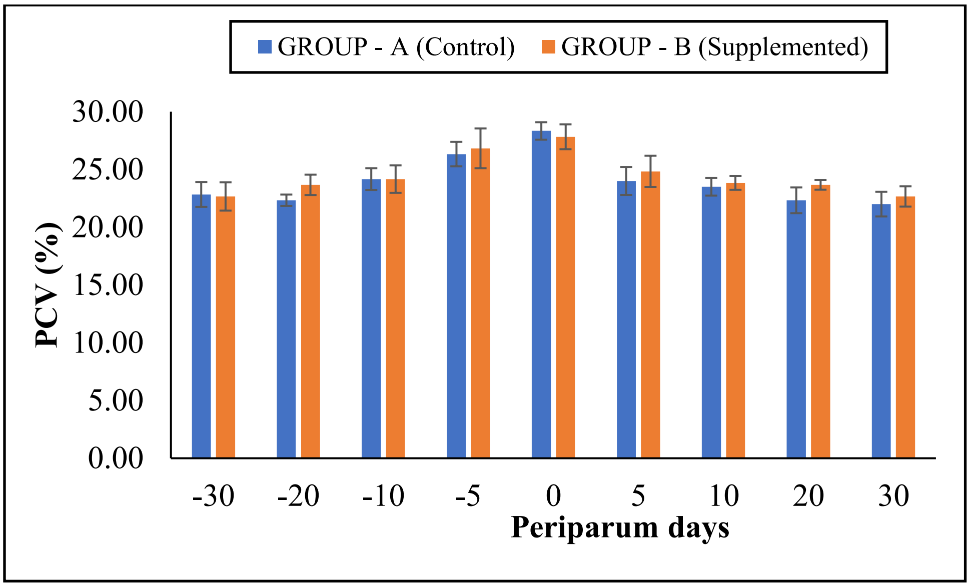

Figure 3: Effect of *Tinospora cordifolia* supplementation on PCV (%) in twin fetus bearing periparturient Surti goats.

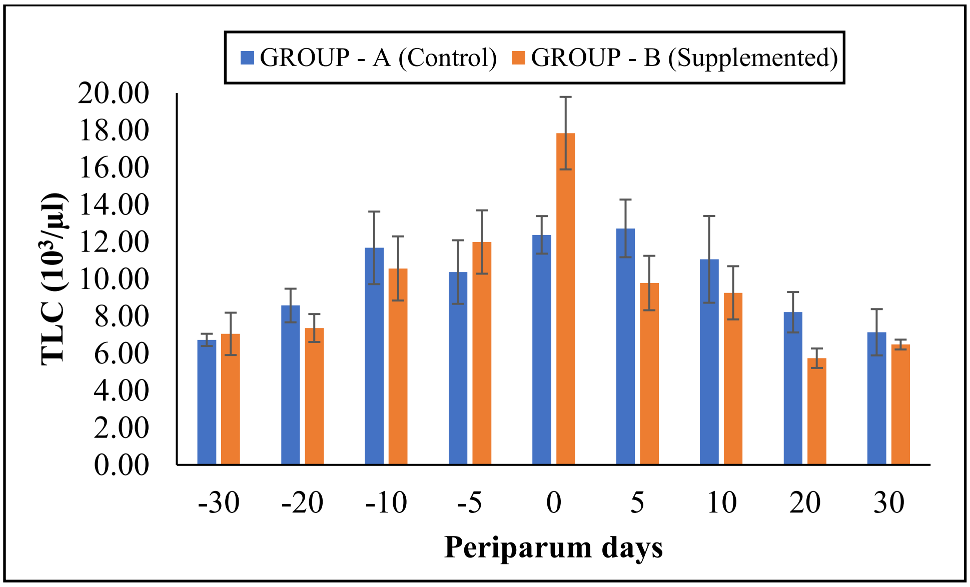

Figure 4: Effect of *Tinospora cordifolia* supplementation on TLC (10^3/µl) in twin fetus bearing periparturient Surti goats.

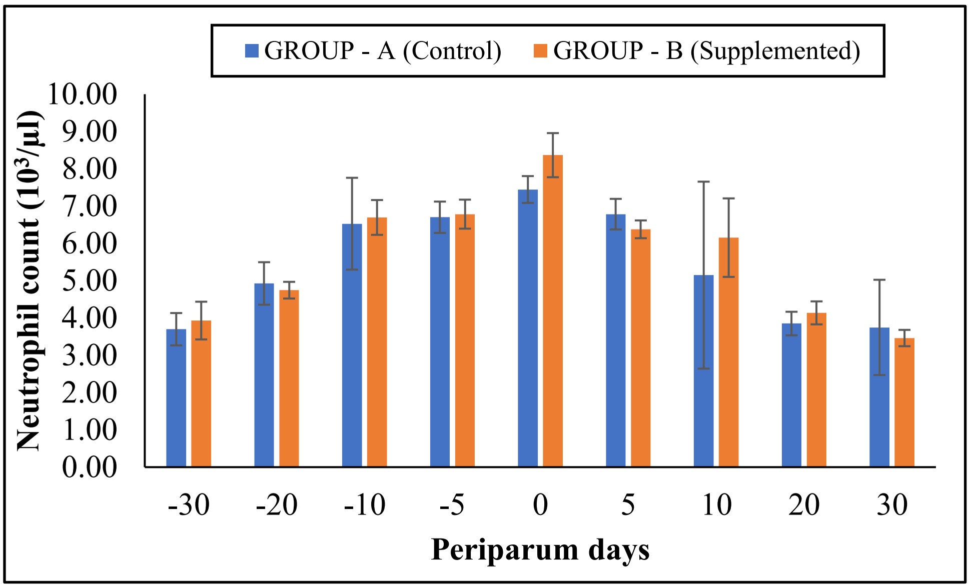

Figure 5: Effect of *Tinospora cordifolia* supplementation on Neutrophil count (10^3/µl) in twin fetus bearing periparturient Surti goats.

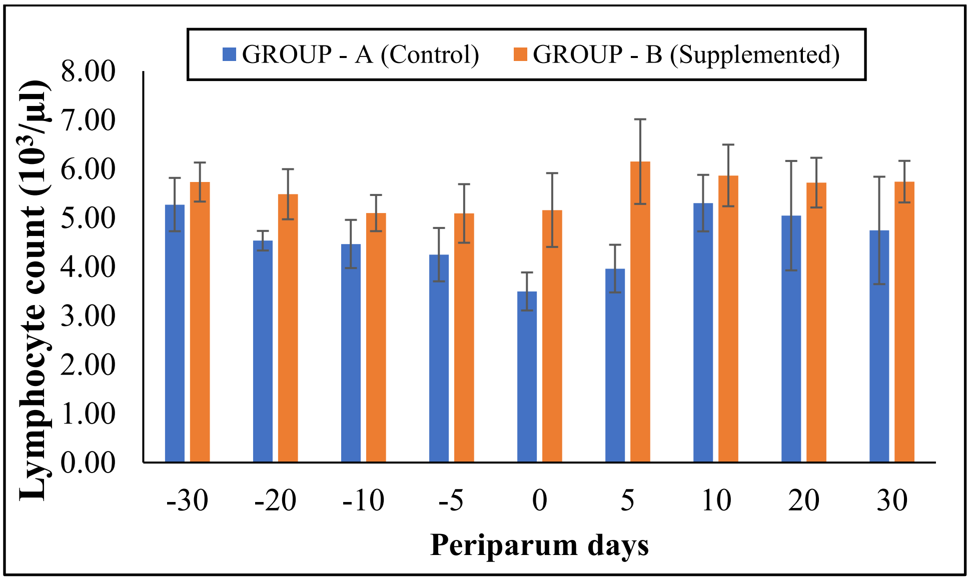

Figure 6: Effect of *Tinospora cordifolia* supplementation on Lymphocyte count (10^3/µl) in twin fetus bearing periparturient Surti goats.

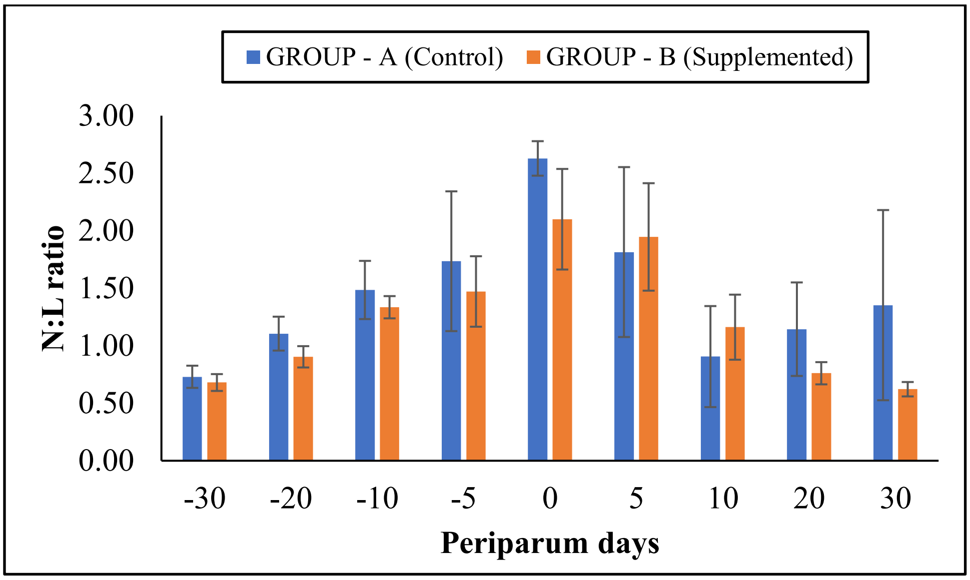

Figure 7: Effect of *Tinospora cordifolia* supplementation on N:L ratio in twin fetus bearing periparturient Surti goats.

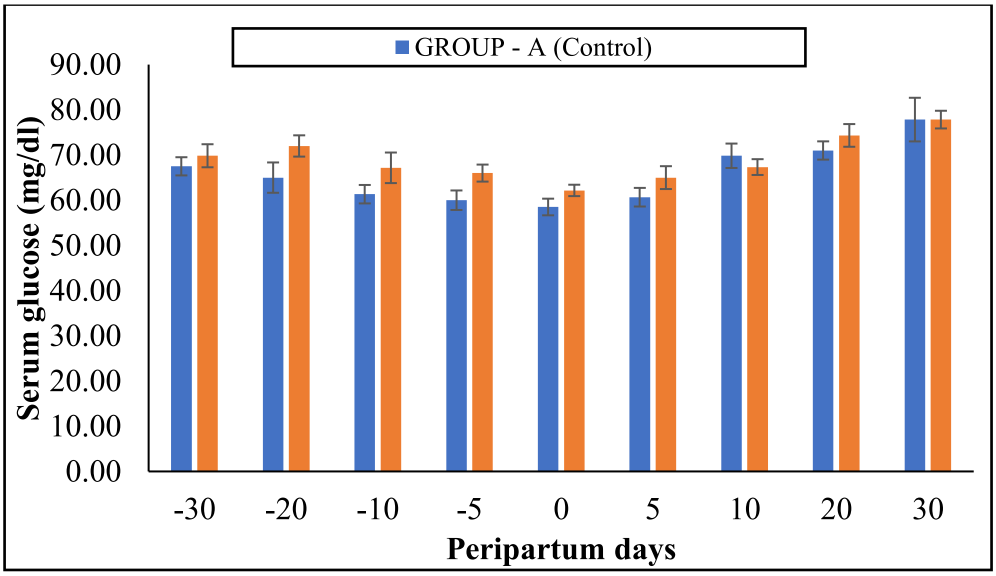

Figure 8: Effect of *Tinospora cordifolia* supplementation on serum glucose (mg/dl) in twin fetus bearing periparturient Surti goats.

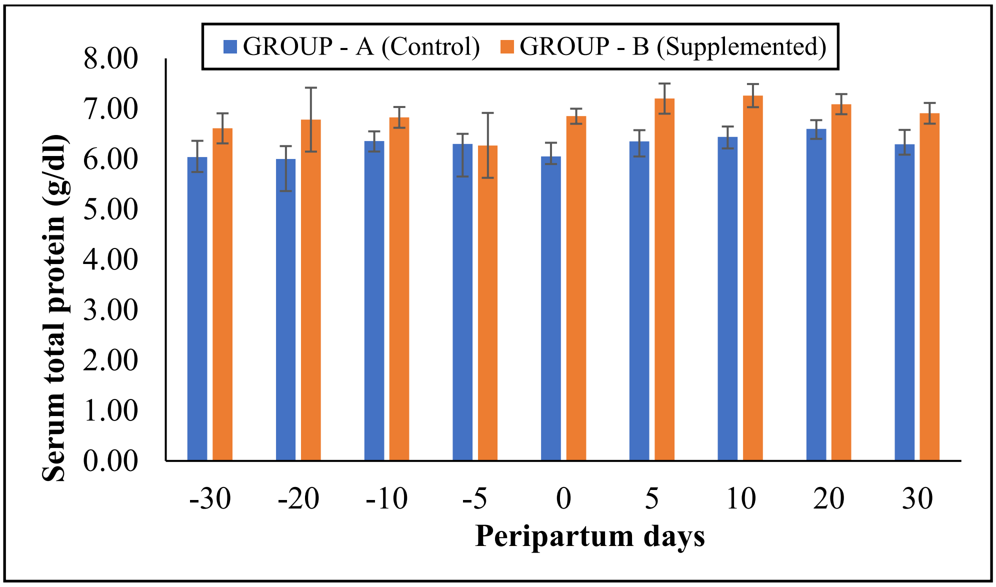

Figure 9: Effect of *Tinospora cordifolia* supplementation on serum total protein (g/dl) in twin fetus bearing periparturient Surti goats.

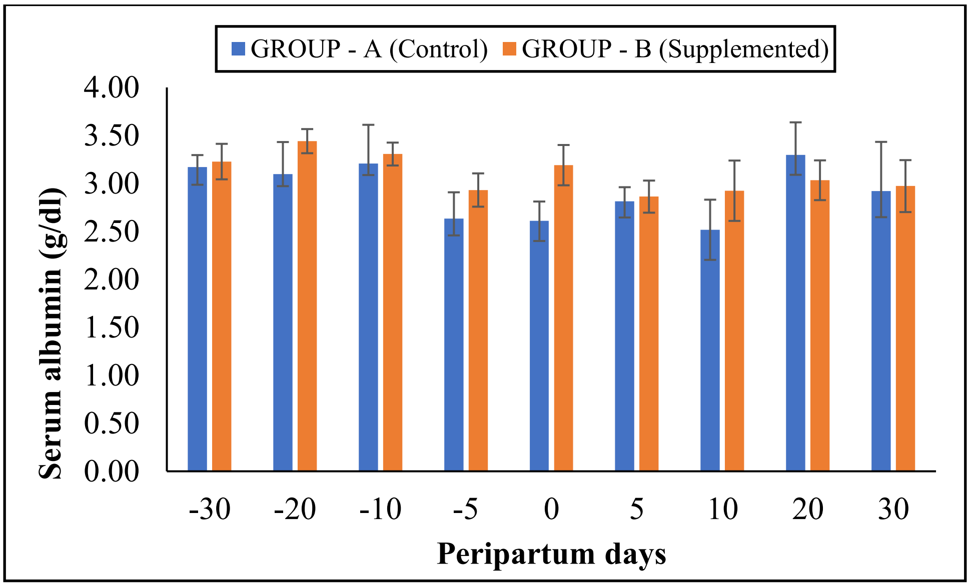

Figure 10: Effect of *Tinospora cordifolia* supplementation on serum albumin (g/dl) in twin fetus bearing periparturient Surti goats.

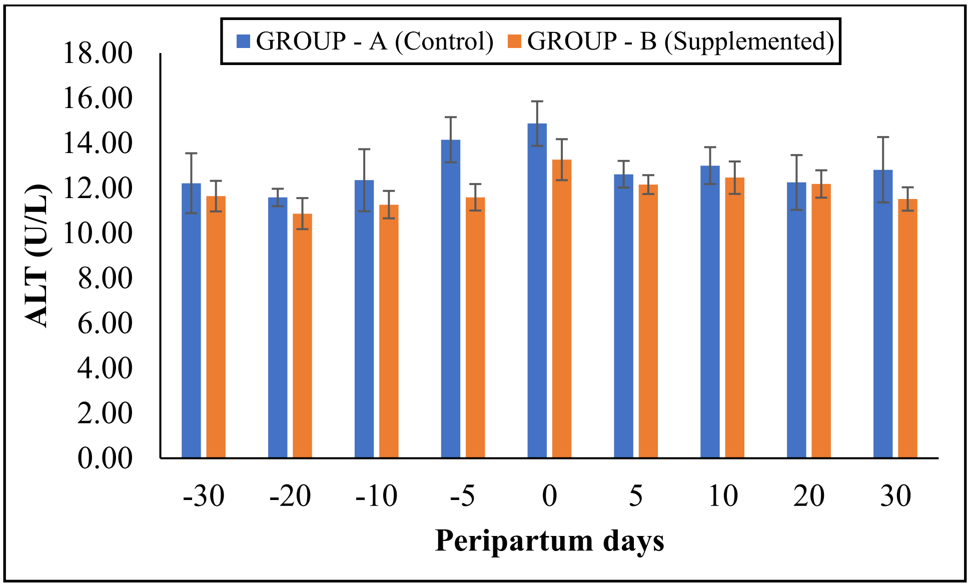

Figure 11: Effect of *Tinospora cordifolia* supplementation on ALT (U/L) in twin fetus bearing periparturient Surti goats.

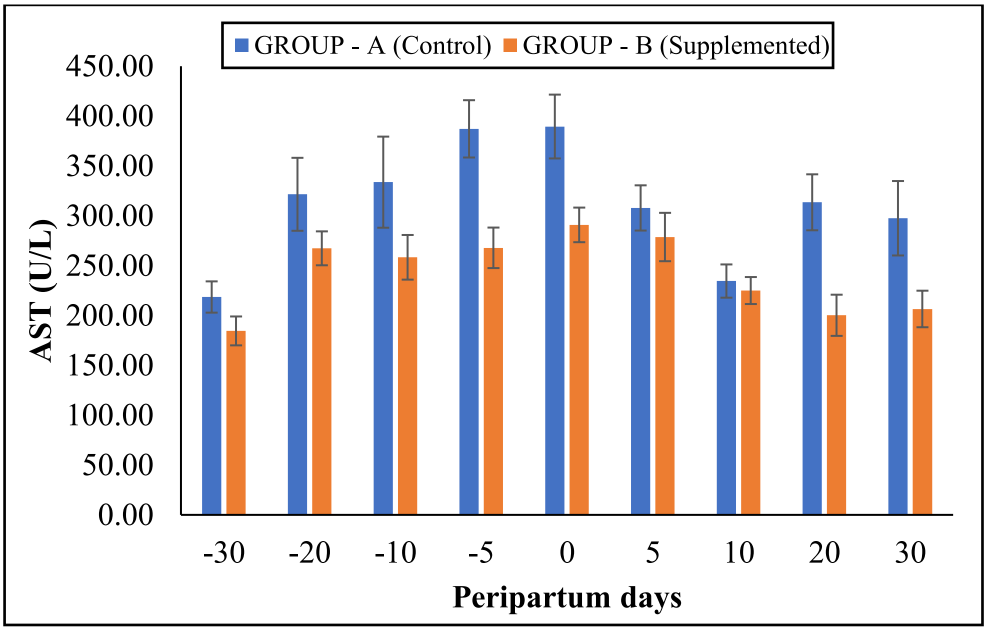

Figure 12: Effect of *Tinospora cordifolia* supplementation on AST (U/L) in twin fetus bearing periparturient Surti goats.

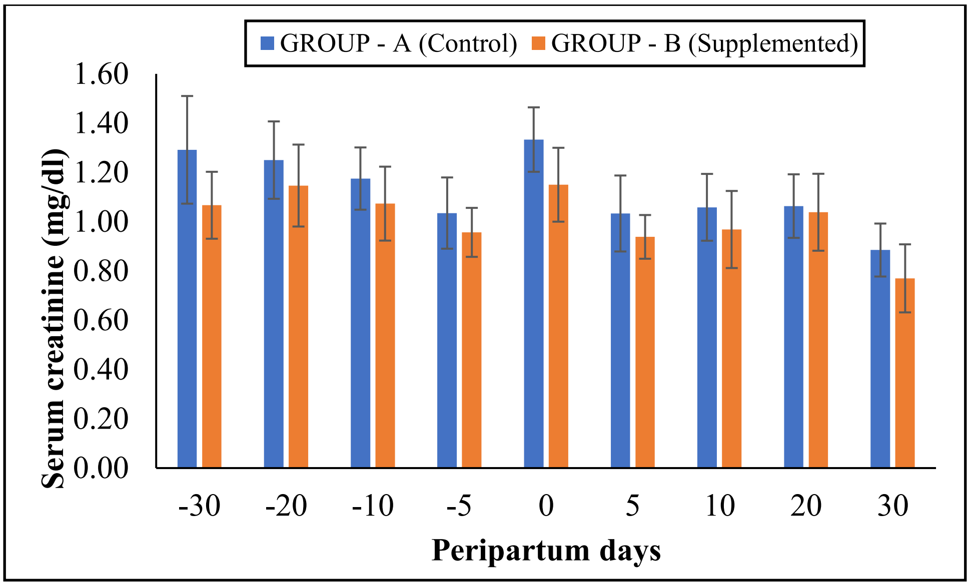

Figure 13: Effect of *Tinospora cordifolia* supplementation on serum creatinine (mg/dl) in twin fetus bearing periparturient Surti goats.

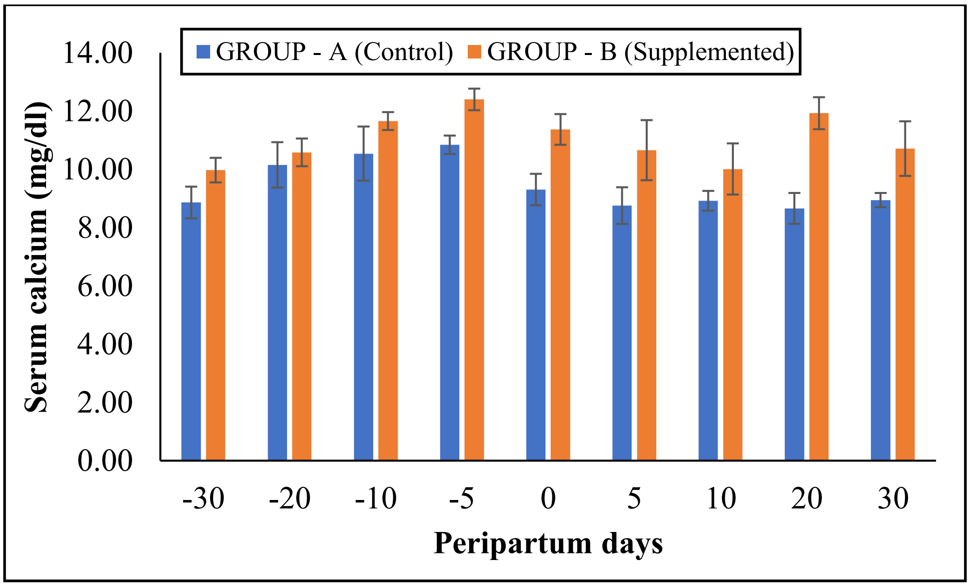

Figure 14: Effect of *Tinospora cordifolia* supplementation on serum calcium (mg/dl) in twin fetus bearing periparturient Surti goats.

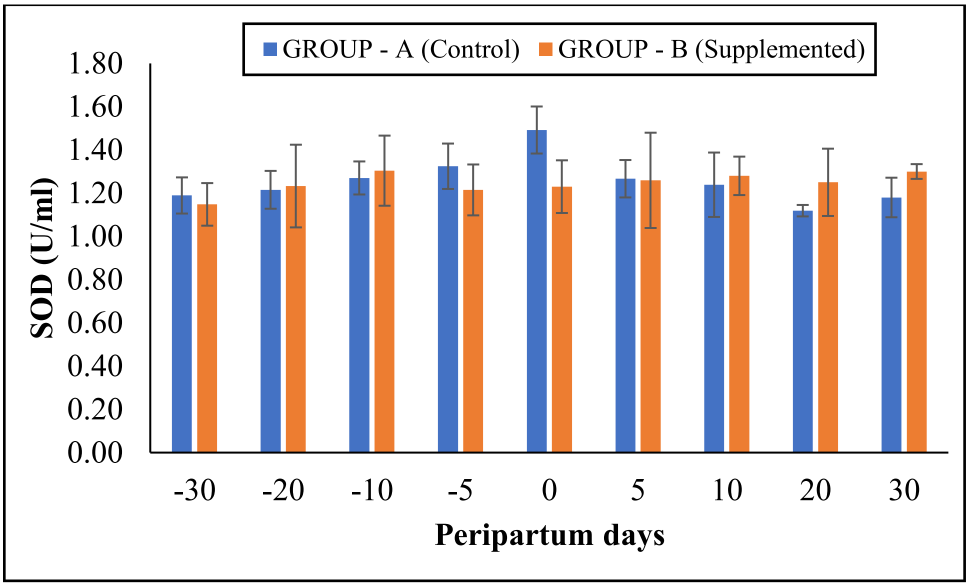

Figure 15: Effect of *Tinospora cordifolia* supplementation on SOD (U/ml) in twin fetus bearing periparturient Surti goats.

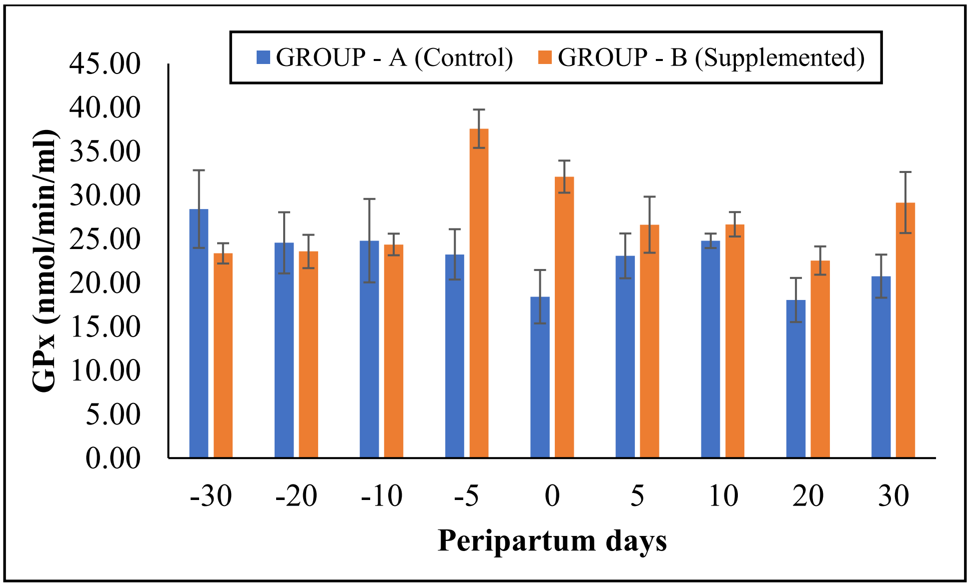

Figure 16: Effect of *Tinospora cordifolia* supplementation on GPx (nmol/min/ml) in twin fetus bearing periparturient Surti goats.

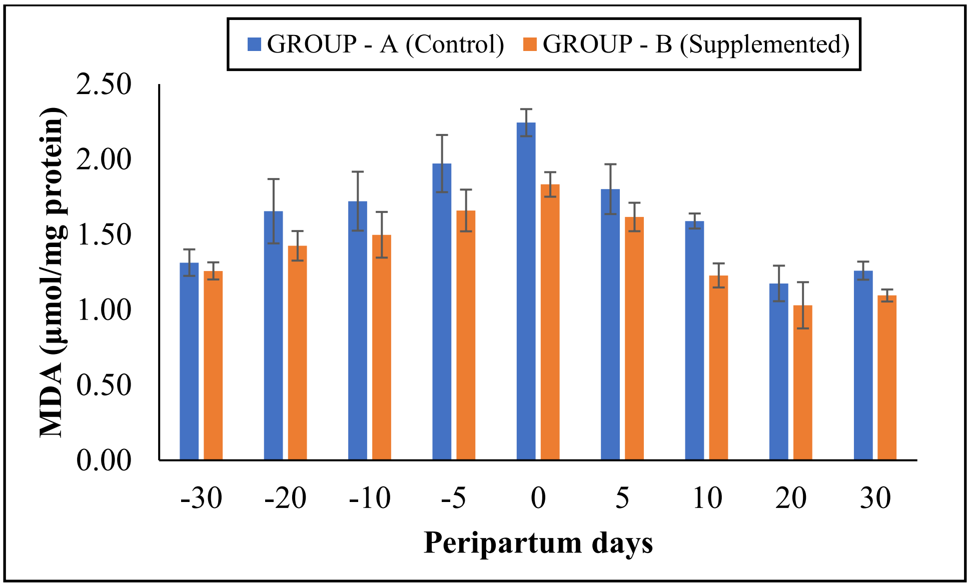

Figure 17: Effect of *Tinospora cordifolia* supplementation on MDA (µmol/mg protein) in twin fetus bearing periparturient Surti goats.

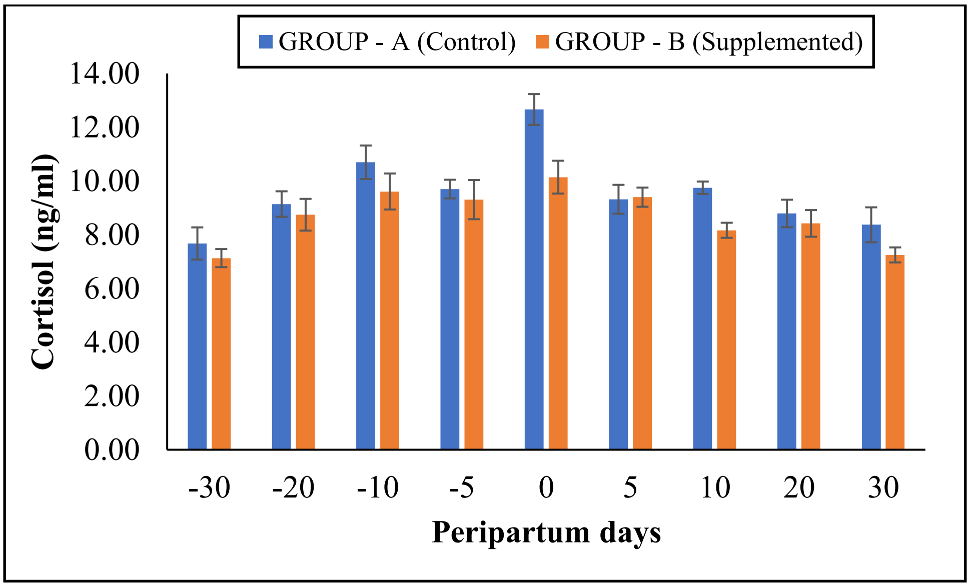

Figure 18: Effect of *Tinospora cordifolia* supplementation on cortisol (ng/dl) in twin fetus bearing periparturient Surti goats.

Discussion

The haematological changes observed in the present study broadly align with earlier reports, though some variations were evident. Unlike Iriadam (2007), who reported a significant decline in RBCs count with advancing pregnancy followed by a sharp rise at parturition in Kilis goats, only partial concordance was observed, likely due to differences in breed, nutritional management and experimental conditions. In contrast to Samui *et al*. (2023), who documented a progressive post-partum increase in haemoglobin concentration in Black Bengal goats, the present haemoglobin pattern differed, possibly reflecting variation in physiological adaptation and sampling design. The observed increase in packed cell volume is consistent with Farrag *et al*. (2024), who reported improved erythrocytic indices in *Moringa oleifera* supplemented Baladi goats, suggesting a beneficial effect of phytogenic supplementation. The significant rise in total leukocyte count corroborates the findings of Mallick and Prakash (2011), who demonstrated enhanced leukocyte response following *guduchi* supplementation, indicating immunostimulatory activity of *Tinospora cordifolia*. The increase in neutrophil counts during the early postpartum period agrees with Tharwat *et al*. (2015) and reflects parturition-associated stress and immune adaptation. Additionally, the observed leukocytosis accompanied by relative lymphopenia on the day of kidding supports the findings of Azab and Maksoud (1999), indicative of stress-mediated hematological shifts. The significant alteration in neutrophil–lymphocyte ratio further aligns with Mallick and Prakash (2011), reinforcing the role of *Tinospora cordifolia* in modulating immune responses during the peri-parturient period. The biochemical profile observed in the present study largely corroborates earlier reports, with some parameters showing partial divergence.

Serum glucose concentrations were comparable to those reported by Soni *et al*. (2022) in Gaddi goats, with no significant differences between *Tinospora cordifolia*–supplemented and non-supplemented groups on day 0 and day 30, indicating stable energy metabolism during the peri-parturient period. The significant rise in serum total protein is in strong agreement with Soares *et al*. (2018), who documented a marked ($p<0.01$) increase in total protein concentrations around kidding in multiparous goats, reflecting enhanced protein mobilization and metabolic adaptation. Similarly, the increase in serum albumin aligns with Jayaganthan *et al*. (2013), who reported a modest but significant ($p<0.05$) elevation in albumin following *Tinospora cordifolia* supplementation, suggesting improved protein synthesis or hepatic function. In contrast, ALT activity in the present study did not closely correspond with Soni *et al*. (2022), who observed no significant treatment effect, indicating possible differences in hepatic enzyme response due to physiological status or experimental design. The observed AST activity, however, is consistent with Jayaganthan *et al*. (2013), who reported a significant ($p<0.05$) reduction in AST levels in *Tinospora cordifolia* supplemented animals, suggesting a hepatoprotective effect. Changes in serum creatinine parallel the findings of Samui *et al*. (2023), who reported a highly significant ($p<0.01$) elevation around parturition that persisted into the postpartum period, likely reflecting increased muscle metabolism and altered renal dynamics. The marked ($p<0.01$) decline in serum calcium around parturition, followed by recovery postpartum, concurs with Tharwat *et al*. (2015) and underscores the transient hypocalcaemia associated with parturition and early lactation.

The present findings corroborate earlier reports highlighting the antioxidant potential of *Tinospora cordifolia* supplementation. In agreement with Jayaganthan *et al*. (2013), supplemented animals in the present study exhibited enhanced antioxidant defence, as evidenced by elevated SOD activity, reflecting improved neutralization of reactive oxygen species. Similar support is drawn from Soni *et al*. (2022), who documented a significant ($p<0.05$) increase in GPx activity in *Tinospora cordifolia* supplemented Gaddi goats, suggesting augmentation of enzymatic antioxidant capacity. Furthermore, the observed modulation of lipid peroxidation aligns with the findings of Manat *et al*. (2017), who reported peak MDA concentrations during the immediate postpartum period in Surti goats, indicative of heightened oxidative stress during early lactation. Collectively, these observations suggest that *Tinospora cordifolia* supplementation may effectively strengthen antioxidant defences and mitigate oxidative stress during physiologically demanding periods, thereby supporting metabolic resilience and health in small ruminants.

The present findings are in close agreement with the observations of Soni *et al*. (2022), who reported significantly ($p<0.05$) lower cortisol concentrations in *Tinospora cordifolia* supplemented male Gaddi goats compared to non-supplemented controls. The reduced cortisol levels observed in the supplemented group indicate an improved stress response and enhanced adaptive capacity, likely attributable to the adaptogenic and anti-stress properties of *Tinospora cordifolia*. These findings suggest that dietary supplementation with *Tinospora cordifolia* may attenuate hypothalamic–pituitary–adrenal axis activation, thereby alleviating stress burden during critical physiological phases and supporting overall animal welfare and productivity.

Conclusion

In conclusion, the periparturient period in Surti goats was associated with marked physiological alterations in haematological, biochemical, antioxidant and stress-related parameters, reflecting adaptive responses to the metabolic and immunological demands of transition. Compared with the control group, goats supplemented with *Tinospora cordifolia* exhibited comparatively improved erythrocytic indices, a more stable leukocyte profile and a moderated neutrophil-to-lymphocyte ratio, indicating enhanced immune competence and physiological resilience. Supplemented goats also demonstrated improved biochemical indicators related to energy, protein and mineral metabolism, along with significantly enhanced antioxidant enzyme activities (SOD and GPx) and reduced lipid peroxidation as evidenced by lower MDA concentrations, suggesting effective alleviation of oxidative stress during late gestation and early lactation. Furthermore, the attenuated cortisol response observed in the supplemented group indicated reduced physiological stress and improved adaptation during the transition period. Collectively, these findings suggest that *Tinospora cordifolia* possesses potent immunomodulatory, antioxidant and adaptogenic properties and may serve as a promising natural phytogenic supplement for improving health, metabolic stability and overall productivity of periparturient goats under field conditions.

Author contributions

Dipan N. Suthar: Writing-original draft, Methodology, Data Curation and Formal Analysis. Neelamsetti S V S S Eesawar: Writing – review & editing. Sana Chavda: Writing – review & editing. Mohsinkhan M. Pathan: Supervision, Writing – review & editing. S. P. Madhira: Supervision. Jayesh Chaudhary: Writing – review & editing.

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Declarations

Ethics approval

All the procedures involving animals were approved by the Institutional Animal Ethics Committee (F. No.483/VPB/2025) and were conducted in accordance with institutional guidelines for the care and use of animals in research.

Data availability statement

Not Applicable.

Competing interests

The authors declare that there is no conflict of interest.

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