FINAL REPORT

Project Title :

Trace-Elements Status in Saudi Arabian Camels: A comparative study

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1. **Introduction**

Camels belong to the family camelidae and genera Camelus and Lama (Mugerwa, 1981) with two and four species in each genus respectively. These species are *Camelus bacterianum, Camelus dromedarius, Lama ilama, Lama guanicoe, Lama pucos* and *Lama vicugna.*

The world population of the dromedary and bacteriarus camels is estimated to be 17 million. Dromedary camels constitute about 91% of this figure and are concentrated mainly in the Arab world, particularly in the Arabian countries of Africa. In addition the ability of the Arabian camel (dromedary camel) to withstand the hot and harsh environmental conditions is not matched by any other animal species.

There are about 415 thousands camels in Saudi Arabia, most of which are used to provide meat and milk for a growing number of human population. Biochemical determination of blood constituents can provide valuable information to physiologists and pathologists. Previous studies on the normal blood parameters of dromedary camels have been mostly concerned with the haemogram of these animals, while data on extracellular blood elements such as minerals, enzymes, proteins and various other metabolites are comparatively sparse. However, most of the parameters cited were at variance with each other. This, however, is not unexpected, since some of these parameters are known to be affected by breed, locality, age, sex, season and nutritional status of animals. Many workes compared results obtained in camel sera with those of true ruminants (Abdalla *et al*., 1988; Haroun, 1994).

The macronutrients are calcium, phosphorus, sodium, potassium, magnesium, chlorine and sulphur. Some of the macrominerals are required as structural components of the skeleton, other function in acid-base balance, while many are contained in the enzyme system, the majority of macrominerals have more than one function (Church and Pond, 1988).

The essential trace elements are copper, zinc, iron, manganese, selenium, cobalt and iodine. These trace elements are generally included in enzymes molecules, for example copper in cytochrome oxidase, alkaline phosphatase, cystyl-oxidase, DNA and RNA polymerase and dehydrogenases, manganese in pyruvate carboxylase and selenium in gluthione peroxidase. Some are included in hormones (Iodine in thyroid hormones), vitamins (cobalt in vitamin B12) and metalloprotein (iron in haemoglobin and myoglobin).

The determination of the activities of certain enzymes in serum is of great value in clinical diagnosis. For example, alkaline phosphatase (ALP) activity may be increased in rickets, hyperparathyroidism, clinical cases of mandibular fracture and other diseases involving bones. The activities of aminotransferases are also of clinical interest in the differential diagnosis of certain muscle and liver disorders. The aim of this study was :-

1- To establish normal concentrations of macrominerals and microminerals in she camel, cow and sheep sera.

2- To establish standard norms for the activities of some of the enzymes important for clinical diagnosis in the serum of she camels, cows and ewes.

3- To determine the concentrations of selected trace elements in liver samples of she camels, cows and ewes.

4- To determine the concentrations of other parameters and metabolites in the serum of she camels, cows and ewes.

2- Literature Review :

2.1 Calcium and phosphorus

Calcium and phosphorus are closely associated in metabolism. In mammals the major portion of calcium in the diet is used for bone formation. Calcium also is essential for clotting of the blood, is required along with sodium and potassium for the normal beating of the heart, and is concerned in the maintenance of acid-base balance. In addition to its role in bone formation, phosphorus has important functions in the metabolism of carbohydrates and fats, it enters in the composition of important constituents of all living cells, and salts formed from it play an important part in the maintenance of acid-base equilibrium.

The mean serum calcium level in the serum of healthy camels is not lower and phosphorus not higher than those in other ruminants as claimed earlier (Wilson, 1984). However, calcium is lower and phosphorus is higher than in the horse (normal levels; calcium = cow 8.4 – 11; sheep 9.3 – 11.7; goat 9 – 11.6; horse 10.4 – 13.4 mg/dl; phosphorus = cow 4.3 – 7.8; sheep 4 – 7.3; goat 3.7 – 9.7; horse 2.3 – 5.4 mg/dl (Fraser *et al*., 1991). Therefore, the critical plasma calcium (8 mg/dl) and phosphorus (4 – 4.5 mg/dl) used for other ruminants may be applied to camels.

In camels, as in other animals, plasma phosphorus concentration is high when young and increases by cereal feeding and by haemolysis, while serum calcium elevates significantly by racing (Snow *et al.*, 1988) and by dehydration (Yagil *et al*., 1975) and decreases by long serum separation time and during active trypanosome parasitaemia (Boid *et al*., 1986).

2.2 Sodium and chloride:

Sodium ions, mainly extracellular are important in maintaining osmotic pressure, acid-base balance and membrane potential. Chloride ions follow passively the movement of sodium ions (Fraser *et al*., 1991). Sodium and water metabolism are closely related, and in the camel as in other mammals are controlled by aldosterone, rennin-angiotensin, antidiuretic hormone and atrial natriuretic peptide (Yagil, 1985); Dahlborn *et al*., 1992).

Camels in their natural habitat are exposed to dehydration (Dahl and Hjort, 1980; Yagil, 1985) salty bushes or salty water (Wilson, 1984) and are well adapted to it. The camel kidney is adapted for sodium and water reabsorption and hence the ability to concentrate urine (Abdalla and Abdalla, 1979).

A number of authors have reported normal serum levels for sodium and chloride in camels. The camel sera show a wide range of normal levels of sodium and chloride and these are generally higher than those reported for other ruminants (Bono *et al*., 1983; Abdalla et al., 1988). 147 meq/L sodium in camel sera were reported by Bhattacharjee and Banerjee (1962); Sharma *et al*. (1983) in India, Wahbi *et al*. (1980) in Sudan 151 meq/L; 164 meq/L and 168 meq/L sodium were found in Saudi Arabia (Hussein *et al*., 19982), 154 meq/L were reported by Abdalla *et al*. (1988) in United Arab Emirates.

Ayoub *et al.* (1960) found that the chloride level in camel sera was higher than that in cattle and buffaloes, and that the level increased with age but was not affected by pregnancy or lactation. However, plasma chloride is affected by changes in blood acid-base balance i.e. high in metabolic acidosis and low in metabolic alkalosis (Abu Damir, 1992; Wernery and Wensvoort, 1992). Serum chloride is also affected by urinary diseases. Animals with urinary retention are hypochloraemic, azotaemic and hyponatraemic as a result of cell hypoxia.

2.3 Magnesium (Mg):

Magnesium is widely distributed in the body. About half of the body Mg is in the bone at concentration of 0.5 – 0.7 % of the bone ash (Wacker and Vallee, 1964). Mg in soft tissues is concentrated within the cell, the highest concentration is in the liver and skeletal muscles. 75% of blood Mg is in the red blood cells and 25% in serum (Church and Pond, 1988). Magnesium is required for normal skeleton development as a constituent of bone. It is required for oxidative phosphorylation reaction in the mitochondria. It is also required for activation of enzymes in reactions involved in ATP utilization (McDowell *et al.*, 1993). Mg also acts as a cofactor in decarboxylation reactions and is required for activation of certain peptidases (Wacker and Vallee, 1964).

Mg in the serum of healthy camels was measured by Wahbi *et al* (1980) who found 2.5 mg/100 ml Mg in the blood of nomadic camels in the Sudan.

2.4 Potassium (K) :

Potassium is the third most abundant element in the animal body and is the principal caution of intracellular fluid. It is also a constituent of extracellular fluid where it influences muscle activity. Potassium is required for a variety of

body functions including osmotic balance, acid-base equilibrium, several enzyme system and water balance. An ionic balance exists between K, Na, Ca and Mg.

The homeostatic mechanism for K is inseparable from that of Na and aldosterone was found to affect K excretion, high level of K in the extracellular fluid stimulates aldosterone secretion in the same way that low Na does. In K deficiency some Na is transferred inside the cell to replace K, and in that way preserves osmotic and acid-base equilibrium (Church and Pond, 1988). The K requirement appears to be increased for livestock under stress such as pregnancy. Excitement tends to increase urinary loss of K.

A high level of dietary K reduces the apparent absorption of Mg (Kemp *et al.*, 1961). Prolonged elevation of K in blood plasma of ruminants may lead to a series of metabolic disturbances including elevated insulin (Lenz *et al.*, 1976).

2.5 Copper (Cu):

Copper and iron are needed for normal red blood cell formation. Furthermore, Cu is essential for normal activity of many enzymes, including such important ones as lysyl oxidase, cytochrome-c oxidase, superoxide dismutase and other oxidases.

Copper plasma level may be considered as a good reflection of Cu intake in ruminants, normal levels lie between 70 – 120 µg/100 ml. Most of the observed values in camels fluctuate between these two values. However, some interspecies comparisons show that the Cu plasma values are, on average, slightly higher than other ruminants (Tartour, 1975; Faye *et al*., 1984, 1990).

Camels graze more forage trees than grasses, and these are generally richer in Cu (Tartour, 1966; Faye *et al*., 1986).

Wide variations in liver Cu values have been reported in the literature. Liver copper values ranging between 6.5 – 543 ppm were found in Sudani camels (Tartour, 1969, 1975; Abu Damir, 1983). Khalifa *et al*., reported a range of 20 – 286 ppm in Egyptian adult camels. More recently, lower values have been reported in deficient young camels (19 – 88 ppm) at Dijibouti (Faye *et al*., 1992). Bengoumi *et al*. (1998) reported mean liver value of 10 ppm in Moroccon adult camels. This mean value increased to 26 ppm following a 3 months oral trace element supplementation. Their results suggest that trace elements requirements are lower in camels than in cows.

2.6 Zinc (Zn) :

More than 20 different enzymes are known to be either zinc metallo enzymes or to require zinc for activation. Zinc has been implicated in conditions such as dwarfism and poor sexual development and in other metabolic processes including maintenance of the integrity of the male gorads and of the brain, the skin, the eye and the bones.

In camels plasma zinc levels fluctuate between 70 – 120 µg/100 ml (Abdel Moty *et al*., 1968; El Tohamy et *al.*, 1986; Faye *et al*., 1986). However, lower values were observed in Dijibouti (Faye *et al*., 1991) and in the United Arab Emirates (Abdalla *et al*., 1988). It seems that camels have lower values than other species kept in the same ecological and feeding conditions.

The variation of plasma zinc level according to age and sex has rarely been studied. El Kasmi (1988) found that young camels have lower values. Other

workers found that plasma zinc was a discriminant parameter of the age of camels (Faye and Mulato, 1991). But no variation owing to sex has been observed, although a significant decrease in plasma zinc was reported in the she camel at the end of pregnancy (EL-Tohamy *et al*., 1986), due to an active transfer to the foetus in the last part of gestation.

An enriched ration (with protein-energy supplementation) improves plasma zinc level in deficient camels (Faye *et al.*, 1992), as in non-deficient camels (Abdel Rahim, 1983), but the effect is less significant than for copper.

2.7 Iron (Fe) :

Iron is a characteristic constituent of the blood and pure crystals of haemoglobin contain 0.335 iron. Enzymes such as cytochromes, catalases and peroxidases also were shown to contain iron. The flavoprotein enzymes, NADH – cytochrome reductase and xanthine oxidase, have been found to contain iron. The muscles contain an oxygen-carrying compound, myoglobin, which also contains iron.

In camels some data are available concerning whole blood (Bhattacharjee and Banerjee, 1962), serum (Tartour, 1969; Tartour and Idris, 1970), Ghosal *et al*., 1976; Abdalla *et al*., 1988), or plasma iron levels (Barakat and Abdel Fattah, 1970; Faye *et al*., 1986; Bengoumi *et al*., 1992).

All interspecies comparative studies indicate lower blood iron values in the camel compared with other ruminants (Tartour and Idris, 1970, Faye *et al.*, 1986).

Reported liver iron values in camels ranged between 260 – 560 ppm (Tartour, 1969; Awad and Berschneider, 1977). Iron content of liver was found to be higher in young camels and in the foetus (Tartour, 1969).

2.8 Manganese (Mn) :

Manganese occurs in relatively constant amounts in the tissues and organs of both plants and animals and that manganese is especially concentrated in the reproductive organs. Manganese is essential for normal growth and normal reproduction. High mortality, testicular degeneration and poor lactation accompany manganese deficiency in rats.

Manganese may be a limiting factor in the diet of ruminants and there is a risk of deficiency considering observed levels of manganese in subdesertic forages (Faye *et al*., 1986).

Only two reports could be traced in the literature concerning manganese concentration in the plasma of camels. El-Kasmi (1989) observed a mean value of 174 µg/100 ml with no age or sex differences. However, El-Tohamy *et al.* (1986) reported lower plasma manganese (33.6 µg/100 ml) in non-pregnant camels. According to these authors, no variation owing to pregnancy was observed, contrary to other trace elements. In ruminants plasma manganese values were generally lower than 10 µg/100 ml (Lamand, 1987).

Low hepatic manganese values, as for other ruminants were reported in the camel. These values ranged between 2 – 10 ppm (Abu Damir, 1983, Awad and Berschneider, 1977).

2.9 Enzyme activity :

The determination of the activities of certain enzymes in serum is of great value in clinical diagnosis. For example, creatine kinase (CK) is of diagnostic significance in skeletal muscle. Muscle anoxia in patients in prolonged recumbency causes remarkable increases in CK. Animals postsurgically often have markedly increased CK activity. Creatine kinase has a short half-life in serum and returns to normal very quickly as the stress ceases.

Lactate dehydrogenase catalyzes the reversible oxidation of lactate to pyruvate with the cofactor NAD. A large amount of LDH activity is found in all tissues. Lactate dehydrogenase isoenzyme profiles were the first isoenzyme profiles used by clinical laboratory medicine. The activities of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are also of clinical interest in the differential diagnosis of certain muscle and liver disorders.

The alkaline phosphatase (ALP) activity may be increased in rickets, hyperparathyroidism, clinical cases of mandibular fracture and other diseases involving bones. The gamma-glytamyltransferase (GGT) cleaves C-terminal glutamyl groups and transfers them to peptides and other suitable acceptors. Obstructive liver disease causes the greatest magnitude of increase in serum GGT activity in human beings. This enzyme may be a more specific indicator of obstructive hepatic disorders in animals than ALP (Ford, 1974; Johnson, 1976).

2.10 Concentrations of other metabolites:

The concentrations of substances such glucose, cholesterol, triglycerides, urea, creatinine and proteins in animal sera is a very important tool in the

diagnosis of diseases and other metabolic disorders. Serum glucose has a wide range of levels in camels, ranging from 74 to 140 mg/100 ml (Al-Ali *et al.*, 1988; Mohamed and Hussein, 1999; Osman and Al-Busadah, 2000). Ruminants have a lower blood glucose values than camels (Chandrasena *et al.*, 1979). Other serum constituents including serum proteins, urea and creatinine could be affected by disease and dehydration. Total serum proteins are elevated in dehydrated camels (Ghosal *et al.*, 1975). Other workers found that total serum proteins decline after dehydration, due to a fall in globulins (Hassan, 1971).

3. Materials and Methods

3.1 Animals :

The camels used in the present study belonged to the Camel Research Centre, King Faisal University. The camels were kept under reasonable hygienic conditions and veterinary supervision. The animals were fed on hay and barley. Water was available ad libitum. The cows and ewes belonged to the Agriculture and Veterinary Training and Research Station of King Faisal University. The cows and ewes were lactating and were fed on long hay and concentrates.

3.2 Blood sampling :

Blood samples were collected by jugular venipuncture from 5 adult she camels, 5 lactating cows and 5 lactating ewes in to silicon-coated vacuum containers. The blood was allowed to clot and after centrifugation the serum was separated and stored at –20^{o}C until analysed.

3.3 Collection of liver samples :

Visits were paid to Al-Ahsa abbatoir. Liver samples from slaughtered camels, sheep and cattle were collected. To avoid contamination, first use stainless steel surgical blades were used to cut off the liver samples. The samples were transferred into clean sterile containers and immediately frozen at –20^{o}C until analyzed.

3.4 Biochemical analysis

3.4.1 Analysis of serum samples :

The serum was divided into two parts. The first part was used for determination of serum parameters including proteins, enzymes,

macrominerals and other metabolites. These serum constituents were analysed spectrophotometrically (RA-50 Chemistry Analyzer, Ames, Bayer Diagnostics) using commercial reagent kits (United Diagnostic Industry, Dammam, Kingdom of Saudi Arabia). The activities of creatine kinase, lactate dehydrogenase, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase and gamma-glutamyltransferase were measured. The concentrations of sodium, potassium, chloride, magnesium, calcium, inorganic phosphorus, glucose, cholesterol, triglycerides, urea, creatinine, total protein and albumin were determined. The remaining part of the serum was used for the determination of trace-elements concentrations. The concentrations of copper, zinc, iron and manganese were measured by atomic absorption spectrophotometry (Shimadzu, Model 6601).

3.4.2 Analysis of liver samples :

Liver samples were digested in a mixture of 2:1:0.5 nitric acid (HNO_3, 65%, perchloric acid ($HCLO_4$, 60%) and sulphuric acid (H_2SO_4, 97%). The samples were further diluted and aspirated into an atomic absorption spectrophotometer (Shimadzu, Model 6601). The concentrations of copper, zinc, iron and manganese were determined.

3.5 Statistical analysis :

The data were analyzed statistically using analysis of variance (ANOVA). The statistical differences between means were estimated by Duncan's Multiple Range Test. The computation was facilitated by statistical package SAS.

4. Results

4.1 Serum concentrations of macrominerals :

The mean ± SE concentrations of sodium, potassium, chloride, magnesium, calcium, inorganic phosphorus are shown in Table 1. The serum concentrations of sodium and chloride were significantly higher ($P < 0.05$) in she-camels when compared with either cows and ewes, and the mean values of these two electrolytes were significantly higher in ewes ($P < 0.05$) as compared with cows. Serum potassium concentration was significantly higher ($P < 0.05$) in ewes when compared with she-camels and cows. The concentrations of magnesium and in the serum of she-camels was significantly lower ($P < 0.05$) as compared with cows and ewes. Mean serum calcium concentration was significantly lower ($P < 0.05$) in she-camels when compared with ewes, but difference between she-camels and cows was not statistically significant. The serum concentration of inorganic phosphorus was significantly lower ($P < 0.05$) in she-camels as compared with cows, but the difference between she-camels and ewes was not statistically significant.

Table 1. Mean ± S.E. concentrations of Na, K, CL, Mg, Ca, P and Fe in the serum of she-camels (n=5), cows (n=5) and ewes (n=5)

Parameter	Unit	She camel	Cow	Ewe
Na	mEq./l	168.2 ± 0.7^{a}	139.0 ± 2.0^{c}	162.0 ± 1.5^{b}
K	mEq./1	4.0 ± 0.2^{b}	4.2 ± 0.1^{b}	5.3 ± 0.1^{a}
Cl	mEq./l	130.2 ± 1.9^{a}	103.6 ± 2.0^{c}	114.8 ± 1.5^{b}
Mg	mEq./l	2.16 ± 0.09^{b}	2.68 ± 0.04^{a}	2.84 ± 0.11^{a}
Ca	mg/dl	9.0 ± 0.1^{b}	9.4 ± 0.2^{ab}	9.9 ± 0.1^{a}
P	mg/dl	3.8 ± 0.5^{b}	6.1 ± 0.6^{a}	4.8 ± 0.5^{ab}

Note: Duncan's Multiple Range Test was performed at $P < 0.05$
Means with the same letter are not significantly different

4.2 Serum concentrations of trace-elements :

The mean $\pm$ SE concentrations of copper, zinc, iron and manganese are shown in Table 2. Mean serum Cu and Mn concentrations of she camels were significantly higher ($P < 0.05$) when compared with values obtained in cows and ewes. Conversely, mean serum Fe concentration of she camels was significantly lower ($P < 0.05$) as compared with concentrations obtained in cows and ewes. The difference in mean serum Zn concentration between the three species was not statistically significant.

4.3 Liver concentrations of trace-elements :

Liver concentrations of Cu, Zn, Fe and Mn are shown in Table 3. The concentration of Cu in the liver of she camels was significantly higher ($P < 0.05$) as compared to cows and ewes. However, the differences in liver concentrations of Zn, Fe and Mn, between the three species, were not statistically significant.

4.4 Serum enzyme activities :

The serum enzyme activities of creatine kinase (CK), lactate dehydrogenase (LDH), aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP) and gamma-glutamyltransferase (GGT) are shown in Table 4. Serum CK activity was significantly higher ($P < 0.05$) in camels as compared with cows and ewes. The activities of LDH and ALT were significantly higher ($P < 0.05$) in the serum of cows when compared with either she-camels and ewes. Serum AST activity was

significantly higher ($P < 0.05$) in she-camels as compared with cows, but the difference between she-camels and ewes was not statistically significant. Serum ALP and GGT activities were significantly higher ($P < 0.05$) in ewes when compared with mean activities recorded for she-camels and cows. However, no statistical significant differences in mean ALP and GGT activities were found between she-camels and cows.

Table 2. Mean ± S.E. concentrations of Cu, Zn, Fe and Mn in the Serum of she-camels (n = 5), cows (n = 5) and ewes (n = 5)

Parameter	Unit	She camel	Cow	Ewe
Cu	μg/dl	113.5 ± 15.1[a]	70.2 ± 11.5[b]	95.6 ± 10.3[b]
Zn	μg/dl	103.4 ± 12.6[a]	98.5 ± 8.6[a]	110.7 ±13.1[a]
Fe	μg/dl	80.2 ± 16.0[b]	168.4 ± 13.9[a]	178.6 ± 23.7[a]
Mn	μg/dl	30.0 ± 4.5[a]	8.3 ± 2.5[b]	7.5 ± 1.8[b]

Note: Duncan's Multiple Range Test was performed at $P < 0.05$.

Means with the same letter are not significantly different.

Table 3. Mean ± S.E. concentrations of Cu, Zn, Fe and Mn in the liver (DM basis) of she camels (n = 5), cows (n = 5) and ewes (n = 5)

Parameter	Unit	She camel	Cow	Ewe
Cu	mg/kg	265.1 ± 30.6[a]	150.5 ± 18.1[b]	154.6 ± 11.2[b]
Zn	mg/kg	148.7 ± 9.6[a]	139.4 ± 7.9[a]	141.0 ±8.5[a]
Fe	mg/kg	295.2[a] ± 21.6	229.14 ±15.6[a]	251.4 ± 19.5[a]
Mn	mg/kg	6.1 ± 2.2[a]	7.5 ± 2.9[a]	8.6 ± 3.1[a]

Note: Duncan's Multiple Range Test was performed at $P < 0.05$.

Means with the same letter are not significantly different.

Table 4. Mean ± S.E. activities of CK, LDH, AST, ALT, ALP and GGT in the serum of she-camels (n=5), cows (n=5) and ewes (n=5)

Parameter	Unit	She camel	Cow	Ewe
CK	U/l	408.6 ± 127.6^{a}	119.0 ± 15.0^{b}	121.6 ± 9.2^{b}
LDH	U/l	455.0 ± 75.9^{b}	726.8 ± 56.7^{a}	382.4 ± 23.5^{b}
AST	U/l	164.6 ± 39.9^{a}	72.4 ± 7.1^{b}	141.6 ± 25.4^{ab}
ALT	U/l	17.2 ± 3.6^{b}	34.0 ± 3.0^{a}	21.0 ± 1.4^{b}
ALP	U/l	60.0 ± 7.2^{b}	49.8 ± 3.1^{b}	112.4 ± 25.1^{a}
GGT	U/l	25.6 ± 7.8^{b}	29.0 ± 4.0^{b}	77.0 ± 3.5^{a}

Note: Duncan's Multiple Range Test was performed at $P < 0.05$
Means with the same letter are not significantly different

4.5 Serum concentrations of other metabolites :

The serum concentrations of glucose, cholesterol, triglycerides, urea, creatinine, total protein and albumin are shown in Table 5. Mean serum glucose and triglycerides concentrations were significantly higher in she-camels when compared with their respective mean concentrations in cows and ewes. Conversely, mean serum cholesterol concentration was significantly lower ($P < 0.05$) in she-camels when compared with mean values obtained in cows and ewes. Mean serum urea concentration was significantly lower ($P < 0.05$) in cows as compared with she-camels and ewes. Mean serum creatinine concentration was significantly higher ($P < 0.05$) in she-camels as compared with ewes, but the difference between she-camels and cows was not statistically significant. The mean serum total protein and albumin concentrations were significantly lower ($P < 0.05$) in she-camels when compared with their respective values in cows, but no differences were found between she-camels and ewes.

Table 5. Mean ± S.E. concentrations of glucose, cholesterol, triglycerides, urea, creatinine, total protein and albumin in the serum of she-camels (n=5), cows (n=5) and ewes (n=5).

Parameter	Unit	She Camel	Cow	Ewe
Glucose	mg/dl	134.4 ± 11.0^{a}	49.0 ± 2.5^{b}	65.0 ± 4.8^{b}
Cholesterol	mg/dl	58.4 ± 8.6^{a}	149.4 ± 10.1^{b}	69.6 ± 5.7^{b}
Triglycerides	mg/dl	31.4 ± 3.0^{a}	14.6 ± 1.8^{b}	19.4 ± 1.2^{b}
Urea	mg/dl	49.8 ± 5.5^{a}	17.2 ± 1.8^{b}	52.6 ± 4.9^{a}
Creatinine	mg/dl	1.5 ± 0.1^{a}	1.3 ± 0.04^{ab}	1.0 ± 0.03^{b}
Total protein	g/dl	7.1 ± 0.3^{b}	8.2 ± 0.1^{a}	6.9 ± 0.1^{b}
Albumin	g/dl	3.7 ± 0.3^{b}	4.5 ± 0.1^{a}	3.7 ± 0.1^{b}

Note: Duncan's Multiple Range Test was performed at $P < 0.05$
Means with the same letter are not significantly different

5. Discussion

Most of the minerals and electrolytes concentrations obtained for she-camels were in reasonable agreement with previous studies (Tartour and Idris, 1970; Ghosal et al., 1974; Wahbi et al., 1979; Hussein et al., 1982; Abdalla et al., 1988; Wenery et al., 1999). In general our findings on minerals and electrolytes concentrations of cows and ewes are within the normal ranges reported in the literature (Kaneko, 1989). The higher values of sodium and chloride concentrations found in she-camels are in agreement with previous reports that sodium and chloride levels are generally higher in camel sera when compared with other ruminants (Ayoub et al., 1960; Bono et al., 1983; Abdalla et al., 1988). Serum iron and magnesium concentrations of she-camels were significantly lower as compared with cows and ewes. Similar findings of low iron concentration in camel sera have been reported by Hussein et al. (1982), Abdalla et al. (1988) and Mohamed and Hussein (1999).

In the present study the concentrations of trace elements (Cu, Zn, Fe, Mn) obtained in sera of she camels were comparable to values recorded in Sudan (Tartour, 1975; Wahbi *et al.*, 1979; Abu Damir *et al.*, 1983), Egypt (Abdel Moty *et al.*, 1968), Ethiopia (Faye *et al*., 1986) and United Arab Emirates (Abdalla *et al.*, 1988). Low plasma Cu values have only been observed in the Horn of Africa (Faye and Mulato, 1991). It concerns secondary deficiencies (forages are rich in molybdenum and sulfur, which are well known antagonists of copper) particularly in the Rift Valley. Plasma Zn is a good and early reflection of the zinc status. However, little work has been done with respect to Zn in camels and the clinical

deficiency is not known. Young camels have lower plasma Zn than adults but there is no sex difference (El-Kasmi, 1989).

Plasma Zn level significantly increases in haemolytic blood or in blood contamination during the collection, storage or processing. The Fe content of serum decreases during pregnancy (El Tohamy *et al*., 1986) from 68.0 µg/100 ml at the beginning to 64.0 by the end of gestation. El Kasmi (1989) did not observe significant differences with age or sex, but Barakat and Abdel Fattah (1971) reported higher values for whole blood Fe in she camel during the rainy season and lower values during the dry season compared to males. Tartour and Idris (1970) found that racing camels have higher serum Fe levels than pack camels.

The concentrations of Cu, Zn, Fe and Mn found in sera of cows and ewes of the present study fall within the normal range reported for ruminants (Sanson *et al.,* 1984; Kirk *et al.,* 1985; Black *et al*., 1985; Stoszek *et al*., 1986; Kaneko, 1989; Engle *et al.,* 2001). Serum Cu concentration of she camels was significantly higher than values found in cows and ewes. This is in agreement with previous reports that serum Cu values are higher in camels than in ruminants (Tartour, 1975; Faye *et al.,* 1984, 1990). This may be attributed to the fact that camels graze more forage trees than grasses (Rutagwenda *et al*., 1990). Forage-trees are generally richer in copper (Tartour, 1966; Faye *et al.*, 1986). No differences were found in serum Zn concentrations between she camels, cows and ewes of the present study. These levels fall within the general range reported for other animals (Underwood, 1977). On the other hand, serum Fe concentration was significantly lower in she camels as compared to cows and ewes. This is in accordance with previous studies which revealed lower blood iron values in the camel compared to other ruminants

(Faye et al., 1986; Tarour and Idris, 1970; Ghosal et al., 1976), but this is not the case for transferrin (Tartour and Idris, 1970) which possesses a lower iron-binding capacity (30%) than other ruminants. Serum Mn concentrations of she camels was significantly higher than mean values found in cows and ewes. Only two references are available concerning Mn level in camel plasma, El Kasmi (1989) observed a mean value of 174 µg/100 ml with no age or sex differences. These values are higher than the values recorded in the present study and higher than those observed by El Tohamy *et al*. (1986). No variation owing to pregnancy has been observed, contrary to other trace-elements. These values should be reconsidered since the observed values on other ruminants are generally lower than 10 µg/100 ml.

Concerning liver trace elements, little data are available. In the present study the mean hepatic concentrations of Cu, Zn, Fe and Mn found in she camels agree with previous reports (Tartour, 1969, 1975; Awad and Berschneider, 1977; Khalifa *et al.*, 1983; Abu Damir *et al*., 1983; Wensvoort, 1992). More recently, lower hepatic Cu concentrations have been reported in deficient young camels by liver biopsy (19 – 88 ppm) at Djibouti (Faye *et al*., 1992). The status was improved with mineral supplementation.

In the present study, liver concentrations of Cu, Zn, Fe and Mn obtained on cows and ewes fall within the general range recorded for ruminants (Kirk *et al.* 1985; Black *et al*., 1985; Stoszek *et al*., 1986; Hatfield *et al*., 2001; Bailey *et al*., 2001; Arthington and Pate, 2002). With the exception of Cu, no significant differences were found in hepatic trace elements between she camels and cows or ewes. This may be due to accumulation of Cu in the liver by camels owing to the fact that the camels graze more forage trees which are generally richer in copper

(Tartour, 1966; Faye *et al*., 1986). As for other ruminants, hepatic Mn is generally low in camels compared to other trace-elements: from 2.6 $\pm$ 1.5 ppm to 10.3 $\pm$ 8.8 ppm according to different authors (Awad and Berscheider, 1977; Abu Damir *et al.*, 1983; Wensvoort, 1992). These values compare well with Mn status in other ruminants. Abu Damir *et al*, (1983) found lower hepatic Zn values (39.6 $\pm$ 17.7 ppm) in Sudani camels. On the other hand, higher hepatic Fe (558.1 $\pm$ 266.4 were recorded in camels in the Sudan (Tartour, 1969) and values of 460.0 $\pm$ 85 ppm in Egyptian camels (Awad and Berschneider, 1977). However, in natural conditions, iron deficiency is not observed in ruminants (Underwood, 1977).

Serum CK, LDH, AST, ALT, ALP and GGT activities (Table 4) found in she-camels are in reasonable agreement with the values reported by Bengoumi et al (1977) and Osman and Al-Busadah (2000). The activities of these enzymes are slightly higher than those given in some previous studies (Boid et al., 1988; Khataria and Bhatia, 1991; Beaunoyer, 1992; Sarwar et al., 1992; Nyang'ao et al., 1997). The activities of LDH, AST, ALT, ALP and GGT found in the present study fall within the normal range reported for cow and sheep (Kaneko, 1989). However, mean serum activity of CK found in cows (119.0 ± 15.0 U/L) or ewes (121.0 ± 9.3 U/L) in the present study were much higher than values of 7.4 ± 2.4 and 10.3 ± 1.6 U/L reported for cow and sheep, respectively (Kaneko, 1989).

In our study, serum activity of CK was significantly higher in she-camels, LDH and ALT activities were significantly higher in cow whereas ALP and GGT activities were significantly higher ewes. These findings indicate that differences in normal serum activity values of some enzymes exist between camel and true ruminants, as well as between cattle and sheep.

The data on serum glucose, cholesterol, triglycerides, urea, creatinine, total protein and albumin of she-camels were comparable with those reported by Soliman and Shaker (1967), Abdel Gadir et al. (1979), Hussein et al. (1982), Abdalla et al. (1988), Rezakhani et al. (1997), Mohamed and Hussein (1999) and Osman and Al-Busadah (2000). The values of the above serum parameters obtained in cows and ewes were within the normal established range for cattle and sheep (Kaneko, 1989). The glucose concentration determined in the serum of she-camels used in the present work is in excellent agreement with values obtained by Barakat and Abdel-Fattah (1970) 80-140 mg/dl, Chandrasena et al. (1979) 129 mg/dl, Al-Ali et al. (1988) 138 ± 17.7 mg/dl, Nyang'ao et al. (1997) 91.8 – 178.2 mg/dl and Mohamed and Hussein (1999) 45 – 167 mg/dl. This could be the cause of high levels of blood lactic acid reported in camels (Mathur et al., 1981). Serum glucose concentration of she-camels was significantly higher than values obtained in cows and ewes. The blood glucose concentration is lower and more stable in ruminants and mean values of 57.4 ± 6.8 mg/dl and 68.4 ± 6.0 mg/dl were found in cow and sheep, respectively (Kaneko, 1989; Welles et al., 1992).

In the present study significantly lower serum cholesterol concentration was found in she-camels. Similar findings of low cholesterol level in the camel have been reported by Al-Ali et al. (1988), Manefield and Tinson (1996), Nazifi and Maleki (1998), Mohamed and Hussein (1999) and Osman and Al-Busadah (2000). Conversely, serum triglycerides concentration of she-camels was significantly higher as compared with cows and ewes. Mean serum triglycerides concentration of she-camels was much lower than the value of 79.7 ± 8.9 mg/dl reported in adult normal Iranian camels (Nazifi and Maleki, 1998).

The present study has thus provided a comprehensive biochemical analysis of the major constituents of she-camel, cow and ewe serum. The observed biochemical values of she-camel serum were within the physiological limits described elsewhere and the variations observed between the present results and those from previous studies may be attributed to differences in breed, nutrition, husbandry, environment and methods of the assay. In the present study higher values of CK, sodium, chloride, glucose and triglycerides were found in she-camels as compared with cows and ewes. Conversely, the values of magnesium, iron and cholesterol were lower in she-camels in comparison with cows and ewes. Thus the findings obtained in the present study form a useful baseline for subsequent biochemical studies on camels, cattle and sheep in Saudi Arabia.

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