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TRACE ELEMENTS AND HEAVY METALS IN HEALTHY CAMEL BLOOD OF UNITED ARAB EMIRATES

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ABSTRACT

In the present paper, 240 camels were sampled for the determination of trace elements and different heavy metals. The variation factors included age, sex and physiological status which were assessed for some parameters. On the average, the mineral contents were 190.3 µg/100ml (iron), 60.1 µg/100ml (copper), 44.0 µg/100ml (strontium), 22.5 µg/100ml (arsenic), 20.0 µg/100ml (zinc), 19.7 µg/100ml (selenium), 19.3 µg/100ml (boron) and 14.6µg/100ml (barium). Other minerals like aluminium (3.7 µg/100ml), molybdenum (2.9 µg/100ml), chromium (2.0 µg/100 ml), nickel (1.8 µg/100ml), lead (1.5 µg/100ml), manganese (0.16 µg/100ml), cobalt (0.08 µg/100ml) and cadmium (0.07 µg/100ml) were in very small concentration.

Key words : Blood, camel, heavy metals, trace elements, UAE

The main trace elements in camel blood (copper, zinc, iron) were commonly determined in several countries where camel is an important part of the livestock economy. Some reviews are now available in the literature (Faye and Bengoumi, 1994; Abu Damir, 1998; Faye and Bengoumi, 2000). Normal ranges and deficiency status are described in numerous cases. However, the data on other trace elements and some heavy metals are scarce. The importance of those other trace elements and their potential toxicity is more and more described in other species as small ruminants and cattle. In camel, the references are very few or, for some elements, are non-existent in published papers. In United Arab Emirates, the racing camel has a central cultural place in the leisure of population. The racing activity has a strong effect on the metabolism and physiology of the camel (Rose *et al*, 1994). Those animals have specific mineral requirements under effort. The determination of a wide type of trace elements could be beneficial for a better understanding of the specific physiology of sport animal in desert conditions.

In the present paper, copper, zinc, iron which are classically determined in camel blood are enriched by the determination of other minerals as aluminium, arsenic, boron, barium, cobalt, chromium, cadmium, manganese, molybdenum, nickel, selenium, strontium and lead. Some of these elements are biologically essential, some others are potentially toxic.

Materials and Methods

Animals

The animals were provided by Al-Ochouche farm at Al-Ain Emirates including 3000 dromedary camels (*Camelus dromedarius*) in extensive management of three breeds adapted to race: local, Sudanese and crossbred. As the whole, 240 animals between 2 and 10 years old were randomly selected for the present study. Before blood collecting, a general examination of all the selected camels was achieved and only healthy animals were retained. To discard the animals with trypanosome, common disease in Arab Emirates, a diagnosis was performed by three different tests: mercury chlorate test, agglutination test and blood examination test according to Woo method (Woo, 1971). Each positive animal at one of the test was discarded. A faecal examination for internal parasites was done by floating method (Soulsby, 1982).

Finally, the analyses were achieved in 235 animals. The camel samples were shared into two groups according to the gender. The sample included 83 males and 152 females; a part of the she-camels was pregnant (n = 68), 55 non pregnant and 29 lactating. Each dromedary camel was identified by a number tied to the neck. The males and females animals

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were distributed into 3 age classes i.e., 3-4 years, 5-7 years and 8 years and more. The males were mainly less than 4 years old (n = 51) or mature breeding animals more than 8 years old (n = 32). Females less than 4 years old were 49. The number of females in other classes was 97 (class 5-7 years) and 6 (8 years and more). On the whole population, 156 were local breeds, 6 Sudanese only and 73 crossbreed.

Animals were fed with a basal diet including green alfalfa, commercial concentrate, dates and a mixture of three types of lentils. They were watered *ad libitum*. No specific mineral supplementation was given for the experimental time except selenium and vitamin E which were regularly introduced in the commercial supplement.

Blood Sampling

The blood samples were collected aseptically from the jugular vein in two 10 ml tubes without EDTA. Those samples were carried later to the laboratory for analyses performed immediately after collecting.

The collected samples were centrifuged at 4300 rpm for 5 min. The main trace elements (Zn, Cu, Fe) were determined after separation of serum by atomic absorption spectrophotometer according to the classical method of Bellanger and Lamand (1975) using kit (Dade Boehring, USA). Those analyses were achieved at the Veterinary Lab of Agricultural Department at Al-Ain, U.A.E.

The other mineral analysis (Al, As, B, Ba, Cd, Co, Cr, Mn, Mo, Ni, Pb, Se, Sr) were achieved on serum stored at 4°C before analysis according to the Brown and Watkinson method (1977). The samples were digested for destroying proteins and amino acids in order to separate the minerals linked to proteins. This first step was performed at the private department of H. H. Sheikh Zayed Bin Sultan Al-Nahyan, in the Scientific Centre of Racing Camel, Al-Ain. The concept is to mix in the 6 tubes of the rotator in a microwave digestor, 2ml serum, 6ml hydrogen peroxide (H_2O_2) at 30%, then 1ml nitric acid (HNO_3) at 60%. The tubes are placed in the rotator by increasing order from 1 to 6 and well tightened, then introduced in the apparatus. After serum digestion, the sample was poured in sterile tube, then exported to Al-Salamate lab analysis -Al Ain for determining the minerals with an ICP (Induced coupled plasma Varian Vista MPX-CCD).

Statistical analysis

The differences between groups (age classes, sex groups, physiological status groups, breeds) were tested by variance analysis according to the procedure General Linear Models (GLM) with R software©. If the probability (p) was below 0.05, the differences between groups were considered as significant. The correlation of Pearson between the analysed elements was calculated. The interactions between variation factors were taken in account in statistical models.

Results

To facilitate the comparison, all the results are expressed in µg/100ml. On average, the main trace element in camel serum were iron (190.3 µg/100ml) followed by copper (60.1 µg/100ml), strontium (44.0 µg/100ml), arsenic (22.5 µg/100ml), zinc (20.0 µg/100ml), selenium (19.7 µg/100ml), boron (19.3 µg/100ml) and barium (14.6µg/100ml). Other minerals like aluminium (3.7 µg/100ml), molybdenum (2.9 µg/100ml), chromium (2.0 µg/100 ml), nickel (1.8 µg/100ml), lead (1.5 µg/100ml), manganese (0.16 µg/100ml), cobalt (0.08 µg/100ml) and cadmium (0.07 µg/100ml) were in very small concentration.

Age effect (table 1)

There was no observed age effect on Al, Ba, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb and Sr. When an age effect was reported (table 1), the young adult animals (5 to 7 years old) had a significant higher concentration of arsenic (28.3 µg/100 ml), boron (35.8 µg/100 ml) and selenium (28.1µg/100 ml). The oldest animals more than 8 years old had highest values of iron (283 µg/100ml). However, the differences between age groups were low. Concerning zinc, a significant lower value was reported in group 2 (5-7 years old).

Sex effect (table 2)

Some elements (As, Ba, Cd, Co, Cr, Mn, Mo, Pb) had similar values between sex. Females had significant higher values of boron (23.3 µg/100 ml), copper (61.9), selenium (22.9) and strontium (47.6). Aluminium was also slightly higher in female (4.6 µg/100 ml). Iron value was significantly higher in male (213.1 µg/100ml), as far as zinc (24.3 µg/100 ml). Nickel was slightly higher in male also (2.0 vs 1.7).

Physiological status effect (Table 3)

As for former variation factors, no effect of the physiological status was observed for Cd, Co, Cr, and Mo. Elsewhere, Ba, Cu, Mn, and Ni did not change according to the status of the female (non pregnant, pregnant or milking). In non pregnant animals, strontium (52.9 µg/100ml), iron (189.1µg/100ml) and zinc (27.3 µg/100ml) were in higher concentration

Table 1. Mean values of trace elements and heavy metals in camel serum according to age groups (in µg/100ml).

Groups	Al	As	B	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Sr	Zn
3-4 y	2.1	18.7	7.1	15.4	0.06	0.07	2.5	57.7	174.1	0.20	3.0	1.8	1.6	14.1	44.0	25.6
5-7 y	6.6	28.3*	35.8**	14.5	0.09	0.02	1.6	62.9	171.5	0.07	3.6	1.7	1.2	28.1**	44.6	12.1**
>7 y	0.7	17.9	9.3	12.7	0.16	0.28	1.8	59.0	283.8**	0.29	1.2	1.9	1.8	12.4	42.3	25.1

Table 2. Mean values of trace elements and heavy metals in camel serum according to sex groups (in µg/100ml).

Groups	Al	As	B	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Sr	Zn
Male	2.1	22.3	11.9	14.7	0.17	0.16	2.6	56.7	213.1**	0.24	2.2	2.0*	1.7	13.6	37.4	24.3**
Female	4.6*	22.6	23.3**	14.6	0.02	0.04	1.6	61.9**	177.8	0.12	3.3	1.7	1.3	22.9**	47.6**	17.6

Table 3. Mean values of trace elements and heavy metals in camel serum according to physiological status groups (in µg/100ml).

Groups	Al	As	B	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Sr	Zn
No-Preg	1.0	12.7	1.3	14.7	0.02	0.06	1.8	60.2	189.1*	0.19	2.9	1.7	1.6*	13.8**	52.9**	27.3**
Pregnant	5.1	26.5	29.1	15.7	0.03	0.03	1.6	64.7	174.7	0.10	2.5	1.7	1.7	28.1	45.9	13.5
Milking	10.2**	32.4**	51.7**	11.7	0.00	0.00	1.5	58.9	163.9	0.00	6.2	1.9	1.7	28.2	41.5	8.9

Table 4. Mean values of trace elements and heavy metals in camel serum according to breed groups (in µg/100ml).

Groups	Al	As	B	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Sr	Zn
Local	4.3	23.8*	22.7	14.6	0.06	0.07	2.1	61.0	198.3	0.12	2.5	1.8	1.4	19.6	45.1	19.0
Cross breed	2.0	19.8	11.7*	14.8	0.02	0.02	1.7	58.3	176.3	0.21	3.7	1.7	1.4	19.5	40.6	22.0
Sudanese	9.7	21.5	22.7	13.9	0.24	0.28	1.9	58.4	153.4	0.54	5.8	1.9	3.2	20.9	56.4	21.0

* $p < 0.05$; ** $p < 0.01$

in plasma while selenium was significantly lower (13.8 µg/100ml). In pregnant animals, values of copper were slightly higher but were nonsignificant (64.7 µg/100ml). In milking animals, significantly higher values of arsenic (32.4 µg/100ml), boron (51.7 µg/100ml) and aluminium (10.2 µg/100ml) were observed.

Breed effect (Table 4)

Few elements change according to the breed. The observed differences were slightly significant. Boron is slightly lower in crossbreed group (11.7 µg/100ml vs 22.7 µg/100 ml in other groups). Arsenic was also lower in crossbreed group (19.8 µg/100ml vs 23.8 and 21.5 in the other breeds).

Interactions

The interaction between age and sex was observed for boron and selenium only ($p < 0.01$), essentially because no males belonged to age group 2 where highest values of B and Se were observed.

Discussion

Except for copper, zinc, iron and in a less extent selenium, the references concerning trace element concentrations in camel blood, serum or plasma are quite marginal. The discussion will concern first the main trace elements as copper, zinc, manganese, iron and selenium, secondly the rarely analysed trace elements (aluminium, boron, barium, chrome, cobalt, molybdenum, nickel and strontium) and last the toxic minerals (arsenic, cadmium, lead).

The main trace elements

Serum or plasma copper : is a good reflect of copper intake. In ruminants, normal copper concentrations are between 70 to 120 µg/100ml (i.e. 12 and 19 µmol/l). Most of the reported values in camel are inside those thresholds (Faye and Bengoumi, 1994). With a mean value close to 60 µg/100ml, the copper status of the camel in our study is at the deficiency limit. In the literature, no significant variation due to sex was reported (Abdalla *et al*, 1988; Bengoumi *et al*, 1995), but the change along the gestation was observed (Liu *et al*, 1994) with a decrease of copper concentration at the end of pregnancy, contrary to our results. The results concerning age effect are contradictory: significant differences were not observed (Faye and Mulato, 1991; Bengoumi *et al*, 1995) higher value on camels more than 5 years old were observed (Marx and Abdi, 1983) which was in consonance to the present study.

As for copper, zinc concentration in plasma or serum for most of the ruminants is between 70

and 120 µg/100ml. The present results confirm that it is not the same for camel as it has already been published. Indeed, normal values in camel are around 30 to 50 µg/100ml (Faye *et al*, 1992). In the present study, the zinc values are below these limits in most of the cases and vary between 0.2 and 115 µg/100ml. Low values were already reported in Emirates (Abdalla *et al*, 1988) and zinc deficiency was commonly suspected in the camel stock from this part of the world.

The age and sex variations of plasma or serum zinc were rarely reported. Young camels below 2 years have generally lower values (Faye *et al*, 1995). The highest values observed by some authors on non weaning camel calves are due to the milk feeding which provides sufficient zinc in the diet. A decrease of zinc concentration was observed at the end of gestation in some studies (Faye and Mulato, 1991) similar to the observations of present study. This decrease could be linked to an active transfer of plasma zinc to the foetus. In Bactrian camel, similar trends are observed in pregnant animals (Liu *et al*, 1994). In our sample, the values in milking camel are very low, but no clinical symptoms of zinc deficiency were observed. These very low values, probably due to zinc transfer into the milk, could explain the sex difference reported in our sample, the lowest values being reported in milking animal. A recent study has shown an active transfer of zinc in camel milk (Cattaneo *et al*, 2005).

Manganese can be a limiting factor of the mineral diet in ruminants and deficiencies can be locally present according to the low values of some grasses in southern countries (Faye *et al*, 1986). Usually the quantity of manganese in blood is very low and can be detected only recently with high accuracy with the latest sophisticated apparatus as ICP. The mean values reported in the literature vary from 8.4 µg/100ml in Morocco (Bengoumi *et al*, 1994) to 30 µg/100ml in Egypt (Eltohamy *et al*, 1986). In ruminants, the values of blood manganese concentration are generally below 10 µg/100ml (Lamand, 1987). No variations factors were reported in the literature. In our sample, the values are effectively very low with a wide range (1.64 + 6.69 µg/ml) and very slight difference was observed according to physiological status. Probably, the transfer to foetus, then to milk could explain the low plasma values in pregnant and milking female.

Iron is a common element of the nature, especially in tropical conditions. It is the most important element in the blood which contributes to haemoglobin composition. The references on plasma, serum or whole blood iron in camel are common. In serum, the values vary on average from 98 µg/100ml (Tartour and Idris, 1970) to 186 µg/100ml (Moty *et al*, 1968). In Emirates, Abdalla *et al* (1988) reported mean values at 113 µg/100 ml. Our results are in the upper limit of those published data.

As for other main trace elements, iron decreased in pregnant and milking camel (Eltohamy *et al*, 1986). However, this change is not significant in our results. The iron concentration is generally higher in adult camels (Marx and Abdi, 1983; Shekhawat *et al*, 1987; Ghosal and Shekhawat, 1992) as in our sample. Concerning sex effect, the results in the literature are quite contradictory (Faye and Bengoumi, 1994). Our results mentioning a higher mean value in males are only in accordance with those of Hussein *et al* (1997).

The selenium deficiency was described in young camel by several authors (Finlayson *et al*, 1971; Hamliri *et al*, 1990; Musa and Tageldin, 1994). In whole blood, Hamliri *et al* (1990) reported values between 10.9 and 11.8 µmg/100 ml in Morocco. Age or sex effect was not observed. Similar values involving Bactrian camels were published in China (Liu *et al*, 1994) with 9.7 to 11.4 µg/100 ml. Higher values (28.1 µg/100 ml) were observed in camel plasma from Oman (unpublished data).

In a trial including a supplementation period (Bengoumi *et al*, 1998), the mean plasma selenium concentration in camel was 2.1 µg/100 ml (before supplementation), 12.9 µg/100 ml (during supple-mentation) and 8.3 (after supplementation period). The maximum mean value was observed the day before the end of supplementation period: 20.1 µg/100ml. According to Liu *et al* (1994), selenium concentration did not change according to the physiological status. In Emirates, selenium supplementation in pregnant camels was common. This practice explained the highest values reported in pregnant and milking females, and in age group 2 (due to interaction between sex and age).

Rare trace elements and heavy metals

The cobalt concentration is generally very low in the plasma (Lamand, 1987). There is no data on cobalt in dromedary camel blood. Some results are available in Bactrian camel from Mongolia and China. According to Burenbayar (1989), cobalt concentration in blood varied from 3.4 to 13.2 µg/100 ml according to the season and mineral supplementation but the analysis method was not given. By atomic absorption spectrometry, Liu *et al* (1994) reported blood cobalt

concentration at 39 µg/100 ml in non-pregnant camel, 56 µg/100 ml in pregnant female and 53 µg/100 ml after parturition, without significant difference. These values are quite higher than our results (0.08 µg/100 ml in average). The analysing method could be debatable for the previous studies.

Molybdenum is generally in competition with copper. Excess of molybdenum associated with sulphur is known to decrease copper digestibility in ruminants. Some cases of molybdenosis were described in camels grazing bush with Salvadora persica as predominant plant (Faye and Mulato, 1991). In Bactrian camel blood, molybdenum concentration was between 19 to 23 µg/100ml according to Liu *et al* (1994) and 0.43 to 0.53 µg/100 ml only for Ma (1995). Our values are intermediate between those published results. No pregnancy effect was observed in Bactrian camel (Liu *et al*, 1994).

No nickel plasma values were reported in camel, in spite of the recent interest for nickel in ruminants. In Mongolia, a "roll disease" linked to nickel intoxication was described in Bactrian camel (Tao *et al*, 1995).

Lead is a toxic element which can have an interest as indicator of environment pollution. No case of lead intoxication was described in camel. Elamin and Wilcox (1992) reported lead concentration in camel milk from Saudi Arabia: 180 µg/g DM that seems considerable. In cow blood, lead concentration is generally between 0.6 and 4.8 µg/100ml (Jeffrey *et al*, 2003).

No data was available for the other elements in camel. Aluminium, chromium and strontium were analysed in muscle and hump fat, but only traces were observed. In dairy cow, blood concentration of chromium in non supplemented animals was between 0.33 and 0.42 µg/100ml according to Pechova *et al* (2002). Generally in cow, cadmium is below 0.1µg/100 ml.

Conclusion

Except for the main trace elements, very few data or even no data are available to compare those results to the literature concerning camel. The camel seems to be less efficient than other ruminants as the goat to detoxify its organism (Al-Qarawi and Ali, 2003), so the sensitivity of camel to some toxic elements could be more important. It is expected that other determinations of heavy metals and toxic elements in blood and other biological fluids will be achieved to enlighten the standard values in this species.

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References

Abdalla OM, Wasfi IA and Gadir FA (1988). The Arabian race normal parameters. I. Haemogram enzymes and minerals. Comp. Biochem. Physiol. 90A:2337-239.

Abu Damir H (1998). Mineral deficiencies, tonicities and imbalances in the camel (*Camelus dromedarius*): A review. Veterinary Bulletin 68:1103-1119

Al-Qarawi AA and Ali BH (2003). Variations in the normal activity of esterases in plasma and liver of camels, cattle, sheep and goats. Journal of Veterinary Medicine A 50:201-203.

Bellanger J and Lamand M (1975). Méthodes de dosage du cuivre et du zinc plasmatique. Bull. Tech. CRZV. Theix Inra 20:53-54.

Bengoumi M, Faye B and Tressol JC (1994). Composition minérale du lait de chamelle du sud marocain. Actes de l'atelier "Chameaux et dromadaires, animaux laitiers", Nouakchott, Mauritanie 24-26 Oct.

Bengoumi M, Faye B, Elkasmi K and Tressol JC (1995). Facteurs de variation des indicateurs plasmatiques du statut nutritionnel en oligo-element chez le dromadaire au Maroc. II. Effect d une complementation minerale. Rev. Elev. Med. Vet. Pays. Trop. 48: 277-280.

Bengoumi M, Essamadi AK, Tressol JC, Charconac JP and Faye B (1998). Comparative effect of selenium concentration and erythrocyte gluthatione peroxidase activity in cattle and camels. Animal Science 67:461-466.

Brown MW and Watkinson JH (1977). An automated fluorometric method for the determination of nanograms quantities of selenium. Anal. Chem. Acta. 89:29-35.

Burenbayar R (1989). Supply of trace-elements for female camels in Mongolia. VIth Int. Trace-element symp., Leipzig, DDR, 2.

Cattaneo D, Dell'Orto V, Fava M and Savoini G (2005). Influence of feeding on camel milk components. Proceedings of Intern. Workshop, " Desertification combat and food safety : the added value of camel producers". Ashkabad (Turkménistan), 19-22 april 2004. In "Vol. 362 NATO Sciences Series, Life and Behavioural Sciences". B. Faye and P. Esenov (Eds), IOS press Publ., Amsterdam (The Netherlands). pp 181-186.

Elamin FM and Wilcox CJ (1992). Milk composition of Marjheim camels. Journal of Dairy Science 75:3155-3157.

Eltohamy MM, Salama A and Youssef AEA (1986). Blood constituents in relation to the reproductive state in she-camel (*Camelus dromedarius*). Beitrage zür Trop. Landwirtschaft und Vet. Med. 24:425-430.

Faye B, Grillet C and Tessema A (1986). Teneur en oligo-éléments dans les fourrages et le plasma des ruminants domestiques en Ethiopie. Rev. Elev. Méd. Vét. Pays Trop. 39:227-237.

Faye B and Mulato C (1991). Facteurs de variation des paramètres protéo-énergétiques, enzymatiques et minéraux dans le plasma chez le dromadaire de Djibouti. Rev. Elev. Méd. Vét. Pays Trop. 44:325-333.

Faye B and Bengoumi M (1994). Trace-element status in camel. A review. Biol. Trace Elem. Res. 41:1-11.

Faye B, Saint-Martin G, Cherrier R and Ali Ruffa M (1992). The influence of high dietary protein, energy and mineral intake on deficient young camel: II. Changes in mineral status. Comp. Bioch. Physiol., 102A:417-424.

Faye B, Jouany JP, Chacornac JP and Ratovonanahary M (1995). L'élevage des grands camélidés. Analyse des initiatives réalisées en France. I.N.R.A. Prod. Anim., 8:3-17.

Faye B and Bengoumi M (2000). Le dromadaire face à a sous-nutrition minérale: un aspect méconnu de son adaptabilité aux conditions désertiques. Revue Sécheresse 11(3):155-161.

Finlayson R, Keymer IF and Manton JA (1971). Calcific cardio-myopathy in young camels (*Camelus* spp.). Journal of Comparative Pathology 81:71-77.

Ghosal AK and Shekhawat VS (1992). Observations on serum trace elements levels (zinc, copper and iron) in camel (*Camelus dromedarius*) in the arid tracts of Thar Desert in India. Rev. Elev. Méd. Vét. Pays Trop. 45:43-48.

Hamliri A, Khallaayoune K, Johnson DW and Kessabi M (1990). The relationship between the concentration of selenium in the blood and the activity of glutathione peroxidase in the erythrocytes of the dromedary camel (*Camelus dromedarius*). Veterinary Research and Communication 14:27-30.

Hussein MF, Al Mufanej SI, Mogarver HH, Le Nabi ARG and Sanad HH (1997). Serum iron and iron binding capacity in the Arabian camel (*Camelus dromedarius*). Journal of Applied Animal Research 11:201-205.

Jeffrey SL, Whitaker SM, Borger DC and Willett LB (2003). Pharmacokinetics of lead in cattle: transfer to calf. Animal Science and Rev. Special Circular. pp 156.

Lamand M (1987). Place du laboratoire dans le diagnostic des carences en oligo-éléments. Rec. Med. Vet. 163: 1071-1082.

Liu ZP, Ma Z and Zhang YJ (1994). Studies on the relationship between sway disease of Bactrian camels and copper status in Gansu Province. Veterinary Research and Communication 18:251-260.

Ma Z (1995). Studies on sway disease of chinese bactrian camels. Epidemiological and aetiological aspects. Report of International Foundation for Science Project, Stockholm, Sweden. pp 17.

Marx W and Abdi HN (1983). Serum levels of trace elements and minerals in dromedaries (*Camelus dromedarius*) in South Somalia. Anim. Res. Dev. 17:83-90.

Moty IA, Mulla A and Zaafer SA (1968). Copper, iron and zinc in the serum of egyptian farm animals. Sudan Agriculture Journal 3:146-151.

Musa BE and Tageldin MH (1994). Swelling disease of dromedary camel. Veterinary Record 135:416.

Pechova A, Podhorsky A, Lokajova E, Pavlata L and Illek J (2002). Metabolic effects of chromium supplementation in dairy cows in the peripartal period. Acta Vet. Brno, 71:9-18.

Rose RJ, Evans D, Henkel P, Knight PK, Cluer D and Saltin B (1994). Metabolic responses to prolonged exercise in the racing camel. In: The racing camel. Physiology, metabolic functions and adaptations (chap. VII), Saltin B and Rose RJ (Eds), Suppl. Acta Physiol. Scand. 150: 49-60.

Shekhawat VS, Bathia JS and Ghosal AK (1987). Serum iron and total iron capacity in camel. Indian Journal of Animal Sciences 57:168-169.

Soulsby EJL (1982). Helminths, Arthropods and Protozoa of Domesticated Animals. 7th ed. Bailliere Tindal London.

Tao G, Geng C, Tao Y, Jiao H and Fan Y (1995). "Roll disease" of camels in Mongolia. Acta Vet. Zootechn. Sinica 26: 541-544.

Tartour G and Idris OF (1970). Studies of copper and iron metabolism in the camel foetus. Acta Vet. (Brno) 39: 397-403.

Woo PTK (1971). The hematocrit centrifuge technique for the detection of low virulent strains of trypanosomes of Trypanosome congolense subgroup. Acta. Trop. XXVII. 304-308.