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Review Article

Calcium and Phosphorus: Backbone of Camel Health - A Review

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Abstract

In dromedary camels requirements of macrominerals are not well known. Calcium and phosphorus are integral minerals to many vital body functions in camels. This review attempts to apprehend the precise studies on calcium and phosphorus till present day.

Keywords: *Calcium; Phosphorus; Camel*

Introduction

Camels (*Camelus dromedarius*) have adapted to the harsh desert environment and considered to be the most efficient animal in the arid and semi-arid rangelands of tropical and subtropical countries. They convert poor feed resources into highly nutritious milk and meat and fulfill the dietary needs of desert inhabitants. Minerals are essential for the growth and normal life processes of camels like other living beings. The season, mineral supplementation and health status significantly affect the metabolic profile of the camels. There is usually variations in the dromedary mineral levels due to diversity in feeding conditions in different parts of the world. The maximum and minimum serum levels for camels have not been established as research in mineral status concentrated on cattle, sheep and goats. The supplementation in dromedaries is usually based on estimated needs for cattle. The present study aims at giving a review on previous and current knowledge on the status of essential macrominerals calcium and phosphorus in the dromedary based on all data concerned with requirements, serum and milk levels, nutritional imbalances leading to various disorders available in the scientific literature.

Functions of calcium and phosphorus

In the body P (80%) and Ca (99%) function as structural components of bones and teeth and act as a mineral source when dietary supply is inadequate [3]. Calcium is one of the important raw material in milk synthesis. Various important physiological functions mediated by Ca are blood clotting mechanism, neuromuscular excitability, membrane permeability, hormone secretions and certain enzyme activation processes. Phosphorus widely acclaimed as master mineral is essential for a broad range of enzymatic reactions, concerned with energy metabolism and transfer (ATP, ADP, AMP and creatine phosphate). It is the most abundant mineral in the body after calcium. It is also a component of the various fluid buffering systems and as a constituent of DNA and RNA it participates in the transfer of genetic information. Furthermore, it forms the phospholipids which are necessary for maintenance of cell wall structure and integrity and as an integral component of myelin sheath, which encloses the nerves [1].

Calcium and P metabolism in animals and humans is regulated by parathyroid hormone, 1,25-dihydroxy vitamin D (both elevated in dehydrated camels) and calcitonin. In lactating camels, as in other ruminants, exogenous PTHrP transiently but significantly increases mammary calcium and phosphorus secretion, but it doesn't affect milk mineral composition.

Camel feeding habits and managemental strategies

Camels browse only on local vegetation and rarely receive any supplementary feed except draught animals provided minerals during dry spells. According to Underwood and Suttle [1] ruminants fulfill their mineral requirements from forage plants. Camels have different feeding habits than cattle. Camels prefer to browse rather than grazing like cattle. They browse a wide range of fodder plants, including trees and shrubs to halophytic thorny and bitter plants, natural habitats in the desert and semi-arid areas. Under natural conditions they generally browse young twigs, leaves, fruits, flowers and pods. Leaves are richer in minerals than grasses. But a great percentage of trees and shrubs decline during the dry season and shed off their leaves. During drought, there is a limited choice for camels to concentrate on either evergreen shrubs or trees. The factors affecting mineral contents of plants include genus, species, strain (variety), type of soil season during plant growth stage of plant maturity and fertilizer application. Mineral concentrations in the body fluid will therefore depend on the mineral content of feed, the level of feed intake and availability of the minerals. The browse, trees and shrubs being the main feed of camels are high in protein, Ca and P that decline with dry up and plant maturity at a slower rate than the grazing plants. Similarly grazing plants with > 0.3% P during early stages of growth are available only for short time periods. Summer forage maturity adversely affects P and potassium but not Ca levels. Therefore summer forages provide adequate calcium for cattle. Likewise, legume for ages, which make bulk of camel feed usually contain more Ca than grasses. Calcium availability in ruminants may be adversely affected by presence of calcium oxalate or high sodium and potassium contents in some for ages. In most livestock grazing areas soils and plants are deficient in P, the most prevalent mineral deficiency in livestock recognized worldwide. It is found in plants either in organic form (phospholipids, phosphosugars, nucleic acids polymers, phytate, adenosine diphosphate and adenosine triphosphate) or inorganic form (orthophosphate and pyrophosphate). Roots and leaves contain very little amount of P Seeds contain predominant form of phytate which acts as storage form for phytates and inositol.

Management systems of dromedaries depend on certain factors including environmental conditions, size and composition of the herd. The management systems for camels include the nomadic and sedentary system. Centuries-old nomadic (Pastoral) camel production system is characterized by seasonal migration and mobility of herds in communal rangelands in search of better quality forage and water. Traditional nomadic system exhibited a wide variation in the diet of camels with mixed feeding behavior. This behavior limits the risk of mineral deficiencies because the vegetation selected is also of high nutritious quality [35]. Increasing pressure of human population on nomadic grazing areas have resulted in reduction of feed resources and environmental degradation.

In sedentary camel production system a number of factors can be attributed to the low productivity in animals. The most important single factor is dwindling quality and quantity of feed [35]. The gradual shift from nomadic to sedentary camel production system restricted camels to short-range areas for grazing and browsing resulting in increased risk of mineral deficiencies. Mineral deficiencies associated specific behavior in camels has been observed and confirmed by further investigations on the mineral status of camels in research centers and under free-ranging conditions [34].

Calcium and phosphorus requirements

Calcium and phosphorus requirements of camel have not been determined. The calcium and phosphorus requirements for ruminants depend on body weight and performance and requirement correspond to DM intake [36]. The recommendations for cattle producing 10 kg milk are used as reference values for camels, although camel milk yield is less than cattle. Recommended levels of Ca and P in cattle by German Society for Nutrition Physiology are 50 gd^{-1} and 32 gd^{-1} respectively. According to NRC (2001) recommendations Ca and P requirements are 125 mg-kg^{-1}DM and 3.2 gKg^{-1}DM respectively. Keeping in view the requirements of dairy and beef cattle and sheep [2,3] inclusion of 0.5 - 0.6% Ca and 0.3 - 0.35% P to camel diet might be satisfactory to fulfill requirements of racing camels.

Serum calcium and phosphorus levels

Camels are highly acclimatized to the arid and semi-arid environment and also have developed ways of adapting to various nutritional requirements and physiological changes in serum mineral concentrations. Various studies have shown that blood P levels are not good indicator of the P status because quick compensatory reaction for repletion maintain P at normal levels for long duration even after animals have been exposed to serious mineral deficiency [6]. Nonetheless a marked hypophosphatemia is a good indicator of a severe P deficiency, even if serum levels of Ca are unaffected. Normal serum Ca and P levels reported in various studies are given in the table 1. Calcium level in the serum of healthy camels is not lower and phosphorus is not higher than those in other ruminants except in equines (normal levels: Ca = cow 8.4 - 11; sheep 9.3 - 11.7; goat 9 - 11.6; horse 10.4 - 13.4 mg/dl; P = 4.3 - 7.8 cow; 4 - 7.3 sheep; 3.7 - 9.7 goat; 2.3 - 5.4 mg/dl horse) as described by Fraser., *et al* [39]. Therefore, the critical plasma Ca (8 mg/dl) and P (4 - 4.5 mg/dl) levels used for other ruminants may be applied to camels [2]. Faye., *et al*. (1992) studied the interaction between concentrate and mineral supplementation in camels already on basal diet deficient in protein, energy and minerals. The study concluded that improved general nutritional status had a strong effect on minerals (P = 7.09 ± 1.04 mg/100 ml; Ca = 8.4 ± 1.7 mg/100 ml) concentration in plasma. Similarly, Snow., *et al.* [5] stated that cereal feeding increased serum P level in dromedaries. Seasonal variation in serum concentration of minerals was reported in various studies [4,30]. Serum levels of Ca and P were highly significant ($p < 0.05$) during the wet season as compared to the summer season that is attributed to the availability of plants rich in minerals during the rainy season. Desalegn., *et al*. (2012) reported mean serum levels of calcium in adult camels in wet (4.79 ± 0.31 mEq/l) and dry (5.91 ± 0.31 mEg/l) season and found insignificantly higher ($P > 0.05$) serum Ca in winter in both sexes in camel. Moreover, water deprivation caused a slight decrease in serum calcium and phosphorus concentration from 2.71 to 2.57 mmol/l and 1.94 to 1.82 mmol/l respectively. During dehydration, the tubular reabsorption of phosphate is not affected, that of calcium decreased slightly from 99.9% to 99%. Serum Ca levels elevate significantly by dehydration.

Patodkar., *et al*. [10] studied the influence of sex on certain biochemical parameters in nomadic camels and concluded slightly higher levels of minerals in males (Ca = 10.12 ± 0.289 mg/dl; P = 5.68 ± 0.458 mg/dl) as compared to females (Ca = 9.20 ± 0.479 mg/dl; P = 5.59

Sex	Age	Unit	Serum		Milk		References
			Ca	P	Ca	p	
M	A	mmol/L	3.12 ± 0.19	1.70 ± 0.10			Kamalu., *et al*. 2000
M&F	1-10yrs	mmol/L	2.24 ± 0.6	1.58 ± 0.7	ND	ND	Aichouni., *et al*. 2010 [18]
M	A	mg/dl	10.12 ± 0.289	5.68 ± 0.458			Patodkar., *et al*. 2010 [10]
F	A	mg/dl	9.02 ± 0.479	5.59 ± 0.694	ND	ND	Patodkar., *et al*. 2010 [10]
M&F	A	mmol/L	2.21 ± 0.26	1.82 ± 0.65	ND	ND	Nazifi., *et al*. 1998
F	2 yrs./ Y	mg/dl	5.60 ± 1.042	8.70 ± 1.745	ND	ND	Eltahir., *et al*. 2010 [13]
M&F	A&Y	mg/100ml	9.5 ± 0.58	ND	ND	ND	Faye and Mulato, 1991
M&F	A	mg/100ml	9.1 ± 1.00	5.1 ± 0.7			Abu Damir, 1980 [40]
M&F	A	mg/100ml	9.7 ± 0.60	6.2 ± 0.5	ND	ND	Abu Damir, 1990 [41]
M&F	A	mg/dl		5.2 ± 1.0	ND	ND	Bogin, 2000 [12]
F	A	mg/dl	9.0 ± 0.1	3.8 ± 0.5	ND	ND	Osman and Al-Busadah, 2003 [14]
M&F	4-7 yrs	mg/dl	8.98 ± 1.08	5.02 ± 1.15	ND	ND	Mohamed and Hussein, 1999 [15]
M	A	mg/dl	9.56 ± 0.18	6.56 ± 0.32			Abdalmula., *et al*. 2019 [38]
F	A	mg/dl	10.05 ± 0.08	4.42 ± 0.26			Abdalmula., *et al*. 2019 [38]
F	A	g/L	ND	ND	1.232 ± 0.292	1.003 ± 0.217	Konuspayeva., *et al*. 2008 [17]
F	A	mg/L	ND	ND	1206 ± 166	821 ± 104	El-El Kashmi., *et al*. 2001
F	A	mg/100g	ND	ND	40-94	86-139	Knoess, 1980 [7]
F	A	g/l	ND	ND	1.15	0.84	Abu-Lehia, 1987 [9]
F	A	g/l	ND	ND	1.232 ± 0.292	1.003 ± 0.217	Konuspayeva., *et al*. 2008 [17]
F	A	g/l	ND	ND	1.43	1.16	Konuspayeva., *et al*. 2010 [16]
F	A	mg/g	ND	ND	143	116	Nikkhah, 2011 [32]
F	A	g/100g	ND	ND	0.11 ± 0.02	0.05 ± 0.01	Al-Juboori., *et al*. 2013 [31]
F	A	mg/L	ND	ND	944 ± 37	ND	Mostafidi., *et al*. 2016 [33]

Table 1: *Mineral contents of serum and milk in dromedary camels.*

± 0.694). Patel., *et al*. [11] reported significant decrease in serum Ca concentration and no significant alteration in serum P levels during early lactation (Ca = 9.17 ± 0.30 mg/dl; P = 3.55 ± 0.20 mg/dl); mid-lactation (Ca = 7.94 ± 0.43 mg/dl; P = 3.63 ± 0.21 mg/dl) and late lactation (Ca = 6.70 ± 0.38 mg/dl; P = 3.73 ± 0.07 mg/dl) in Kutchi camels. The continuous decrease of Ca level might be due to the drainage of blood calcium in milk and insufficient adjustment by the parathormone through bone Ca mobilization. On the other hand, maintenance of normal P level was due to plasma homeostasis of inorganic P metabolism, which is controlled by absorption, urinary excretion and bone resorption. Eltahir., *et al*. [13] compared serum Ca and P values (3.39 - 8.9 $mEqL^{-1}$; 5.68 - 13.0 mg/dl^{-1}) in Omani racing Arabian camels and claimed that serum calcium concentration was similar to the values reported for racing camels in the Arabian Gulf region and other countries in various studies [14] and serum P concentration at its upper level was higher than the upper range as reported by Mohamed and Hussein [15], Osman and Al- Busadah [14]. However, wide variation in serum Ca and P levels (1.6 - 2.8 $mmolL^{-1}$; 1.65 - 2.01 mg/dl^{-1}) were also reported by researchers in various countries. Aichouni., *et al.* [18] reported no significant difference among the mean values of serum calcium in adult camels from four different breeds of Algerian one-humped camels. Snow., *et al.* [5] stated that age matters in plasma P concentration and is comparatively higher when camels are young. Yet Barakat and Fattah [19] reported insignificant difference in Ca and P levels in male (6.12 ± 0.22 mEq/l, 12.2 ± 0.44 mg/dl) and female (6.55 ± 0.11 mEq/l,13.1 ± 0.22 mg/dl) camels with insignificant difference between ages, sexes, lactation and pregnancy status in female dromedaries.

Calcium and phosphorus in camel milk

Milk mineral composition is an indicator of mineral status in dairy animals. Mineral nutrition has been underscored, but maybe one of the major limiting factors to camel milk production along with supply of energy and crude proteins. Prolonged mineral deficiencies lead to low milk yield and affect the milk composition. There is wide variation in milk yield (2 - 14 ld^{-1}) in various parts of the world. Mineral composition of camel milk varies throughout the world as shown in the table 1. The general picture shows that it is quite comparable to cow milk. Camels from Saudi Arabia have comparable Ca and P levels reported by GfE (2001) in cattle. Knoess [7] reported that mineral concentration in camel milk (Ca = 40 - 94 mg/100g; P = 86 - 139 mg/100g) is higher than goats (Ca = 133 mg/100g; P = 97 mg/100g). The findings are in contrast to GfE (2003) reporting higher mineral contents in goat milk (Ca = 12820 $mg\text{-}l^{-1}$; P = 1310 $mg\text{-}l^{-1}$) than in camel milk (Ca = 1160 $mg\text{-}l^{-1}$; P = 870 $mg\text{-}l^{-1}$). Phosphorus highly influences feed intake and so it is unclear in many situations whether animal responses to P supplementation are due to P per se or simply to increased feed intake [6]. Generally, when P increases in diet, it results in increased uptake by mammary glands and cause increased milk P and or milk yield. Camels like other dairy animals react to low levels of Ca and P in feed, which is followed by a low serum level and reduced milk production. The effect of mineral supplementations on the milk yield of free-ranging Somali camels were investigated in semi-arid region of northern Kenya during wet and dry season. In the first phase the milk yield increased from 3.4 L/d to 4.3 ± 0.3 L/d in dry and wet season [29]. In the second phase of the study milk yield was 5.4 ± 0.5 and 6.5 ± 0.7 L/d during dry and wet season. Milk yield in animals supplied with P and other minerals increased significantly ($p < 0.05$) and was concluded that mineral supplementation was beneficial to lactating camels.

If we generalize the situation mineral composition of camel milk varies with parity, breed, locality (feeding pattern) availability of minerals from forage or by supplementation and water intake [28]. Similarly, Alwan and Zwaik [8] reported wide variation ($P < 0.05$) in Ca, P and other mineral contents of Libyan Maghrebi camels reared under farm and desert conditions. They attributed those significant effects to some factors as age, number of calving, management, stage of lactation, sampling techniques used and feed quality. Camel colostrum is rich in minerals than milk (1.44 - 2.8% vs 0.6 - 1%). Konuspayeva., *et al.* [16] reported physiological changes in multiparous Arvana camels milk all along the lactation and observed a parallel change of calcium and P in milk, the maximum value (1.43 g/l for Ca and 1.16 g/l for P) was observed at the beginning of lactation and the minimal values (Ca = 0.70 and P = 0.57g/l, respectively) at the peak lactation. Moreover, the ratio Ca/P was relatively constant. In another study by Konuspayeva., *et al.* [16] calcium to P ratio was stated to be the lowest among the dairy species. The ratio of Ca to P is 1.5 for camel milk verses to 1.29 for cow.

Calcium and phosphorus related deficiencies and disorders in camels

Simple Ca deficiency is very rare in ruminants and it occurs only when pasture contains less than 0.2% Ca, however, phosphorus deficiency is global. A number of authors have attributed various conditions in the camel to Ca and/or P deficiencies or imbalances. These conditions are Ca/P imbalance (Kraft), bend leg, urinary calculi, pica.

Calcium and phosphorus deficiencies/imbalances and nutritional disorders

Calcium/Phosphorus imbalance (Kraft)

This type of osteopathy is described in calcareous soils, with phosphorus deficiency and wide Ca/P ratio in soil (25:1) and pasture (11:1). The condition was first reported in underfed camels living in south of Tunisiain 1958. It was also reported from Algeria and Morocco [20]. The condition is characterized by spontaneous fractures of appendicular bones, lameness with intense joint pain, low mobility and death of the animal due to starvation. The histopathological lesions in long bones, ribs and vertebrae and blood picture indicated hypophosphatemia. This osteopathic condition develops due to either calcium-rich diet that reduces rumen P solubility or low dietary and salivary P that suppress rumen activity and leads to poor appetite. Another theory is that water deprivation influence bone metabolism as has been observed in desert rodents. But found no significant effect of dehydration and Ca and /P deficiency on development of Kraft in camels. Critical research is needed to elucidate the etiology of Kraft.

Bent leg/rickets/osteomalacia

Metabolic bone diseases are closely associated with mineral imbalances either due to dietary deficiency of Ca and/or dietary excess of P as seen in large domestic animals. Generally, camels are more prone to bone deformities especially those resulting from P deficiency/ vitamin D than other ruminants.

In United Arab Emirates, Al-Juboori and Korian [37] observed gradual Ca and P deficiency in young dromedaries that resulted in clinical symptoms related to mineral deficiencies. In the early stage of the disease one-month-old camel calves show arched back, difficult and stiff mobility with enlargement of joints especially in the forelimbs leading to lameness. Bend leg was first described in camel calves in Kenya and recently reported in 15% young camels in Sultanate of Oman and UAE. Blood analysis and nutrition management suggests that the condition arise due to feeding poor quality roughage low in calcium and or phosphorus in weaned camel calves but in newborn animals and very young animals the etiology is still in infancy.

Although rickets and osteomalacia have been reported in cattle, water buffaloes, sheep and dogs [21,22] but scarce data availability in camels. Rickets is one of the nutrition-related metabolic bone disease. It is characterized by mineralization failure in bones and cartilage structures resulting in visibly swollen joints, knock-kneed and lameness. If the problem gone unnoticed long bones deformities, angular limb defects, and bone fractures aggravate the situation. Calcium, phosphorus, vitamin D and some combinations result in absolute or induced deficiency recognized as rickets.

Osteomalacia occurs in adult camels and is characterized by general weakness, emaciation, bone fragility with stiff gait and lameness. Affected camels are often seen chewing bones, rocks and other objects [21]. Heuer and Bode (1998) reported that osteomalacia cases in water buffaloes were closely associated with serum P < 0.97 mmol/l. In Bactrian camels in osteomalacia P levels in serum, hair, bones and teeth reduced and serum AKP level increased as compared with control group. So it was concluded that disease was caused by P deficiency. The pathogenesis of P deficiency-related bone deformities in animals involves activities of various hormones including 1,25-dihydroxycholecalciferol (calcitriol) and parathyroid hormone PTH. The concentration of PTH in serum from affected animals was significantly higher than those for healthy animals.

Acid-base disturbances

High energy diets such as cereal grains, sorghum, and dates are extensively fed to racing camels. Such diets can cause mineral disturbances and metabolic acidosis in dromedaries. High calcium secretion in urine, increased bone resorption and decreased mineral retention in the body are the consequences of acute or chronic acidosis. This fact is attributed to kidney failure to reabsorb Ca [23]. Metabolic acidosis leads to clinical bone diseases in young camels quicker than in other ruminants. Lameness suspected as osteochondrosis has been seen in grain-fed young fast-growing camels. Therefore it is assumed that high energy unbuffered diet feeding can result in bone weakness and impairment of the primary mechanism of energy utilization by low intracellular pH that adversely affect the performance.

Urolithiasis

Urolithiasis is a common problem in male ruminants. Various calcium salts, silica, phosphatic complexes and oxalates are all potential mineral sources causing uroliths [24]. In most cases, struvite (magnesium-ammonia-phosphate) crystals are formed secondary to high grain feeding and low dietary calcium-to-phosphorus ratio and cause the blockage. Young male ruminants fed on high energy alkaline diets are more prone to this condition. However, the diet of racing camels in some of the Arab countries (barley, sorghum grains, dates, milk and lucerne does not contribute to urolith formation. Nevertheless, cases of urolithiasis in concentrate fed camels have been reported by Kock [25] in UK. Two adult camels fed on high energy diet with high phosphate content were reported with uroliths. In the first case penis urethra was blocked with rough irregular shaped calculi. Bilateral valgus deviation of the carpal joint was evident which might indicate calcium-phosphorus imbalance. In the second case again chalky, seed shaped Ca calculi were reported.

Pica

Pica is generally associated with mineral insufficiencies associated with clinical findings biting or ingesting wood, sticks, plastic, paper, with continuous licking of hair, manager walls, floors and other equipment in nearby. Although the cause of pica in animals is not well understood there are many reasons effective in etiology which are mainly the deficiency in some proteins,α-amino acids, trace elements, vitamins as well as reduction in alkali reserve of body, dietary unbalanced calcium-phosphorus ratio and high consensus on phosphorus and Ca deficiency [26]. Circulating inorganic phosphorus levels were significantly lower in the animals behaving pica than in healthy camels, buffaloes and cattle respectively. Kachhawah., *et al.* [27] reported 41.8% incidence of pica in southern Rajasthan and stated that pica was common in camels affected by surra and helminths. In advanced stages of the condition camel becomes lean with smaller hump that may disappear. In camels the pica has been associated with heavy infestation of gastro-intestinal worms e.g. *Haemonchus, Strongyloides, Trichostrongylus, Trichuris, Nematodirus* and *Oesophagostomum*, together with deficiencies of minerals such as calcium and phosphorus.

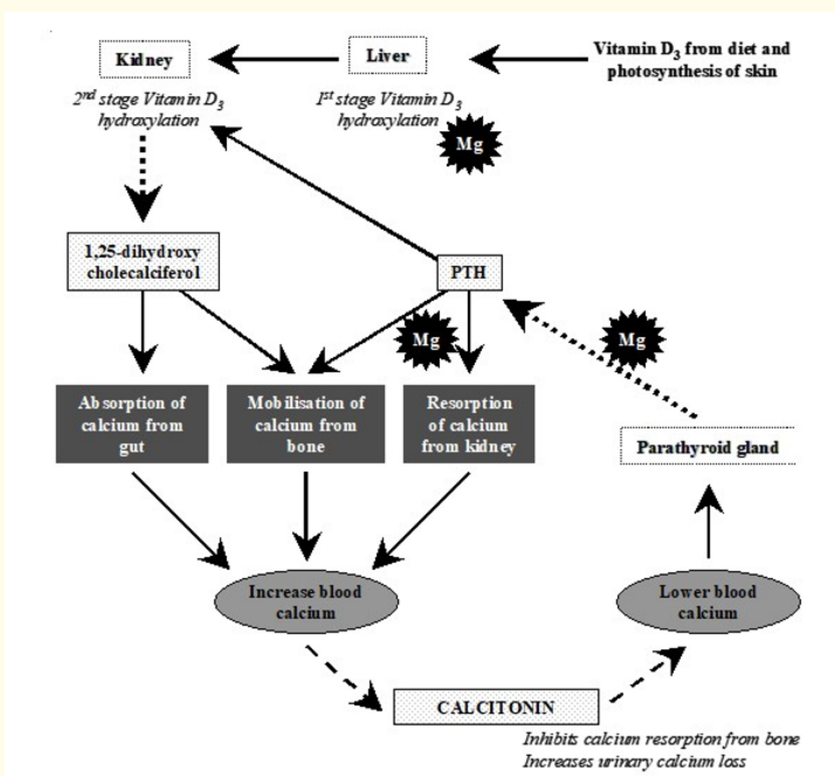

Figure 1: *Hormonal regulation of calcium and phosphorus metabolism.*

Conclusion

By overviewing the literature it is concluded that Ca and Pare essential to satisfy the needs of the camels and provide protection against the more acute effects of prolonged malnutrition. Moreover, milk yield in camels like in other dairy animals is highly correlated with the amounts of Ca and P in blood and feed. The serum mineral values obtained in one country could not be taken as standard in other countries having different climate, nutritional and managemental conditions. So extensive study is needed to establish reference values of Ca and Pin dromedaries according to sex, age, environment and nutritional regime as estimated in other ruminants. Furthermore, blood profile of Ca and P can often provide valuable information regarding health and nutritional disorders related to mineral deficiencies.

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