Research Article

Influence of Organic *Moringa oleifera* Leaves Supplemented during Gestation and Lactation Periods: Modulation of Production Efficiency, Blood and Metabolic Parameters of Ewes and Lambs in Subtropics

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Abstract | Recent attention has been grown to investigate ing *Moringa oleifera* (*M. oleifera*) effects on productive and reproductive performances in mammals. The aims of the current study were designed to explore the effects of *Moringa oleifera* leaves given to ewes during prepartum and postpartum periods on thermo-tolerance responses, body weight gain, ovarian structures growth, blood and metabolic profiles of ewes and resulting lambs in subtropics. Fifteen ewes of body weight 49.1 ± 1.86 kg/head and 2.50 years old were allotted using complete random design to control and two *M. oleifera* groups (50.0 and 100.0 g/day). Relative humidity and ambient temperature were recorded and the temperature humidity index (THI) was calculated. Body weights of ewes and resulting lambs (kg) were recorded during the prepartum and postpartum periods. The small, medium and large ovarian follicles were recoded postpartum on day 18, and corpora lutea (CL) were recorded on day 21. Collection of blood samples from ewes and lambs were performed at -8 weeks and -4 weeks pre-partum, parturition, +4weeks, and +8weeks postpartum. The blood samples were analyzed for blood and metabolic profiles, liver enzymes, and minerals. The results indicated that ewes suffered from thermal stress during the study and the stress was alleviated due to *M. oleifera* supplementation. The body weight of ewes ($p<0.05$) and lambs ($p>0.05$) were higher in *M. oleifera* group compared to the control one. Ovarian structures' development was higher in *M. oleifera* groups if compared to the control group. *M. oleifera* supplementation resulted in significant improvement in hematological (RBCs, Hb, Ht, WBCs, neutrophils, and lymphocytes) and plasma parameters (total protein, albumin, globulin, glucose, urea, and minerals) of ewes and lambs. It could be concluded that *M. oleifera* leaves supplementation to pregnant ewes from eight weeks prepartum to eight weeks postpartum might be ameliorative for both productive and reproductive performances of ewes through modulating thermo-tolerance responses, blood and plasma parameters in subtropics.

Keywords | *Moringa oleifera,* Growth, Blood, Metabolites, Follicles

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INTRODUCTION

Moringa oleifera is referred to as a miracle tree plant cultivated in Afghanistan, Pakistan, India, and Bangladesh countries (Fahey, 2005; Kirmani et al., 2022). Recent attention has grown for investigating *Moringa oleifera* leaves effects as a non-conventional supplement on animal performance and human as well. *M. oleifera* leaf and its extracts were given to animals and humans in respect of therapeutic, productive, and reproductive purposes (Jaiswal et al., 2009; Al-Masruri et al., 2022a, b). *M. oleifera* leaves are confirmed to contain macro and micro nutrients including protein, fiber, sugars, saturated and unsaturated fatty acids, carotenoids, and tocopherols (Saini et al., 2014a, b; Al-Mufarji and Mohammed, 2022), vitamins and minerals (Jongrungruangchok et al., 2010), which are important for both animals and human metabolism (Abdull-Razis et al., 2014; Gupta et al., 2018).

The *M. oleifera* leaves and its extracts were found to improve nutrient digestibilities, rumen environment, and growth performance (El-Hedainy et al., 2020; Pandey et al., 2022), blood indices and metabolites (Srikandakumar et al., 2003; Onu and Aniebo, 2011; Estiyani et al., 2017; Akanmu et al., 2020), milk production and constituents (Kholif et al., 2019; Warastomo et al., 2021; Hernández-Becerra, 2022), ovarian follicle development and the quality of the resulting oocytes, embryos and newborns (Al-Masruri et al., 2022a, b). In addition, the beta-carotene, antioxidant minerals (zinc and selenium), antioxidant vitamins (A, C, and E), and other phytochemicals of *M. oleifera* known with their antioxidant ability can play an important role as anti-stress in subtropics (Vongsak et al., 2014; Afzal et al., 2021; Al-Masruri et al., 2022a, b; Al-Mufarji et al., 2022a, b). Because of the several nutritional and anti-stress characteristics of *M. oleifera* leaves, the current study has been designed to explore the modulation effect of organic *M. oleifera* leaves during prepartum and post partum periods on thermo-tolerance responses, body weight gain, ovarian structures' development, blood and plasma profiles of ewes and resulting lambs.

MATERIALS AND METHODS

The experimental procedures were approved by the ethical committee of the deanship of scientific research at King Faisal University (MAR-EA000532). This study was carried out on the farm of King Faisal University for 4 months. The organic *M. oleifera* leaves were purchased from Nadawy farm located in Gizan of KSA, which has got a certificate for organic *M. oleifera* production according to Saudi Organic law (OSKSA).

Animal management and experimental design

Fifteen healthy ewes of body weight, 49.1±1.86 kg/head and 2.50 year old, were assigned using complete random design to three equal groups including two *M. oleifera* and control groups (50 and 100.0 g/head/day). The ewes were individually living free in a standard pen. The ewes of control and *M. oleifera* were fed daily of a 1kg concentrate diet in addition to *ad-libitum* berseem hay (Table 1). The two *M. oleifera* groups were given daily 50 and 100g per head *M. oleifera* leaves per head. The *M. oleifera* levels were chosen according to previous studies (Vongsak et al., 2014; Ajuogu et al., 2019; Afzal et al., 2021; Al-Masruri et al., 2022a, b; Al-Mufarji et al., 2022a, b). Ewes had given free access to drinking water.

Table 1: Chemical composition of concentrate diet and *M. oliefera* leaves on dry matter basis.

Parameters, %	Concentrate diet	*M. oliefera* leaves
Dry matter	90.10 ± 0.90	90.31 ± 0.99
Organic matter	89.07 ± 0.90	88.58 ± 0.99
Crude protein	15.40 ± 0.41	29.94 ± 0.50
Ether extract	2.40 ± 0.03	2.10 ± 0.03
Crude fiber	15.12 ± 0.40	30.02 ± 0.43
Non-free extract	56.15 ± 0.70	26.52 ± 0.28
Ash	10.93 ± 0.38	11.42 ± 0.35

Thermo-tolerance responses and body weights

Ambient temperature (°C) and relative humidity (%) were recorded simultaneously at 12.00 pm using a digital thermometer and hygrometer device (AcuRite 00613). Thermo-tolerance index (THI) was calculated using Mader et al. (2006) method. The physiological parameters including rectal temperatures (veterinary thermometer, Cornell, USA), respiration rates (flank movement per minute; (Al-Mafurji et al., 2022), partial pressure of oxygen (SPO2), and pulse rate (CMS60D-VET Handheld Veterinary Pulse Oximeter) were recorded monthly of *M. oleifera* and control groups. Body weights of ewes and lambs (kg) were recorded.

Ovarian follicle and corpus luteum development

The ovaries of *M. oleifera* and control groups were investigated for investigating the development of ovarian follicles and corpora lutea. The ovarian follicles were recorded at day 18 postpartum and they were classified into three categories including small, medium, and large follicles, and the corpora lutea were recorded at day 21 postpartum as mentioned in other studies (Senosy et al., 2017, 2018).

Blood sampling and analyses

Five samples of blood were aspirated from all ewes of control and two *M. oleifera* groups during prepartum and postpartum weeks (-8 weeks, -4 weeks, parturition, +4 weeks, and +8 weeks) in addition to three blood samples were aspirated from resulting lambs (parturition, +4 weeks, and +8 weeks). The collected blood samples were analyzed for hematological and biochemistry parameters through hematology and biochemistry analyzers. The readable hematological parameters include RBCs (10^{12}/l), hematocrit (%), and hemoglobin (g/dl) in addition to white blood cells (10^{6}/l) and their types. The recorded plasma profiles include total protein, albumin, urea, glucose, minerals (calcium, phosphorous, sodium, potassium, chloride, and magnesium), and liver enzymes.

Statistical analysis

Values of physiological parameters (respiration rate, rectal temperature, SpO2, and pulse rate), body weight (kg), ovarian follicles and copora lutea development, and blood and plasma profiles due to *M. oleifera* leaves supplementation were analyzed statistically using the GLM procedure of SAS (SAS, 2008) according to model: Yij = μ + Ti+ eij Where: μ = Mean, Ti = Effects of *M. oleifera* levels, and eij= Standard error. Duncans (1955) was used to compare between the two *M. oleifera* and control groups.

RESULTS AND DISCUSSION

The current experimental study explored the influences of *M. oleifera* leaves level (50.0 vs. 100.0 g daily) given to pregnant and lactating ewes during prepartum and postpartum periods on the thermo-tolerance index, body weight gain, ovarian structure development, and blood and plasma indices (Figures 1, 2, Tables 2-7). The current study showed a superior effect of *M. oleifera* leaves (50 and 100g daily) to surpass the negative effect of ewes' transitional period concerning thermos-tolerance index, body weights, ovarian follicle development, and blood and metabolite profiles. *M. oleifera* leaves have been found to contain a substantial amount of carbohydrate (47.82%), protein (28.28%), fiber (28.35%), fat (7.57), saturated (3.76%) and unsaturated (3.79%) fatty acids and other substances (b-carotene, quercetin and antioxidants) as reported in several previous studies (Saini et al., 2014a, b; Teixeira et al., 2014; Al-Mufarji and Mohammed, 2022; Al-Masruri et al., 2022a, b; Moyo et al., 2011, 2012). Because of these novel chemical composition properties of *M. oleifera* leaves, it may give beneficial positive effects on the aforementioned investigated traits upon supplementation.

Figure 1: Effects of *Moringa oleifera* (50.0 and 100 g daily) on body weight of ewes and lambs at week 8 postpartum. [a, b] Values with different superscripts between groups significantly differ at P < 0.05.

Thermos-tolerance responses

The average of ambient temperature, relativity humidity, and temperature humidity index (THI) during the four months experimental period is presented in Table 2. The temperature humidity index during the experimental period is higher than 75 THI, which indicates exposure of ewes to heat stress. Thermos-tolerance responses of ewes during the study (Table 3) revealed that rectal temperature was unchanged (°C) whereas respiration rate (p>0.05) and pulse rate (p<0.05) were decreased versus partial pressure of oxygen (SpO2), which increased (p>0.05) in *M. oleifera* groups compared to control one (Table 3).

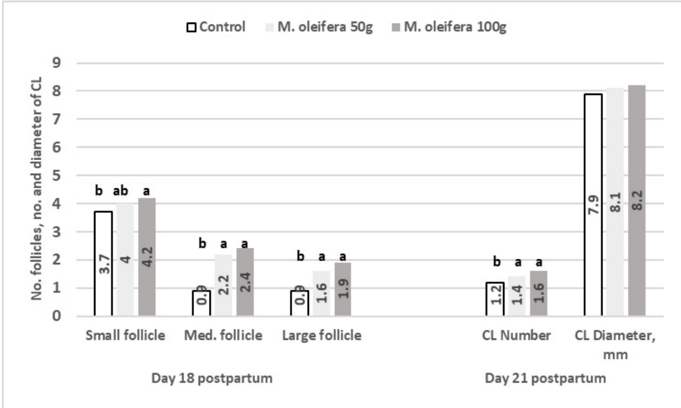

Figure 2: Effects of *Moringa oleifera* supplementation (50.0 and 100 g daily) on ovarian follicles and corpora lutea development. [a, b] Values with different superscripts between groups significantly differ at P < 0.05.

Table 2: Average of ambient temperature, relativity humidity and temperature humidity index during experimental period.

Months	Ambient temperature	Relativity humidity	Temperature humidity index
March	30.90 ± 0.91	44.0 ± 1.99	78.10 ± 0.96
April	37.17 ± 0.40	38.10 ± 1.48	84.72 ± 0.43
May	40.84 ± 0.54	40.55 ± 1.28	89.88 ± 0.54
June	45.60 ± 0.33	38.87 ± 1.40	94.97 ± 0.52
Overall mean	38.62 ± 0.44	40.38 ± 1.30	86.91 ± 0.64

The most common parameter describing the level of heat stress in animals is the temperature humidity index (THI) (Bohmanova et al., 2006). The environmental conditions give a higher rate of heat stress during the summer season versus a lower rate of heat stress during the spring or fall seasons of the Eastern Province of Saudi Arabia. High ambient temperature is a major stumbling block of animals' performance, which is bred in subtropical and tropical environments (Silanikove, 2000). The higher ambient temperature leads to stress-induced hyperthermia and increased metabolic heat production (Srikandakumar et al., 2003).The negative effect of high temperature has risen when it is accompanied by high ambient humidity (Armstrong et al., 2019). The higher values of humidity and temperature negatively affected animals' metabolic performance, growth, and reproduction. The rectal temperature, respiration and pulse rate, and SpO2 are parameters used to investigate heat stress responses in ruminants (Al-Mafurji et al., 2022). These parameters have been improved in *M. oleifera* groups because of the beta-carotene, antioxidant minerals, antioxidant vitamins, and other phytochemicals known for their antioxidant ability as anti-stress in subtropics (Vongsak et al., 2014; Afzal et al., 2021). In addition, red blood cells, hemoglobin, total protein, and albumin values were significantly increased in *M. oleifera* group if compared to the control one in the current study and they significantly improved thermos-tolerance responses (Kassab and Mohammed, 2013, 2014a, b).

Body weight and ovarian structures' development

The recorded final body weights of ewes ($p<0.05$) and their resulting lambs ($p>0.05$) at 8 weeks postpartum were increased due to *M. oleifera* leaves (Figure 1). Moreover, the recorded ovarian follicles and corpora lutea at day 18 and 21 postpartum, respectively were high ($p<0.05$) due to *M. oleifera* supplementation (Figure 2). The recorded final body weight of ewes ($p<0.05$) and their resulting lambs ($p<0.05$) at 8 weeks postpartum were increased due to *M. oleifera* leaves supplementation compared to control diet as reported in previous studies (Elghandour et al., 2017; Al-Masruri et al., 2022b). Feed supplements must be safe for the health and well-being of pregnant and lactating ewes to support their body weight gain and the development of ovarian structures (Mohammed et al., 2021; Al-Masruri et al., 2022b). Several factors could be owing to the positive effects of *M. oleifera* on body weight improvement including higher ($p<0.05$) nutrient digestibility, total bacterial count, and fermentation in addition to a significant decrease in total protozoal count, ruminal ammonia-N, and methane production (Abdel-Raheem and Hassan, 2021). *M. oleifera* extracts supplemented with lambs was proven effective as an anti-methane additive (Akanmu et al., 2020). The recorded ovarian follicles and corpora lutea at day 18 and 21 postpartum, respectively were increased ($p<0.05$) due to *M. oleifera*. Such improvement in ovarian structures development is owing to high performance, as previously indicated, in digestive tract functions and high ($p<0.05$) blood and plasma metabolites (Abdel-Raheem and Hassan, 2021; Al-Masruri et al., 2022a, b). In addition, the contents of saturated and unsaturated fatty acids contents of *M. oleifera* might be used to provide the precursors for prostaglandin and steroid hormone synthesis (Claire Wathes et al., 2007).

Table 3: Effects of *M. oliefera* on thermo-tolerance parameters of ewes over heat stress.

Parameters	Treatments		
	Control	*M. oleifera* 50.0g	*M. oleifera* 100.0g
Rectal temperature, °C	39.03 ± 0.50	39.10 ± 0.60	39.11 ± 0.5
Respiration rate/ min.	29.16 ± 0.18	27.32 ± 0.28	27.04 ± 0.38
Pulse rate/min.	88.52^{b} ± 0.73	86.48^{ab} ± 1.54	81.52^{a} ± 1.29
Partial pressure of oxygen,%	96.60 ± 1.12	97.40 ± 1.31	98.56 ± 1.18

^{a,b} Values with different superscripts between groups significantly differ at $P < 0.05$.

Table 4: Effects of *Moringa oleifera* leaves (50.0 and 100 g daily) supplementation on blood cells and hemoglobin values of ewes in subtropics.

Parameters	Treatments		
	Control	*M. oleifera* 50g	*M. oleifera* 100g
Red blood cells, 10^{12}/L	11.34^{b} ± 0.16	12.47^{a} ± 0.23	12.56^{a} ± 0.24
Hemoglobin, g/dl	12.10 ± 0.22	12.20 ± 0.15	12.35 ± 0.22
Hematocrit, %	32.28^{b} ± 0.51	38.55^{a} ± 1.05	39.59^{a} ± 0.74
MCV, fl or μm^3	28.44^{b} ± 0.41	30.84^{ab} ± 0.46	31.64^{a} ± 0.53
MCH, pg/cell	10.70 ± 0.20	9.87 ± 0.24	9.91 ± 0.25
MCHC, g/dl or %	37.78 ± 0.85	32.23 ± 0.98	31.41 ± 0.71
White blood cells, 10^9/l	8.74^{b} ± 0.26	9.64^{a} ± 0.26	9.79^{a} ± 0.21
Lymphocytes, 10^9/l	3.98^{b} ± 0.16	4.56^{a} ± 0.11	4.62^{a} ± 0.11
Monocytes, 10^9/l	0.05 ± 0.00	0.06 ± 0.00	0.06 ± 0.00
Neutrophils, 10^9/l	3.54^{b} ± 0.10	3.78^{ab} ± 0.16	3.87^{a} ± 0.11
Eosinophils, 10^9/l	1.03 ± 0.01	1.10 ± 0.02	1.10 ± 0.01
Basophils, 10^9/l	0.13 ± 0.00	0.15 ± 0.00	0.15 ± 0.01

^{a,b} Values with different superscripts between groups significantly differ at $P < 0.05$. MCV, Mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration.

Table 5: Effects of *Moringa oleifera* leaves (50.0 and 100 g daily) supplementation to ewes on blood profiles of the resulting lambs in subtropics.

Parameters	Treatments		
	Control	*M. oleifera* 50g	*M. oleifera* 100g
Red blood cells, 10^{12}/L	$11.76^b \pm 0.12$	$12.53^a \pm 0.14$	$12.75^a \pm 0.10$
Hemoglobin, g/dl	$12.30^b \pm 0.32$	$12.75^{ab} \pm 0.30$	$12.91^a \pm 0.28$
Hematocrit, %	$34.37^b \pm 1.03$	$37.99^{ab} \pm 1.77$	$39.15^a \pm 1.04$
MCV, fl or µm^3	29.20 ± 0.73	30.30 ± 1.30	30.70 ± 0.68
MCH, pg/cell	10.47 ± 0.28	10.20 ± 0.29	10.13 ± 0.23
MCHC, g/dl or %	35.97 ± 1.08	34.07 ± 1.37	33. 16 ± 1.06
White blood cells, 10^9/l	$6.90^b \pm 0.31$	$7.60^a \pm 0.34$	$8.31^a \pm 0.30$
Lymphocytes, 10^9/l	$3.16^b \pm 0.21$	$3.56^{ab} \pm 0.21$	$3.93^a \pm 0.17$
Monocytes, 10^9/l	0.05 ± 0.00	0.05 ± 0.00	0.05 ± 0.00
Neutrophils, 10^9/l	$2.58^b \pm 0.13$	$2.84^{ab} \pm 0.15$	$3.11^a \pm 0.15$
Eosinophils, 10^9/l	0.99 ± -.03	1.01 ± 0.03	1.06 ± 0.02
Basophils, 10^9/l	0.13 ± 0.01	0.14 ± 0.01	0.15 ± 0.01

^{a,b} Values with different superscripts between groups significantly differ at P < 0.05. MCV, Mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration.

Table 6: Effects of *Moringa oleifera* leaves (50.0 and 100 g daily) supplementation on plasma biochemistry of ewes.

Parameters	Treatments		
	Control	*M. oleifera* 50g	*M. oleifera* 100g
Total protein, g/dl	$7.50^b \pm 0.12$	$8.28^a \pm 0.09$	$8.42^a \pm 0.11$
Albumin, g/dl	$3.19^b \pm 0.04$	$3.60^a \pm 0.03$	$3.65^a \pm 0.04$
Globulin, g/dl	$4.31^b \pm 0.13$	$4.68^a \pm 0.08$	$4.77^a \pm 0.09$
Albumin/Globulin	0.74 ± 0.03	0.76 ± 0.01	0.76 ± 0.01
Glucose, mg/dl	$86.20^a \pm 1.08$	$80.84^b \pm 1.06$	$79.32^b \pm 1.03$
Alkaline phosphatase, U/L	117.8 ± 1.65	116.20 ± 1.19	114.7 ± 1.10
Aspartate aminotransferase, U/L	158.2 ± 6.27	151.6 ± 5.71	154.0 ± 4.52
Gamma-glutamyl transferase, U/L	68.80 ± 1.55	67.64 ± 1.47	63.32 ± 1.61
Creatine Phosphokinase, U/L	194.5 ± 7.66	197.6 ± 7.26	198.2 ± 6.87
Blood urea nitrogen, mg/dl	$14.22^a \pm 0.36$	$12.45^b \pm 0.27$	$12.15^b \pm 0.27$
Urea, mg/dl	$30.43^a \pm 0.78$	$26.64^b \pm 0.58$	$26.00^b \pm 0.57$
Calcium, mg/dl	$10.01^b \pm 0.15$	$11.62^a \pm 0.12$	$11.66^a \pm 11.66$
Phosphorus, mg/dl	$5.08^b \pm 0.20$	$5.70^a \pm 0.18$	$5.87^a \pm 0.15$
Magnesium, mg/dl	$0.53^b \pm 0.01$	$0.55^{ab} \pm 0.01$	$0.58^a \pm 0.01$
Sodium, mmol/L	141.7 ± 1.04	140.7 ± 0.91	138.4 ± 1.12
Potassium, mmol/L	4.57 ± 0.11	4.80 ± 0.11	4.84 ± 0.11
Chloride, mmol/L	111.9 ± 0.67	110.10 ± 0.84	109.9 ± 0.88

^{a,b} Values with different superscripts between groups significantly differ at P < 0.05.

Blood and plasma profiles

Blood and biochemistry values of ewes and their resulting lambs of the two *M. oleifera* and control groups are shown in Tables 4-7. Significant increases (p<0.05) of RBCs and hematocrit, WBCs, lymphocytes, and neutrophils were found in groups of *M. oleifera* ewes and their resulting lambs (Tables 4-5). In addition, total protein, albumin, globulin, and minerals (calcium, phosphorus, magnesium) values were increased (p<0.05) in groups of *M. oleifera* ewes and their resulting lambs whereas the values of glucose, urea (p<0.05) and hepatic enzymes (aspartate transaminase, γ-glutamyl transferase and alkaline phosphatase) (p >0.05) were decreased if compared to control group (Tables 6-7).

The blood and plasma values of *M. oleifera* and control groups were within the normal range of healthy ewes and lambs (Tables 4-7) (Lepherd et al., 2009; Kassab et al., 2017; Kassab and Mohammed, 2013, 2014a, b; Mohammed and Kassab, 2015; Al-Masruri et al., 2022b). The valuable effects of *M. oleifera* leave on blood and

Table 7: Effects of *Moringa oleifera* leaves (50.0 and 100 g/kg diet) supplementation to ewes on plasma biochemistry of the resulting lambs.

Parameters	Treatments		
	Control	*M. oleifera* 50g	*M. oleifera* 100g
Total protein, g/dl	6.06[b] ± 0.09	6.43[ab] ± 0.13	6.51[a] ± 0.11
Albumin g/dl	2.98[b] ± 0.06	3.24[a] ± 0.05	3.21[a] ± 0.03
Globulin g/dl	3.08[b] ± 0.11	3.19[ab] ± 0.10	3.30[a] ± 0.09
Albumin/Globulin	0.98 ± 0.05	1.02 ± 0.03	0.98 ± 0.02
Glucose mg/dl	81.70[a] ± 3.11	70.10[b] ± 1.95	68.10[b] ± 2.76
Alkaline phosphatase, U/L	119.50 ± 1.89	121.80 ± 2.19	120.20 ± 1.99
Aspartate aminotransferase, U/L	146.80 ± 3.50	146.70 ± 4.36	133.0 ± 4.72
Gamma-glutamyl transferase, U/L	73.80 ± 2.82	70.30 ± 2.65	65.50 ± 3.04
Creatine Phosphokinase, U/L	195.1 ± 10.17	198.1 ± 11.0	196.5 ± 10.17
Blood urea nitrogen, mg/dl	15.64[a] ± 0.94	13.38[b] ± 0.71	13.04[b] ± 0.70
Urea, mg/dl	33.46[a] ± 1.05	28.63[b] ± 1.51	27.90[b] ± 1.50
Calcium, mg/dl	10.63[b] ± 0.10	11.41[a] ± 0.12	12.21[a] ± 0.11
Phosphorus, mg/dl	5.99[b] ± 0.38	7.36[a] ± 0.34	7.59[a] ± 0.17
Magnesium, mg/dl	0.58 ± 0.03	0.63 ± 0.04	0.62 ± 0.03
Sodium, mmol/l	131.90 ± 1.54	135.70 ± 0.63	137.20 ± 1.15
Potassium, mmol/l	4.60 ± 0.18	4.82 ± 0.16	4.94 ± 0.14
Chloride, mmol/l	109.0 ± 1.11	112.5 ± 0.76	115.30 ± 0.84

[a,b] Values with different superscripts between groups significantly differ at $P < 0.05$.

plasma profiles could be attributed to several factors including high ($p<0.05$) body weight, enhanced nutrient digestibility, and rumen fermentation (Giuberti et al., 2021), antioxidative characteristics regulating processes involved in the metabolism (Al-Masruri et al., 2022a, b).

Several studies reported valuable effects of *M. oleifera* on blood and plasma indices (Ashour et al., 2020; Al-Masruri et al., 2022a, b; Al-Mufarji and Mohammed, 2022). The blood and plasma biochemical indicators in the present study were determined to explore the safety of *M. oleifera* leaves as a feed supplement for pregnant and lactating ewes and the resulting lambs. It has been found earlier that *M. oleifera* inclusion (25, 50, 75, 100%) to ewes or goat diets increased blood indices (red blood cells, hemoglobin and hematocrit) while white blood cells values decreased (Fadiyimu et al., 2017; Meel et al., 2018). *M. oleifera* lipid contents of saturated and unsaturated fatty acids might consider key constituents of the plasma membrane (Al-Mufarji and Mohammed, 2022; Mawatari et al., 2003). Polysaccharides of *M. oleifera* might gave positive effects on immune performance and intestinal health (Wen *et al.*, 2022). Moringa polyphenol extract might have immunomodulatory characteristics (Lin *et al.*, 2022). *M. oleifera* leaves contain beta-carotene and other phytochemicals known for their antioxidant ability, antioxidant vitamins, and essential micronutrients with antioxidant activity.

In the current study, the glucose and urea values were decreased ($p<0.05$) due to *M. oleifera* supplementation as indicated in several studies (Owens et al., 2020; Nova et al., 2020; Yasoob et al., 2022). The significant improvement in nutrient digestibility and body weight gain (Abdel-Raheem and Hassan, 2021) could be the reason for consuming glucose in metabolism and urea in protein synthesis.

Hepatic enzymes (AST, GGT, and ALP) are considered as an authoritative indicator of liver functions in ruminants (Liu et al., 2012; Noro et al., 2013), and the liver enzymes' values were not differed due to *M. oleifera* inclusion in the diet either during gestation or lactation periods of ewes. Moreover, *creatine kinase* has been used as a screening diagnosis parameter of endometritis muscular damage or hypocalcemia in lactating cattle (Sattler and Fürll, 2004). In several studies, the *M. oleifera* leaves or its extract was given a protective role against conditions-induced hepatic toxicity (Abdull-Razis et al., 2014; Farid and Hegazy, 2020).

The minerals (calcium, phosphorus, and magnesium) values were increased in *M. oleifera* groups when compared to control one as indicated in several previous studies (Abdull-Razis et al., 2014; Ogbe and Affiku, 2011; Ignatov, 2020; Ignatov and Popova, 2021; Dai et al., 2020). Major minerals of blood (calcium, phosphorus, and magnesium) indicate the animal's health and they are important for animals' production (Nozad et al., 2020). Herein, the aforementioned mineral values were in the normal range and reflected the adequate minerals of *M. oleifera* and control diets (Goff, 2008). The increase in the aforementioned minerals in *M. oleifera* groups could be attributed to their presence in *M. oleifera* leaves (Al-Mufarji and Mohammed, 2022). Calcium, phosphorus, and magnesium minerals are essential elements for skeletal building, muscle contraction, production of energy and anti-inflammatory and anti-viral agents (Ignatov and Popova, 2021). Collectively, the components of *M. oleifera* leaves lead to a significant improvement in the functions of the gastrointestinal tract and liver leading to an increase in body health and body weight gain during gestation and lactation periods of ewes in subtropics.

CONCLUSIONS

The unique properties of organic *M. oleifera* leaves as a source of high protein, saturated and unsaturated fatty acids and minerals after daily supplementation (100.0 g/head) to pregnant and lactating ewes resulted in enhancement of body health and ovarian follicle development through regulating body weight gain, thermo-tolerance responses, blood cells and metabolites, liver enzymes, and minerals values. The positive effects of *M. oleifera* leaves were transmitted to the resulting lambs until weaning age.

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NOVELTY STATEMENT

M. oleifera supplementation to pregnant ewes improves thermo-tolerance parameters, blood and biochemical profiles of ewes and lambs in subtropics.

AUTHOR'S CONTRIBUTION

Authors contributed equally to conceptualization, methodology, data analysis, writing, and editing manuscripts.

Conflict of interest

The authors have declared no conflict of interest.

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