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The Minerals Profile in Desert Ewes (*Ovis aries*): Effects of Pregnancy, Lactation and Dietary Supplementation

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Abstract: The objective of this study was to assess the changes in serum minerals profile in desert ewes in relation to pregnancy, lactation and dietary supplementation. Twenty sexually mature Sudanese desert ewes were assigned to two equal groups, control and supplemented; the supplemented group received daily (500g) of concentrate mixture (crushed sorghum + cotton seed cake). In both groups, oestrus was synchronized with hormonal method and the ewes were naturally inseminated. Following insemination, pregnancy was confirmed by ultrasonography technique. The results indicate that in both groups of ewes, the serum levels of (K), (P) and (Mg) increased significantly with the advance of pregnancy. The serum levels of (Na), (K), (Ca), (P), (Mg), (Cu) and (Zn) which were higher in supplemented ewes, increased significantly at parturition and decreased gradually with the advance of lactation. During lactation, the supplemented ewes maintained higher levels of serum (Na), (K), (Ca), (Cu) and (Zn). The results indicate that the mineral profile in desert ewes is influenced by pregnancy and lactation and the responses are modified by dietary supplementation.

Key words: Ewes · Pregnancy · Lactation · dietary supplementation · Serum minerals

INTRODUCTION

The majority of the sheep population in Sudan is raised under nomadic pastoral system where nutritional conditions are often sub-optimal. The nutritional adaptive traits of sheep breeds indigenous to these systems have not been critically investigated. Previous studies indicated that dietary manipulations can lead to economically important improvements in the nutritional status, metabolic profile and productivity of sheep [1-4].

Metabolism of mineral elements plays a significant role in the regulation of physiological functions of pregnancy and lactation. Pregnancy and lactation constitute metabolic stress, associated with alterations in the minerals profile dependent on the reproductive status of small ruminants [5-7]. Moreover, substantial losses of body minerals occur during pregnancy and lactation. Therefore, the concentrations of macro- and micro-minerals in the serum represent homeostatic mechanisms that are in a close relationship with the hormonal regulation and nutritional status [8, 9]. Previous research demonstrated that minerals have critical roles in the reproductive performance of ewes [10, 11]. These elements function as constituents of organic compounds and are incorporated in many physiological processes such as activators of some body enzyme systems. The deficiencies, excesses or malabsorption of minerals contribute to or cause several diseases for maternal or/and foetus such as metabolic problems, immune and hormonal dysfunctions and negative effects on reproductive efficiency [12, 13]. It was reported [14] that a mineral imbalance could be a cause of infertility in repeat breeder buffaloes. In ruminants, for example, maternal copper deficiency can cause infertility, abortion and stillbirth [12, 15]. Therefore, blood minerals profiles can be used to predict pre-partum and post-partum problems associated with minerals deficiencies. The aim of the present study was to assess the changes in minerals profile during pregnancy and lactation of grazing desert ewes in response to long-term concentrate and minerals supplementation.

MATERIALS AND METHODS

Animals: Twenty sexually mature multiparous Desert ewes were used in this study. The ewes were 2.5-3 years old with an average body weight of 35.19±3.6 kg at the beginning of the study. They were selected from the breeding stock of the Khartoum University Farm. Before commencement o f the studies, the health status of the

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Table 1: The chemical composition of the components of concentrate diet (g/kg DM)

Ingredients	Crushed sorghum grain	Cotton seed cake
Dry matter	945.00	956.00
Oil	26.50	87.80
Crude protein	140.00	254.80
Crude fibre	29.30	241.70
Nitrogen free extract (NFE)	784.40	351.90
Ash	22.80	63.80
Calcium	0.51	4.50
Phosphorus	3.30	3.70
Metabolizable energy (Cal/kg)	13.61	11.91

animals was monitored and evaluated on the basis of physical examination and blood analysis using standard methods. The ewes were dewormed with anthelmintic (1vomec, Anupco-England: 1 ml/50 kg BW) and they were given prophylactic antibacterial treatment (Sulphadiamadin pyrimidine, Richter-pharma, Austria, 1ml/10kg BW). The ewes were identified individually using ear-tags and were randomly assigned to two experimental groups; group A served as control and was kept on grazing only while group B (treated group) was supplemented with a concentrate mixture.

Feeding Regimen: The normal nutrition of the animals (groups A and B) was provided by grazing harvested field residues. Both groups of ewes were put on pasture and allowed to graze daily on the residues of sorghum (*Sorghum bicolor*) and grasses (*Cyndon dacylon*) for 6 hours (from 8:00 am to 2:00 pm). In addition, the animals in group B were offered a supplemental concentrate mixture composed of a high energy source and a source rich in protein. Each animal in group B received daily at 7:00 a.m. a mixture of 250g of crushed sorghum grain and 250g of cotton seed cake. Salt blocks (macro-minerals, micro-minerals and vitamin D) were also provided to the supplemented group in the animal pens. Water was available all the time in the shed. Table 1 shows the chemical composition of the components of concentrate diet used in the study.

Synchronization of Oestrus and Detection of Pregnancy: Synchronization of oestrus in the ewes was performed by hormonal method [16]. Pregnancy was detected by ultra-sound technique (standard device 550 Trioga PIE Medica-Netherlands); after one month following natural insemination; 17 ewes found pregnant, 7 in group A and 10 in group B.

Collection of Blood Samples and Analysis: Blood samples (5 ml) were collected from the external jugular vein and immediately transferred to anti-coagulant-free capped test tube. The blood samples were allowed to stay for 4hrs at room temperature and then centrifuged to collect serum. Heamolysis-free serum samples were harvested into clean plastic vials and immediately frozen at -20°C for analysis of serum mineral.

The serum concentrations of sodium (Na) and (K) were determined by flame photometer (Jenway PFP, England) technique [17]. Serum concentrations of calium (Ca), phosphorus (P) and magnesium (Mg) were determined chemically using a spectrophotometer (Jenway PFP, England) based on methods described [18-20]. The serum copper (Cu) concentration was determined colorimetricaly by dibenzyl-dithiocarbamate method described [21]. Serum zink (Zn) concentration was determined by the atomic absorption technique using a spectrophotometer (Unicam-929, England).

Statistical Analysis: Standard methods of statistical analysis were adopted [22]. Analysis of variance test (ANOVA) was used to evaluate the effects of physiological state on serum minerals. The control and supplemented group of ewes were compared at the end of each period of the experiment, the initial (IN), mating (MT), early- (EP), mid-(MP) and late- (LP) pregnancy and at parturition (PR) periods. After lambing, the two groups were compared in the first, second and third month of lactation (L1, L2 and L3, respectively). The student (t) test was used to compare the control and supplemented group at each of the physiological states.

RESULTS

Serum Macro-minerals: The effects of dietary supplementation during different physiological states on the concentrations of serum macro-minerals (Na), (K), (Ca), (P) and (Mg) are shown in Figs 1, 2, 3, 4 and 5, respectively. The results of statistical analysis are shown in Table 2.

Serum Sodium (Na): Fig. 1 shows that in both control and supplemented group of ewes there was a significant ($P<0.05$) increase in serum level of (Na) during early flushing period compared to the initial values. In both groups of ewes, the levels of (Na) after mating and during three stages of pregnancy were significantly ($P<0.05$) lower compared to those measured during early flushing. At parturition, in the control group, there was a significant

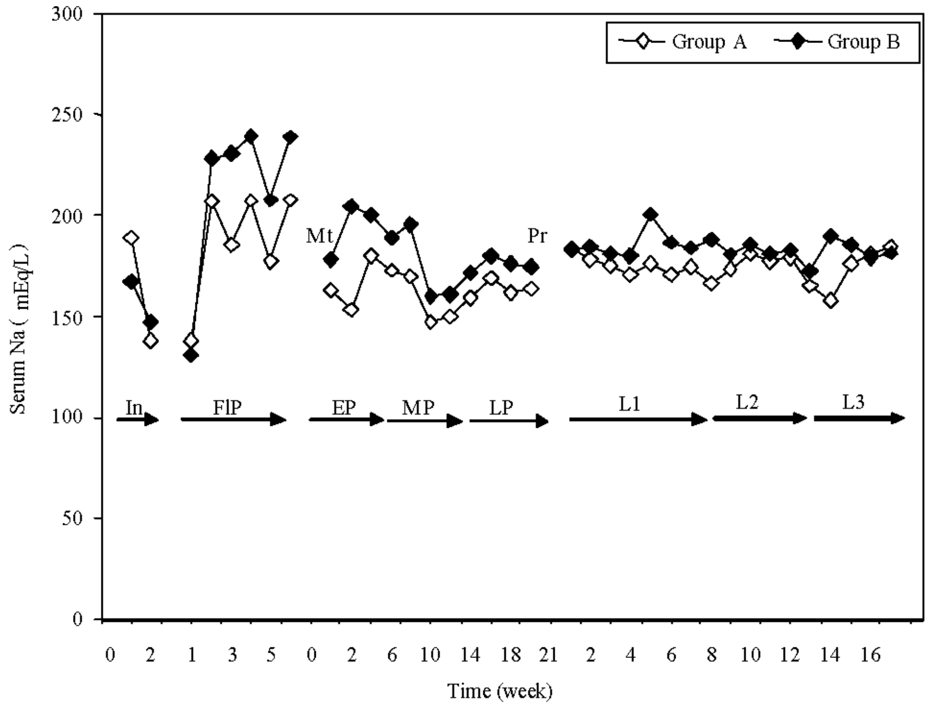

Fig. 1: Effects of dietary supplementation during different physiological states of ewes on serum sodium (Na) level. {Initial (In), mating (MT), early- (EP), mid-(MP), and late- (LP) pregnancy, parturition (Pr), first (L1), second (L2) and third (L3) month of lactation}

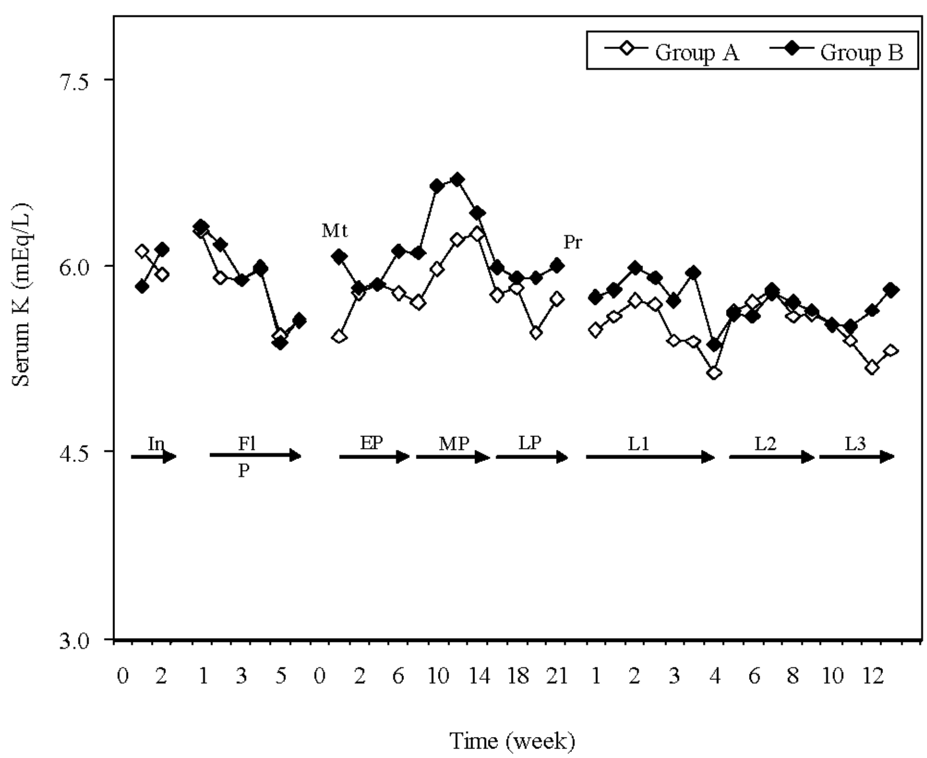

Fig. 2: Effects of dietary supplementation during different physiological states of ewes on serum potassium (K) level

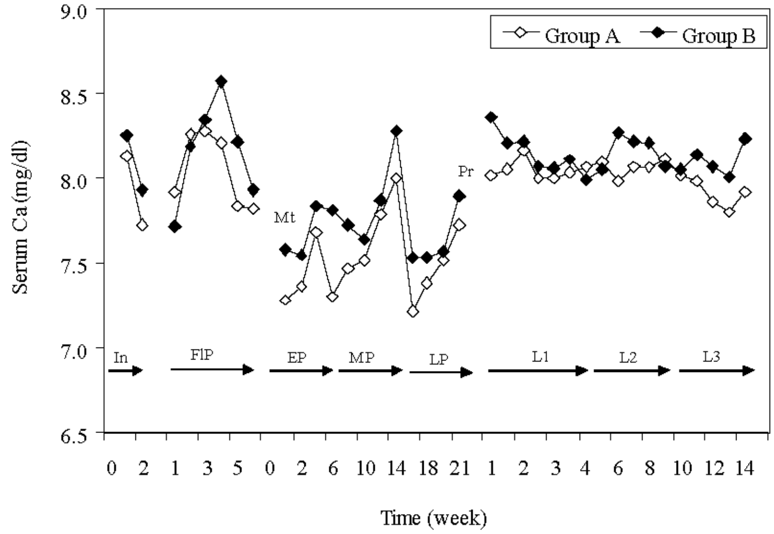

Fig. 3: Effects of dietary supplementation during different physiological states of ewes on serum calcium (Ca) level

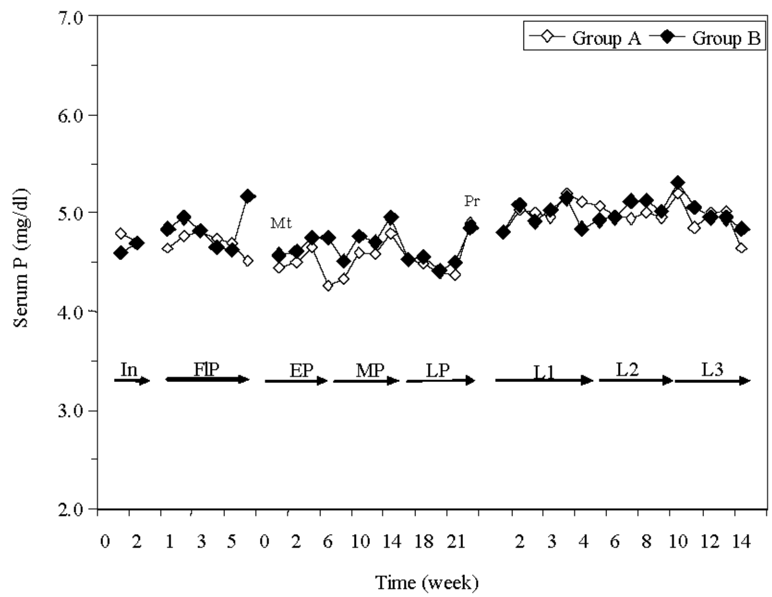

Fig. 4: Effects of dietary supplementation during different physiological states of ewes on serum phosphorus (P) level

($P<0.05$) increase in the level of (Na) compared to the value measured during pregnancy. In both groups of ewes, lactation had no effect on (Na) level. Also it was noted that during early flushing, the supplemented group had significantly ($P<0.05$) higher serum (Na) level compared to the control.

Serum Potassium (K): In both control and supplemented group of ewes, serum (K) level (Fig. 2) was significantly ($P<0.05$) lower during early flushing compared to the initial values. Also in both groups, there was a gradual significant ($P<0.05$) increase in (K) level after mating and during early and mid gestation and then it decreased significantly ($P<0.05$) during late gestation. At parturition, the (K) level increased significantly ($P<0.05$) in both groups of ewes compared to the values obtained during early flushing. Obviously, the supplemented group showed significantly ($P<0.05$) higher (K) levels compared to the control after mating, during early and mid gestation and in the third month of lactation.

Serum Calcium (Ca): Serum (Ca) levels (Fig. 3) measured by the end of early flushing period and after mating were significantly ($P<0.05$) lower in both groups compared to

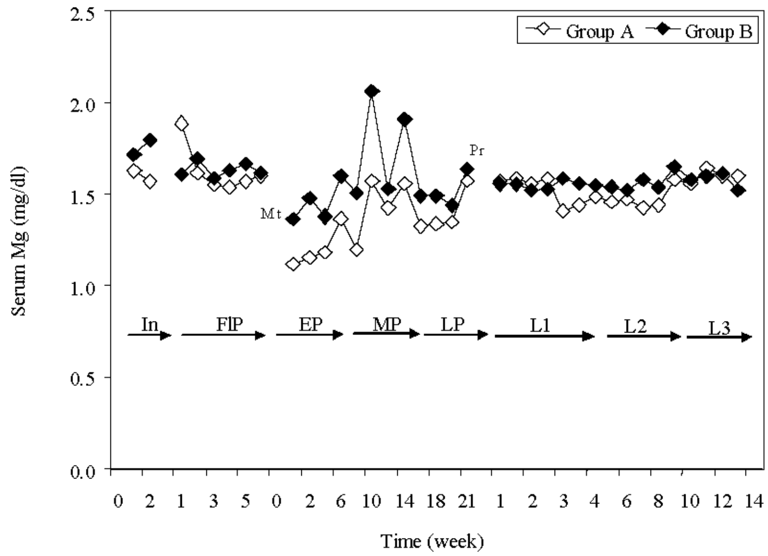

Fig. 5: Effects of dietary supplementation during different physiological states of ewes on serum magnesium (Mg) level

the initial values. The (Ca) level increased significantly ($P<0.05$) at parturition in both groups of ewes. The supplemented group showed a marked decrease in (Ca) level during the first month of lactation and then it tended to increase during the second month of lactation. During the third month of lactation, both groups showed a gradual decrease in (Ca) level. Fig. 3 also shows that the supplemented group maintained significantly ($P<0.05$) higher serum (Ca) level compared to the control during early gestation and in the third month of lactation.

Serum Phosphorus (P): Serum (P) level (Fig. 4) in supplemented group revealed significantly ($P<0.05$) higher value at the end of flushing period compared to the initial value, while (P) level was lower in the control group compared to the initial value. Both groups showed a significant ($P<0.05$) decrease in (P) level after mating. In both groups of ewes, there was a significant ($P<0.05$) decrease in (P) levels during late gestation compared to the initial value. During lactation, in both groups of ewes, there was a significant ($P<0.05$) change in serum (P) level; the (P) level measured during the second month of lactation was higher and the value measured during the third month was lower compared to the initial value. Supplemented ewes showed significantly ($P<0.05$) higher (P) level compared to the control during early gestation.

Serum Magnesium (Mg): The serum (Mg) level (Fig. 5) showed a significant ($P<0.05$) decrease during early flushing in supplemented group. After mating, there was a significant ($P<0.05$) decrease in (Mg) level in both groups. At parturition, there was a significant ($P<0.05$) increase in serum (Mg) level in both groups. During lactation, only the supplemented group showed a significant ($P<0.05$) decrease in (Mg) level during the third month of lactation compared to the value measured after parturition. Fig. 5 also indicates that the supplemented group had significantly ($P<0.05$) higher serum (Mg) levels compared to the control during early and mid gestation.

Serum Micro-Minerals: The results of the effects of dietary supplementation during different physiological states on serum concentrations of (Cu) and (Zn) are shown in Figs. 6 and 7, respectively. The details of statistical analysis of the results are presented in Table 3.

Serum Copper (Cu): In the supplemented group, serum (Cu) level (Fig. 6) increased significantly ($P<0.05$) after mating compared to the initial values. However, the control group showed a significant ($P<0.05$) decrease during early flushing, followed by a significant ($P<0.05$) increase after mating. In contrast to control group, the supplemented group showed a significant increase ($P<0.05$) in (Cu) level with the advance of pregnancy. Also it was noted that the values of (Cu) of both groups measured during pregnancy and lactation were almost similar to those obtained during flushing. The supplemented group maintained a significantly ($P<0.05$) higher (Cu) level compared to the control during early flushing, mid- and late gestation and at parturition.

Table 2. Effects of dietary supplementation during different physiological states on serum macro-minerals (Na, K, Ca, P, Mg) concentration of the ewes

	Na (mEq/L)		`K (mEq/L)		Ca (mg/dL)		P (mg/dL)		Mg (mg/dL)	
Physiological state	C	S	C	S	C	S	C	S	C	S
Initial	189.1^{Aba}±23.84	167.7^{Ab}±8.19	6.11 ^{Aa}±0.10	5.84^{Abcd}±0.10	8.13^{Aa}±0.25	8.25^{Aa}±0.12	4.80^{Abcd}±0.07	4.60^{Adac}±0.04	1.63^{a}±0.13	1.72^{Ab}±0.12
Flushing	208.2^{Ba}±14.48	238.9 ^{Aa}±11.57	5.55 ^{Acb}±0.10	5.57 ^{Aa}±0.07	7.82^{Aba}±0.09	7.93 ^{Ad}±0.08	4.52^{Adf}±0.07	4.63^{Abdac}±0.10	1.60^{a}±0.03	1.62^{Acb}±0.04
After mating	162.9^{Ab}±4.19	177.9^{Ab}±7.99	5.42^{Bcb**}±0.13	6.07 ^{Ab**}±0.07	7.34^{Ac}±0.08	7.58^{Ad}±0.06	4.44^{Aef}±0.12	4.58^{Ade}±0.05	1.16^{Bc}±0.05	1.37^{Ad}±0.05
Early gestation	173.0^{Ab}±7.52	189.0^{Ab}±3.82	5.77^{Bb}±0.15	6.11 ^{Aba}±0.11	7.29^{Bc**}±0.12	7.81^{Adc**}±0.06	4.26^{Bf}±0.07	4.76^{Abdac}±0.08	1.37^{Bb*}±0.09	1.60^{Acb*}±0.06
Mid gestation	163.7 ^{Ab}±4.17	169.0^{Ab}±9.00	6.26^{Aa}±0.08	6.38^{Aa}±0.09	7.90^{Aba}±0.13	8.14^{Aba}±0.11	4.80^{Abcd}±0.11	4.92 ^{Aba}±0.08	1.53^{Bba**}±0.03	1.93^{Aa**}±0.11
Late gestation	163.3^{Ab}±5.19	174.7^{Ab}±7.93	5.46^{Bcb*}±0.15	5.90^{Abcd*}±0.09	7.54^{Abc}±0.13	7.57^{Ad}±0.10	4.39^{Aef}±0.13	4.42^{Ae}±0.10	1.36^{b}±0.05	1.44^{Acd}±0.08
Parturition	183.4^{Aba}±9.29	181.6^{Ab}±5.55	5.73^{Ab}±0.12	6.00^{Abc}±0.17	8.01 ^{Aa}±0.05	8.29^{Aa}±0.10	4.90^{Abc}±0.09	4.88^{Abac}±0.08	1.57^{a}±0.05	1.64^{Acb}±0.03
1st month lactation	174.1^{Ab}±3.26	184.4^{Ab}±4.73	5.63^{Acb}±0.07	5.64 ^{Aed}±0.09	8.00^{Aa}±0.03	8.25^{Aa}±0.08	4.97^{Aba}±0.09	4.98^{Aa}±0.08	1.46^{ba}±0.04	1.54^{Acbd}±0.05
2nd month lactation	165.4^{Ab}±3.73	173.1^{Ab}±4.73	5.60^{Acb}±0.15	5.74 ^{Aecd}±0.12	8.03^{Aa}±0.10	8.07^{Abac}±0.05	5.20^{Aa}±0.10	4.99^{Aa}±0.10	1.58^{a}±0.07	1.65^{Acb}±0.03
3rd month lactation	185.4^{Aba}±3.04	183.4^{Ab}±3.38	5.32^{Bc*}±0.11	5.80^{Abecd*}±0.08	7.54^{Bba*}±0.13	8.27^{Aa*}±0.08	4.65^{Aecd}±0.15	4.88^{Abac}±0.18	1.60^{a}±0.06	1.53^{Acbd}±0.04

Means with in the same column bearing different superscripts (small) are significantly different at P< 0.05

Means with in the same row bearing different superscripts (capital) are significantly different at P< 0.05

* P< 0.01 ** P < 0.001 C: control group S: supplemented group

Table 3: Effect of dietary supplementation on serummicro-minerals (Cu, Zn) concentrations of the ewes during different physiological states

	Cu (mg/dL)		Zn (mg/dL)	
Physiological state	C	S	C	S
Initial	4.63^{Aba}±0.24	4.76^{Abc}±0.13	1.31^{Aa}±0.05	1.33^{Abdac}±0.04
Flushing	4.16^{Bb}±0.05	4.63^{Ac}±0.17	1.25^{Aa}±0.03	1.20^{Ae}±0.03
After mating	4.77^{Aa}±0.19	4.93^{Abac}±0.17	1.30^{Aa}±0.05	1.37^{Abac}±0.03
Early gestation	4.57^{Aba}±0.25	4.80^{Abc}±0.19	1.24^{Ba*}±0.05	1.43^{Aba*}±0.04
Mid gestation	4.66^{Bba}±0.25	5.16^{Aba}±0.14	1.17^{Aa}±0.04	1.26^{Adec}±0.03
Late gestation	4.71^{Bba*}±0.20	5.30^{Aa*}±0.11	1.20^{Aa}±0.05	1.22^{Ade}±0.04
Parturition	4.63^{Bba*}±0.16	5.20^{Aba*}±0.21	1.25^{Ba}±0.07	1.40^{Aba}±0.04
1st month lactation	4.73^{Aba}±0.16	4.91^{Abac}±0.17	1.30^{Ba}±0.05	1.44^{Aa}±0.04
2nd month lactation	4.73^{Aba}±0.07	4.46^{Ac}±0.11	1.27^{Aa}±0.04	1.31^{Abdec}±0.04
3rd month lactation	4.67^{Aba}±0.10	4.72^{Abc}±0.07	1.20^{Ba}±0.06	1.34^{Abac}±0.04

Means within the same column bearing different superscripts (small) are significantly different at P < 0.05

Paired means within the same row bearing different superscripts (capital) are significantly different at P < 0.05

* P < 0.01 C: Control S: Supplemented

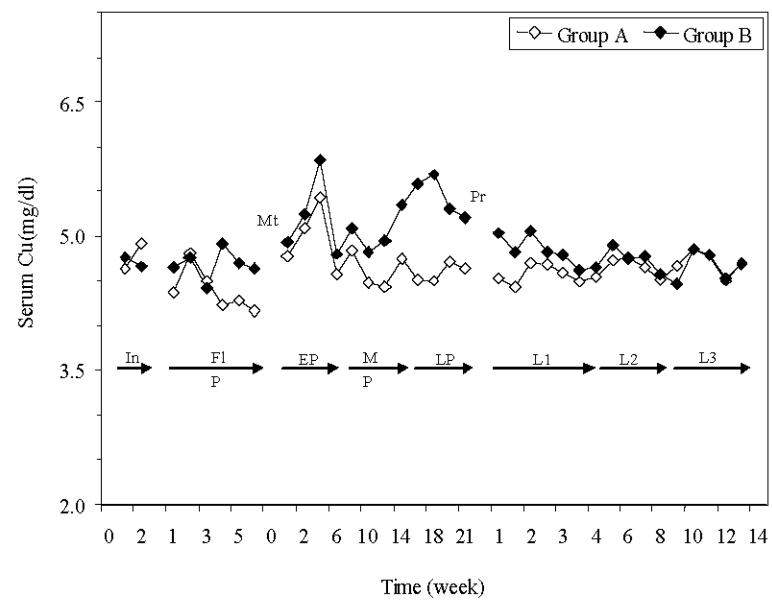

Fig. 6: Effects of dietary supplementation during different physiological states of ewes on serum copper (Cu) level

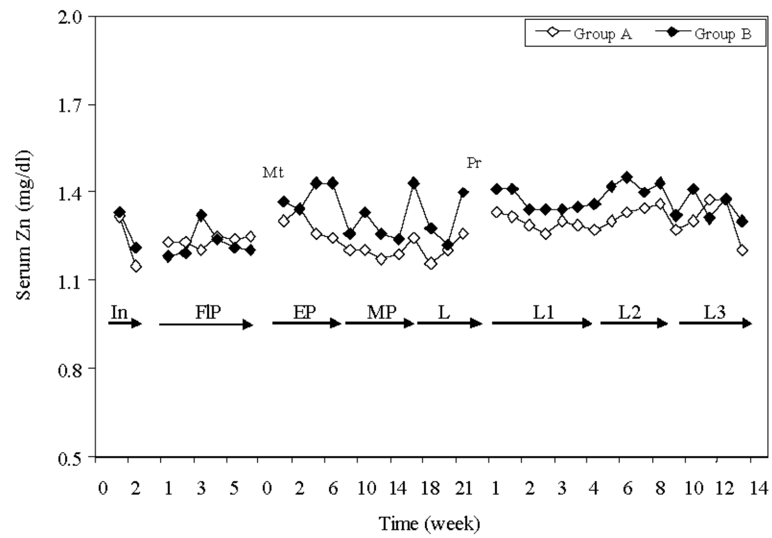

Fig. 7: Effects of dietary supplementation during different physiological states of ewes on serum zinc (Zn) level

Serum Zinc (Zn): In the supplemented ewes, there was a significant ($P<0.05$) decrease in serum (Zn) level during early flushing compared to the initial value and then it increased significantly ($P<0.05$) after mating. During gestation, there was a gradual decrease in (Zn) level to reach a lower value at late gestation and then it increased to reach a higher level during the first month of lactation. However, no significant changes were observed in (Zn)level in the control group during the experimental period. The supplemented group revealed significantly ($P<0.05$) higher values of serum (Zn) level compared to the control during early gestation, at parturition and during the first and second month of lactation.

DISCUSSION

In this study, the serum mineral profile of Desert ewes was investigated systematically during normal cycling, pregnancy and lactation in control and treated group receiving supplemental concentrate and mineral premix. The extended improvement of the plane of nutrition of supplemented ewes and the monitoring of physiological responses provided a detailed account, which facilitated critical evaluation of the changes that occurred in mineral profile in desert ewes. The results indicate that pregnancy and lactation were associated with changes in the profiles of macro- and micro-minerals in Desert ewes.

Response During Pregnancy: The marked decrease in serum (Na) level during pregnancy compared to the values measured during early flushing period in both groups of ewes (Fig. 1) could be related to the changes in renal regulation of water and electrolyte balance. Pregnancy alters (Na) excretion via changes in renal perfusion, glomerular filtration rate (GFR) and proximal tubular morphology [23-25]. The gradual decrease in (Na) level during pregnancy in the present study could be related to increase in (Na) loss in urine due to the effect of progressive increase in progesterone level. Previous workers [26, 27] reported an increase in (Na) excretion during progesterone administration and they suggested that progesterone might antagonize aldosterone action in the kidney tubules. Furthermore, it has been reported [28] that even at low or high level of (Na) intake during pregnancy in sheep, there was an increase in urine output (73%) and most of the increase in urine excretion occurred during the last stage of pregnancy. Also the decrease in serum (Na) level during pregnancy may partly be related to the increase in foetal demands. An increase in accumulation of (Na) in the foetal lamb tissues during pregnancy [29]. The higher serum level of (Na) during the flushing period and gestation in supplemented ewes compared to the control is attributed to the supply of salt lick (36 % NaCl) to supplemented ewes resulting in marked increase in (Na) intake.

In both groups of ewes, the serum (K) level (Fig. 2) increased gradually with the advance of pregnancy to reach a peak level at mid -gestation; the (K) level tended to decrease during late gestation up to parturition. These changes in (K) level during pregnancy could be related to the antagonizing effects of aldosterone and progesterone. Aldosterone increases renal (K) excretion in mammals [30]. During the last week of pregnancy in ewes, while plasma progesterone level decreases, the plasma aldosterone level increases [31]. This pattern of endocrine response may explain the decrease in (K) level observed during the last weeks of pregnancy in the present study. Furthermore, it was noted that the supplemented ewes had higher serum (K) level compared to the ewes kept only on grazing. Since the supplemented ewes received additional (Na) salt during pregnancy, it is possible to explain the higher (K) level in supplemented group by hormonal changes associated with increase in (Na) intake. It has been reported [28] that plasma aldosterone level remained low throughout pregnancy in ewes maintained on high (Na) intake.

During pregnancy, the concentrations of (Ca), (P) and (Mg) (Figs. 3, 4, 5) remained within the normal ranges reported previously by other workers [32-34] when sheep were kept indoor and fed hay ad-libitum with concentrate supplementation. Nevertheless, there were significant changes in these minerals with the advance of pregnancy. The serum (Ca) level is controlled by a sensitive hormonal mechanism involving the hydroxylated metabolites of vitamin (D), parathyroid hormone and thyrocalcitonin [30, 35]. The present results indicate that in both groups of ewes, serum (Ca) level fluctuated during pregnancy (Fig. 3). The enlargement of the parathyroid gland during pregnancy causes (Ca) mobilization from the mother bones, maintaining normal (Ca) level in the mother intracellular fluids as the foetus removes (Ca) for ossifying its owns bones. Accordingly, the significant increase in (Ca) level during mid- gestation could be related to increase in (Ca) mobilization from the skeleton to meet the higher demand of (Ca) [36, 37]. Moreover, oestrogens increase (Ca) retention and in the process, plasma (Ca) may be increased [38]. As a result of (Ca) mobilization, the plasma (Ca) level increased, presumably as the mechanism for (Ca) homeostasis adapted to increasing skeleton drain [39]. Since hydroxyproline concentration in the plasma is an index of the activity of bone resorption and Sansom *et al.* [33] reported a sharp increase in hydroxyproline level at the time of lambing, the marked increase in serum (Ca) level obtained during mid -gestation and at the time of parturition could be related to (Ca) mobilization from the mother. The decrease in serum (Ca) level during late gestation may be related to an increase in the rate of movement of (Ca) out of the blood plasma which is not balanced by increase in the rate of absorption of (Ca) from the gut or bone [33, 36, 37]. Previous results [36, 37] indicated that the lowest concentration of (Ca) occurred in late gestation, at the time when there is a marked increase in the need of foetal skeleton for mineralization. The supplemented group of ewes showed higher (Ca) level compared to the control group during early flushing and during pregnancy; the difference was significant only during early pregnancy. These changes can be attributed to the fact that despite plentiful dietary intake of (Ca), the ewes were unable to absorb sufficient amount of (Ca) during mid- and late gestation. It has been pointed out [36, 37] that the rate of absorption of (Ca) from the intestine increases in early pregnancy and decreases with the advance of pregnancy and they added that endogenous loss of (Ca) increases with the advance of pregnancy.

Phosphorus (P) is also required in large quantities for skeleton mineralization. The present results indicate that the serum (P) level was significantly lower during late stage of pregnancy and it increased at lambing. Previous reports [36, 37] attributed a similar decrease in serum (P) level during late pregnancy to an increase in the rate of mobilization of (P) out of maternal circulation into the foetus, which was not balanced by increase in the rate of (P) absorption from the gut or in the rate of resorption of (P) from the bones of dam.

In the present study, dietary supplementation did not affect the serum (P) level during flushing and pregnancy. This is presumably due to the fact that the extra (P) absorbed was not used to meet the higher demands during pregnancy, but was instead excerted in urine and faeces. In sheep, the concentration of plasma (P) and the rate of salivary secretion were responsible for endogenous faecal excretion of (P) and regulation of (P) balance [40]. The significant difference in (P) level between the groups of ewes obtained during early pregnancy is reasonable, as Braithwaite *et al.*, [36, 37] reported that during pregnancy in sheep, absorption and demands of (P) increased and the endogenous loss of (P) in urine and faeces increased. Many factors associated with diet composition can affect minerals utilization and bioavailability. The serum (Mg) level is influenced by the levels of protein [41] as well as (Ca) and (P) [42] in the diet. In the current study, the serum (Mg) level decreased during early pregnancy in both groups of ewes (Fig. 5). Thereafter, the (Mg) level increased with the advance of pregnancy, before decreasing during late pregnancy. This pattern of change may not be explained in terms of an imbalance between supply and demand. However, factors influencing the absorption of (Mg) from the gut, which include dietary protein and ammonia contents, could be implicated. The changes in serum (Mg) level may not be explained by the reciprocal relation with serum (Ca) level, as the levels of both minerals decreased during late pregnancy, contrary to the established occurrence of hypomagnesaemia in some cases of milk fever [43]. Therefore, the decrease in serum (Mg) level is presumably related to haemodilution which usually occurs during late pregnancy.

Serum (Cu) level (Fig. 6) increased during pregnancy in both groups of ewes compared to the values measured during early flushing period. This could be related to the high progesterone level or to the foetal demand and utilization of maternal (Cu) for the development of the nervous system. Pregnancy is usually associated with an increase in plasma (Cu) level in the from of ceruloplasmin [44, 45]. The administration of oestrogen in female rats [46] increased plasma (Cu) level. The major way of homeostatic control of trace elements for certain essential divalent cations is modification of the percentage of intestinal absorption in response to physiological need and dietary intake [47]. The levels of sulphur (S) and molybdenum (Mo) are the major dietary factors that influence (Cu) requirements. In this study, the serum (Cu) level was slightly higher in supplemented ewes compared to the control. This difference in (Cu) level could be attributed to the diet effect. According to previous studies [48], the variation in plasma level of (Cu) in ruminants could be related mainly to differences in dietary source. Moreover, the amount and the composition of dietary supplementation were kept almost constant throughout the experimental period.

The serum (Zn) level (Fig. 7) decreased gradually with the advance of pregnancy in both groups of ewes. However, the (Zn) level was slightly higher during pregnancy compared to the value obtained during early flushing period. This could be related to the increase in the rate of accumulation of (Zn) in the foetus. Williams *et al.*, [49] showed that the developing foetus accumulates 1 to 2 mg of (Zn) /day and the pregnant ewe increases the demands for (Zn) towards the end of pregnancy. Moreover, other reports [50, 51] have shown that pregnancy results in depletion of (Zn) in grazing ewes. The marked decrease in the serum (Zn) level during late gestation in Desert ewes could be partly related to haemodilution.

The results indicate that the supplemented group of ewes had slightly higher serum (Zn) level compared to the control. Since the supplemented ewes received salt lick (120mg Zn/Kg), the reported difference suggests that the supplemented ewes could provide the foetus with sufficient amount of (Zn) without mobilizing its own body stores. There is also evidence in sheep and cattle that the (Zn) status and intake affect (Zn) absorption from the gut [52, 53]. The results of the current study suggest that a combination of low nutritional status and pregnancy in non- supplemented ewes may increase the efficiency of utilization of ingested (Zn) Furthermore, the absorption of (Zn) from the gut is affected adversely by high dietary (Ca) level and the presence of phytate further aggravates it [54].

Response During Lactation: The serum levels of (Na) (Fig. 1) in both groups of ewes showed a slight gradual decrease during the first month of lactation. This pattern of reduction is most likely a consequence of loss of this element in colostrum and milk. In mammals, the aqueous phase of colostrum contains high concentrations of the main ions (Na and Cl) [55]. Also milk is especially rich in salts to maintain osmotic equilibrium in milk [56]. Accordingly, Underwood [42] indicated that the lactating animal has higher salt requirements. Although, in the present study, the (Na) level showed a slight progressive decrease during the second and third month of lactation, the serum (K) level tended to increase gradually. This could be related to the maintenance of a constant ratio of (Na) to (K) in the extracellular fluid. Moreover, during lactation in goats there was a decrease in (Na) content of milk, while (K) content increased [57].

In the current study, there was a tendency for serum levels of (Ca) and (P) to decrease with the progress of lactation (Figs. 3 and 4, respectively). This could be related to the excretion of both elements into milk. Several workers have previously reported a marked increase in the secretion of (Ca) and (P) in milk during lactation in sheep [36, 37, 58]. However, the observed higher serum (Ca) and (P) levels during lactation compared to the values measured during pregnancy may reflect the higher demands for minerlization of foetal skeleton. Moreover, absorption of (Ca) and (P) was much greater during lactation than during gestation [59]. Furthermore, prolactin may also be involved in (Ca) metabolism during lactation. This hormone can increase intestinal absorption of (Ca) [60] and may regulate (Ca) metabolism independent of vitamin (D) [61]. Also the increase in (Ca) and (P) levels during lactation could partly be related to relief of blood from haemodilution which occurs usually during pregnancy.

The results of the present study also indicate that there was no significant difference between the two groups of ewes in serum levels of (Ca) and (P) during lactation. This could be related to increase in the rate of secretion of (Ca) and (P) into the milk associated with decrease in the absorption in supplemented group, because of the limitation on absorption. The maintenance of serum (Ca) level in the control group may reflect a higher efficiency of (Ca) absorption during lactation. In lactating Suffolk ewes, the efficiency of absorption of dietary (Ca) was higher from the restricted (Ca) and (P) diet than from the plentiful diet throughout lactation [36]. It has been reported [62] that both concentrate supplemented ewes and non-supplemented ewes showed the same degree of negative (Ca) and (P) balance during lactation. Feeding high levels of (Ca) and (P) before parturition may suppress parathyroid hormone and 1,25- dihydroxy cholecalcifenol synthesis [63]. This in turn will favour a reduction in the level of (Ca) binding protein in the gut and a consequent decrease in (Ca) absorption.

The main factors involved in the control of plasma (Mg) level are absorption and excretion [64]; hence dietary (Mg) mostly meets the maternal demands for milk production. In the present study, there was no significant change in (Mg) level in both groups of ewes; the level of (Mg) was almost steady throughout lactation. Rahman and Boqi [65] reported that there was no significant difference in plasma (Mg) level between lactating and non-lactating cows. The slightly higher serum (Mg) level (Fig. 5) in supplemented ewes during the first and second months of lactation compared to the control group could be related to the inclusion of mineral salt lick in the concentrate diet.

The present study showed that lactation influenced the levels of serum micro-minerals of Desert ewes. In both groups of ewes, the serum (Cu) levels were lower during lactation compared to the respective values obtained during pregnancy (Fig. 6). This could be related to the responses of the ewes to the needs of the foetus by increasing mobilization of stored (Cu) to the circulation. The foetus needs the maternal (Cu) for the development of the nervous system [66]. Moreover, supplementation of (Cu) to the mother resulted in excessive storage of (Cu) in the liver of the newborn [67]. Also the present results may be attributed to hormonal effects. Previous studies [46] indicated that administration of oestrogens or progesterone increased plasma (Cu) levels. However, the present results indicated that the serum (Cu) levels measured during lactation were almost similar to the values obtained during the initial and early flushing periods. This could be related to the minor role of (Cu) in milk synthesis and to the fact that milk is deficient in most of the micro-minerals. The serum (Cu) level was slightly higher in supplemented ewes compared to the control ewes. This could be attributed to the diet effect. The level of supplemented concentrate was kept constant during experimental period. According to Underwood [48], the variation in plasma level of (Cu) in ruminants could be attributed to the changes in dietary content of (Cu).

In the present study, the serum (Zn) level was higher during lactation compared to the values measured during early flushing period (Fig. 7). This indicates a higher requirement of lactating ewes for (Zn) as previously reported [51]. The present results also showed higher serum (Zn) concentration during lactation compared to the values measured during mid- and late gestation, which reflects the low absorption capacity of (Zn) in pregnant ewes. The apparent absorption of (Zn) was higher and more consistent for lactating ruminants in comparison to non-lactating ruminants [68]. The increase in serum (Zn) level during lactation also could be associated with the changes in serum albumin level which was reported to be higher during lactation [69]. Davies [70] indicated that (Zn) is bound primarily to albumin; the changes in albumin concentration may have a significant effect on (Zn) level. The author added that the level of circulating (Zn) reflects both serum albumin level and the affinity of albumin for (Zn).

CONCLUSION

The study indicates that the mineral profile in desert ewes is affected by physiological states including pregnancy and lactation. The pattern of changes was influenced by dietary supplementation .The provision of salt lick can improve the mineral status of ewes particularly when exposed to nutritional and physiological stress. Further research is needed to assess the status under natural field conditions. Also critical investigations should provide information regarding to actual mineral requirements of sheep so that appropriate nutritional strategies can be adopted and deficiencies can be managed.

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