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# Mineral profiles and mineral turnover in the forestomachs of camels in Kenya grazing under various seasonal conditions

**HÖLLER (H.), BREVES (G.), LECHNER-DOLL (M.).** Profils et taux de renouvellement en minéraux dans le pré-estomac de dromadaires pâturant en diverses saisons au Kenya. *Revue Élev. Méd. vét. Pays trop.*, 1989, **42** (1) : 81-87.

**Les volumes et les taux de renouvellement du liquide des pré-estomacs ont été mesurés sur quatre dromadaires adultes fistulés entretenus sur pâturage dans les savanes arbustives à épineux du Kenya. Simultanément, les concentrations en minéraux et leur renouvellement ont été déterminés dans les compartiments C1 (rumen) et C2 (réseau). Les études ont été menées durant la saison humide et durant la saison sèche ; les comportements alimentaires ont été observés pour déterminer les régimes. Les volumes du liquide du pré-estomac n'étaient pas différents d'une saison à l'autre mais les taux de renouvellement du liquide étaient beaucoup plus bas en saison sèche. Les profils de concentration en minéraux Na, K, Ca, Mg et en phosphore inorganique variaient dans la journée selon les différents régimes alimentaires et probablement la production de salive. Le renouvellement journalier des cinq minéraux, dans les pré-estomacs a diminué durant la saison sèche.** *Mots clés* : Dromadaire - *Camelus dromedarius* - Liquide biologique - Minéraux - Concentration - Pâturage - Pré-estomacs - Kenya.

## INTRODUCTION

The mineral supply to freely grazing or browsing animals is difficult to evaluate since neither dietary intake nor faecal excretion of minerals can be determined with some degree of certainty in such animals. The experimental problems aggravate if animals are selectively grazing or browsing amongst a great variety of plant species, thus excluding the possibility of feeding representative forage samples in balance experiments. Minerals available for absorption from the gastrointestinal tract must be dissolved in the liquid phase of the gastrointestinal contents, either in the ionized or unionized form. They are of dietary origin or derived from endogenous sources, *e.g.*, secreted with saliva. Therefore, a reasonable though semi-quantitative estimate of the daily supply of dissolved minerals to the gastrointestinal sites of absorption should be possible by measuring, repeatedly over the day, the mineral concentrations in the forestomach fluids, the forestomach fluid volumes and fluid turnover rates.

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Very little information is available on mineral supply to camels which are freely and selectively grazing and browsing in their natural habitat. Mineral concentrations in blood plasma have been reported by several authors for camels kept under different conditions (compilation see GRÜNDEL, 8) but they reflect regulatory functions and dysfunctions rather than actual flow of available minerals through the absorptive alimentary canal. Therefore mineral and fluid parameters were studied in fistulated dromedary camels in Northern Kenya. The experiments were carried out at the field research station Isiolo (about 300 km north of Nairobi, 1,100 m above sea level, mean annual rainfall 510 mm in the two raining seasons, *i.e.* March to May and October to November). The vegetation type can be described as thornbush savannah with various *Acacia* species, annual grasses, herbes and shrubs. The experiments were done during the « green season » after rainfall (November) and during the dry season (September).

## MATERIAL AND METHODS

Four castrated male camels (*Camelus dromedarius*), 4 to 5 years old, were supplied with permanent cannulae in the upper part of forestomach compartment C1, *i.e.*, in the forestomach section resembling rumen and reticulum in ruminants (6). A schematic drawing of the fistulated forestomach is given in figure 1.

The body weights during the green season experiments were between 420 and 515 kg, during the dry season experiments almost one year later between 450 and 560 kg. The animals were kept over night and in periods between grazing in open, roofed enclosures and had access to salt lick blocks throughout. Grazing and browsing was allowed from 8 a.m. to 1 p.m. and from 3 p.m. to 6 p.m., with a rest over midday in the camp. The animals walked between 5 and 10 km per day, with the larger distances falling into the dry season. In both seasons water was regularly provided once a day *ad libitum* at about 1 p.m. In the green season no water was offered on experimental and sampling days, whereas in the dry season the animals were allowed to continue their usual watering regime to avoid disturbance of their water balance. Approximately 30 l water were then ingested by each animal.

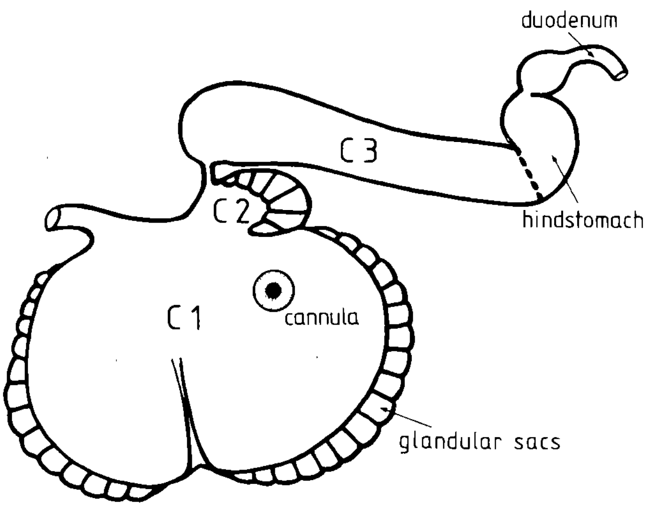


*Fig. 1 : Schematic drawing of camel forestomach system with cannula in C1.*

This means that the determination of the fluid parameter and the mineral profiles in the forestomachs began at least 17 hours after the last watering the day before.

At regular and frequent intervals feeding observations were done as they have been described by BUECHNER (4) to characterize the nutrition of the animals. Each camel was repeatedly observed for two 10-minutes periods during the morning grazing, the two periods being separated by a 30-minutes interphase. During each observation period it was recorded how much time was spent by each animal eating a specific plant, or part of a plant, without moving onwards. So the relative and total feeding times were determined, and the most preferred plant species could be identified, sampled and stored for eventual chemical analysis. It should be noted, however, that this procedure does not allow a quantitative estimate of energy, nitrogen and mineral intake.

Fluid parameters for C1 + C2 were determined by the use of Cr-EDTA as an unabsorbable fluid volume marker. At 6 a.m. approximately 1.35 g Cr as Cr-EDTA dissolved in 150 ml Aqua dest. were given into compartment C1 as a single injection. Fluid volumes, fluid turnover rate constants and fluid turnover rates were calculated on the basis of Cr concentrations in the forestomach fluid measured in 20 ml samples which were taken at hourly intervals from 7 a.m. to 12 p.m. through a tube introduced through the C1 cannula. The equation :

$$C = C_0 \cdot e^{-kt}$$

was applied, where C means the Cr concentration at any given time, $C_0$ Cr concentration at injection time, k turnover rate constant and t time after injection. The same samples were used for determining the mineral concentrations. After measurement of the pH value by a battery-operated pH-meter the fluid was squeezed through several layers of cheese cloth, and 5 ml aliquots were mixed with 0.5 ml conc. formic acid for acidification to < pH 2. These samples were kept in a refrigerator and, after return to the home laboratory, stored at -18 °C. Before mineral analysis the thawed samples were centrifuged at 40,000 g for 20 minutes to obtain particle-free forestomach fluid. Sodium and potassium were determined by flamephotometry (FLM 3, Radiometer, Copenhagen), calcium, magnesium and chromium by atomic absorption spectrometry (Perkin Elmer AAS 400, Überlingen) and inorganic phosphate by the ammonium-molybdate standard method as described by RICHTERICH (14). Conventional standard procedures were applied for feed analyses.

For the calculation of the daily mineral flow out of C1 + C2 to lower parts of the gastrointestinal tract some assumptions had to be made. Firstly, the chromium-based daily fluid turnover rate constitutes fluid outflow to C3 only if the fluid volume in C1 + C2 remains constant over the day. Secondly, it was assumed that no drastic changes of mineral concentrations in the forestomach fluid occurred between midnight and 7 a.m. when there was no sampling and the animals were resting and ruminating.

## RESULTS

In the green season 29 different plant species were selected by the camels but approximately 77 p. 100 of the total feeding time was spent for eating 8 species only. In the dry season the number of selected species was reduced to 7, and about 96 p. 100 of the feeding time was used for grazing or browsing of only 3 species. In table I the preferred plants, the relative feeding time as percentage of total feeding time, and the chemical composition of the plants are given for both seasons.

The pH values of the original forestomach fluid over the day were between 5.8 and 7.5 in both seasons, with a tendency of slightly higher values in the dry season and an indication of peak values during the early grazing phase in the morning. The daily pH profiles (means of 4 animals with standard deviations) are shown in figure 2.

The concentrations of 5 minerals over a grazing day in the acidified and particle-free forestomach fluid are summarized in figure 3.

The decrease of the chromium concentrations in the forestomach fluids could be described by significant monoexponential functions as they are shown in table II. The fluid turnover rate constants were not signifi-

*TABLE I Relative time spent by camels for feeding mostly preferred plant species and chemical composition of those parts of the plants ingested by the animals.*

| Plant species | Feeding time as per cent of total feeding time | Chemical composition | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Crude fiber | Crude protein | Crude fat | Ash | NFE | Na | K | Ca | Inorg. phosphate | Mg |
| | | in per cent of dry matter | | | | | in mg/g dry matter | | | | |
| Green season | | | | | | | | | | | |
| *Sterculia africana* | 22 | 21.5 | 24.5 | 1.9 | 10.1 | 42.0 | 0.08 | 18.1 | 15.8 | 3.0 | 7.2 |
| *Velonix elata* | 10 | 13.2 | 31.6 | 1.9 | 7.4 | 45.9 | 0.15 | 15.1 | 13.5 | 3.1 | 2.8 |
| *Grewia bicolor* | 9 | 20.7 | 23.8 | 1.3 | 9.5 | 44.7 | 0.05 | 21.7 | 16.4 | 3.3 | 4.9 |
| *Indigofera spinosa* | 9 | 33.5 | 12.6 | 1.3 | 9.1 | 43.5 | 0.11 | 12.1 | 33.7 | 2.7 | 4.9 |
| *Acacia mellifera* | 8 | 20.1 | 28.8 | 3.0 | 8.2 | 39.9 | 0.09 | 19.0 | 15.9 | 2.8 | 4.9 |
| *Barleria acanthoides* | 7 | 36.7 | 14.0 | 1.4 | 9.4 | 38.5 | 0.12 | 19.6 | 34.6 | 2.5 | 5.8 |
| *Maerua endlichii* | 6 | 11.4 | 26.3 | 2.8 | 16.3 | 43.2 | 0.27 | 28.1 | 19.8 | 1.6 | 12.2 |
| *Commiphora africana* | 6 | 13.6 | 21.9 | 1.1 | 7.1 | 56.3 | 0.07 | 14.1 | 11.7 | 2.9 | 4.4 |
| Dry season | | | | | | | | | | | |
| *Maerua crassifolia* | 66 | 8.5 | 19.6 | 3.4 | 20.0 | 48.5 | 0.14 | 22.4 | 26.7 | 1.2 | 18.4 |
| *Heliotropium albohispidum* | 17 | 40.9 | 6.9 | 1.5 | 6.9 | 43.8 | 0.31 | 64.0 | 25.6 | 0.8 | 1.8 |
| *Indigofera spinosa* | 13 | 41.1 | 8.8 | 1.7 | 6.4 | 42.0 | 0.10 | 5.8 | 37.1 | 1.3 | 2.5 |

*TABLE II Monoexponential functions obtained for the decrease of the Cr concentrations in forestomach fluids (C = Cr concentration ; t = time in hours).*

| Green season | | | n |
|---|---|---|---|
| Animal No. 1 | $C = 16.5.e^{-0.173\,t}$ | $r^2 = 1.00$ | 16 |
| Animal No. 2 | $C = 17.6.e^{-0.160\,t}$ | $r^2 = 0.99$ | 16 |
| Animal No. 3 | $C = 19.6.e^{-0.171\,t}$ | $r^2 = 0.99$ | 16 |
| Animal No. 4 | $C = 18.8.e^{-0.133\,t}$ | $r^2 = 1.00$ | 16 |
| **Dry season** | | | **n** |
| Animal No. 1 | $C = 25.1.e^{-0.107\,t}$ | $r^2 = 0.87$ | 16 |
| Animal No. 2 | $C = 24.7.e^{-0.091\,t}$ | $r^2 = 0.85$ | 16 |
| Animal No. 3 | $C = 25.5.e^{-0.080\,t}$ | $r^2 = 0.88$ | 16 |
| Animal No. 4 | $C = 24.0.e^{-0.082\,t}$ | $r^2 = 0.85$ | 16 |

cantly affected by water intake.

The mineral pools in C1 + C2 were obtained by multiplying the fluid volumes by the mineral concentrations measured at the time of Cr-EDTA injection into C1. For the estimation of the mineral turnover rate constant and the daily mineral turnover the respective fluid parameters were used, together with the 24 hours means of the mineral concentrations. Since there was no fluid sampling between midnight and 7 a.m. the mineral concentrations for this time interval were obtained by intrapolation. So, for the dry season, the daily mineral turnover rates are rather an underestimation of the true mineral flow because diluting effects of watering on mineral concentrations have been considered in the calculations, but not the transiently higher fluid turnover rates immediately after water intake. The fluid and mineral parameters are given in table III.

It was found that the forestomach fluid volumes did not greatly differ between the two seasons but that the daily fluid turnover was considerably smaller, and hence the mean fluid retention longer, in the dry

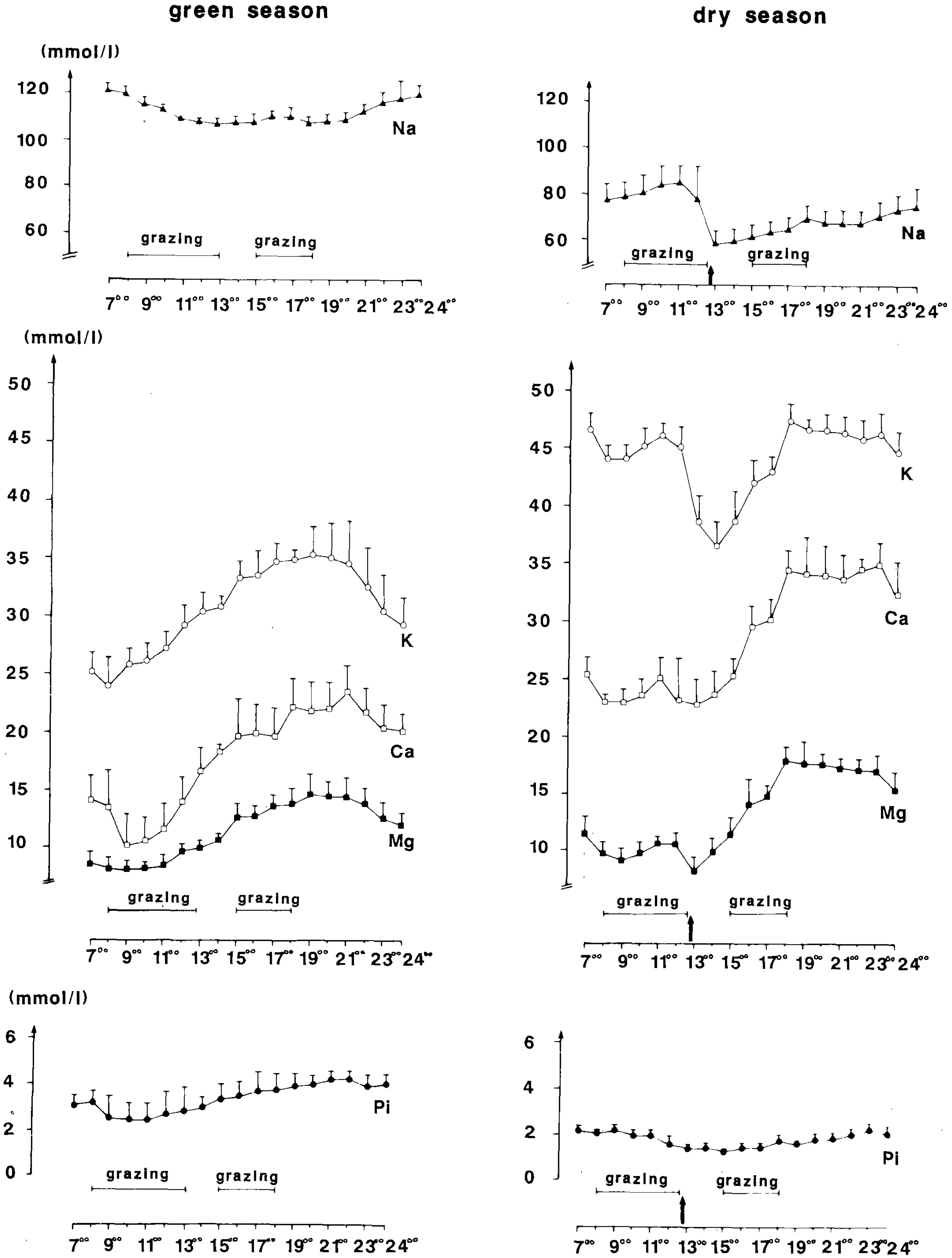


*Fig. 3: Mineral profiles in the forestomach fluid (means of 4 animals + S.D.). The arrow indicates time of watering.*

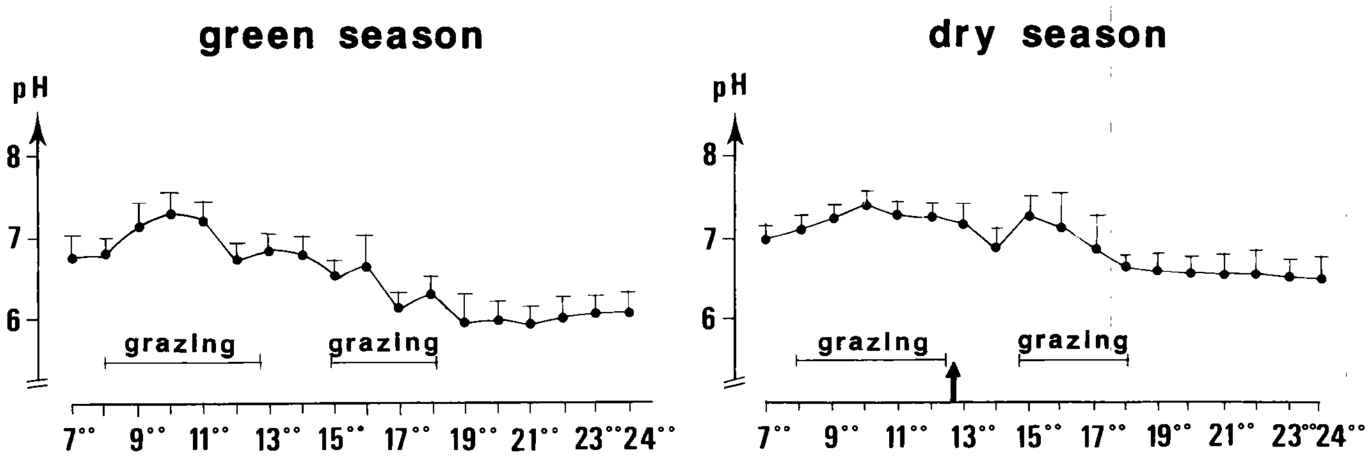


*Fig. 2 : pH values in the forestomach fluid (means of 4 animals + S.D.). The arrow indicates time of watering.*

*TABLE III Fluid and mineral parameters for forestomach compartments C1 + C2 (means of 4 animals ± S.D.).*

| | Green season | Dry season |
|---|---|---|
| Fluid volume [l] | 38.9 ± 2.1 | 39.8 ± 2.9 |
| Fluid turnover rate constant [/h] | 0.16 ± 0.02 | 0.09 ± 0.01 |
| Fluid turnover rate [l/day] | 146.9 ± 17.6 | 86.3 ± 16.8 |
| Mean fluid retention [/h] | 6.4 ± 0.9 | 11.3 ± 1.6 |
| Sodium pool [g] | 103 ± 5.0 | 67 ± 9.0 |
| Sodium turnover rate [g/day] | 390 ± 50 | 145 ± 37 |
| Potassium pool [g] | 44 ± 4.1 | 67 ± 7.0 |
| Potassium turnover rate [g/day] | 166 ± 19 | 146 ± 28 |
| Calcium pool [g] | 28 ± 2.5 | 44 ± 3.4 |
| Calcium turnover rate [g/day] | 105 ± 18 | 95 ± 13 |
| Magnesium pool [g] | 10 ± 1.3 | 13 ± 1.5 |
| Magnesium turnover rate [g/day] | 40 ± 6 | 28 ± 6 |
| Phosphate pool [g] | 4 ± 0.8 | 2 ± 0.1 |
| Phosphate turnover rate [g/day] | 16 ± 2.8 | 5 ± 0.8 |

season than in the green season. Forestomach pools of sodium and inorganic phosphate were smaller in the dry season but potassium and calcium pools were greater. Due to different pool sizes and reduced fluid turnover the daily turnover of all five mineral was smaller in the dry season as compared to the green season.

## DISCUSSION

The fluid volumes in the forestomach compartments C1 + C2 determined 17 hours after the last watering did not markedly differ between the individual animals and between the two seasons. Since the mean chromium turnover rate constants were not significantly changed by water intake 7 hours after marker injection, the calculation of the fluid volumes in the dry season was not adversely affected by the changed watering regime. The forestomach fluid volumes constituted 8.7 ± 0.5 p. 100 of the body weight in the green season and 8.0 ± 0.5 p. 100 in the dry season. When expressed on the basis $kg^{0.82}$ the respective average figures were 261 $ml/kg^{0.82}$ in the green season and 254 $ml/kg^{0.82}$ in the dry season, and these figures compare well with those obtained by FARID *et al.* (7) in two camels kept in a stable and fed once daily a maintenance ration. Higher fluid volumes (46-55 l) were reported by BHATIA *et al.* (2) for 8 stall-fed camels of about the same body weight, and by MALOIY (13) for 2 camels of unknown body weight (45-48 l). Fluid volumes of 14 and 30 l were found by HOPPE *et al.* (12) in camels weighing 162 and 186 kg, and 35 ± 13 l were measured by HELLER *et al.* (9) in 4 camels of 200-250 kg body weight.

Whereas the fluid volumes in C1 + C2 were almost identical in both seasons the daily fluid turnover in the dry season was reduced by more than 40 p. 100. Even if 30 l drinking water are added to the fluid volume leaving the forestomach per day the difference remains highly significant. Accordingly the mean fluid retention in C1 + C2 in the dry season was about twice as long as in the green season. The mean fluid retention in the dry season was similar to that found by HELLER *et al.* (9) in their studies with camels in the Sudan fed once a day different types of diets.

It is still unknown which factors maintain the remarkably constant forestomach volumes, irrespective of the type and nutritional value of the diet consumed. Water

Retour au menu



intake may be one of these factors (7, 9) but it should be noted that the fluid volume determinations were made 17 hours after the last watering. It is also unknown how fluid turnover is regulated. Fluid outflow from C1 + C2 is correlated with fluid inflow which is composed of exogenous (drinking and dietary water) and endogenous (saliva, transmural flux) components. Whereas nothing is known about transmural water fluxes in the camel forestomach, saliva secretion from one parotid gland was studied by several authors (1, 11, 15). Estimates are between 12 and 22 l per day and gland, and the duration of rumination seems to be one of the determining factors. Considering the type and amount of diet consumed by the animals during the two seasons it appears unlikely that the reduced fluid turnover in the dry season was due to a greatly reduced saliva flow as a result of a much shorter time spent for rumination. Possibly the metabolic situation in the forestomach has a direct or indirect influence on fluid turnover since, in these animals, the acetate production rate in C1 + C2 was much smaller in the dry season than in the green season (10).

The mineral concentrations and pools in C1 + C2 are determined by intake with food and drinking water, endogenous inflow with saliva, and outflow with forestomach fluid or across the forestomach wall. The sodium and phosphate pools over the day should mainly result from salivary inflow because the diet contained very little of these electrolytes, and lick blocks were not available during the grazing hours. Lower concentrations in the dry season may reflect a reduced rate of saliva production. The phosphate concentrations in the forestomach fluid in both seasons were similar to those found in the rumen fluid of sheep with an experimental phosphorus deficiency (3). A clinical syndrome possibly caused by phosphorus deficiency (« krafft ») in dromedaries in Tunisia was described by DURAND and KCHOUK (5). The daily profiles of potassium, calcium and magnesium seem to be correlated with the digestion and liquification of food ingested during grazing and browsing, showing peaks during the evening and first part of the night. Greater forestomach pools of potassium, calcium and magnesium in the dry season may be a result of the higher contents of these electrolytes in the preferred plant species as well as of a reduced rate of fluid outflow from C1 + C2.

## CONCLUSION

The results show that camel freely grazing and browsing under various vegetational conditions have a remarkable capacity to maintain a certain forestomach fluid volume, despite of different patterns of water intake and turnover. Under dry season conditions the rate of fluid outflow from the forestomach system was greatly reduced, thus assisting in keeping up normal forestomach fluid volumes. It is still unknown which regulatory processes are involved. The results also show that the mineral supply to grazing camels may become marginal, or even deficient, during the dry season. Such mineral imbalances are not fully reflected by mineral concentrations in the forestomach fluid since the rate of mineral outflow to the sites of absorption in the gut may decrease during the dry season.

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**HÖLLER (H.), BREVES (G.), LECHNER-DOLL (M.).** Mineral profiles and mineral turnover in the forestomachs of camels in Kenya grazing under various seasonal conditions. *Revue Élev. Méd. vét. Pays trop.*, 1989, **42** (1) : 81-87.

**Forestomach fluid volumes and turnover rates, and mineral concentrations, pools and turnover rates in forestomach compartments C1 + C2 were determined in 4 adult fistulated camels during grazing/browsing in the thornbush savannah of Northern Kenya. The studies were done in the green season and again in the dry season, and feeding observations were performed to characterize the nutritional situation. The forestomach fluid volumes were not different between the two**

**HÖLLER (H.), BREVES (G.), LECHNER-DOLL (M.).** Estado y tasa de reposición de minerales en el pre-estómago de dromedarios al pastoreo en diferentes estaciones en Kenya. *Revue Élev. Méd. vét. Pays trop.*, 1989, **42** (1) : 81-87.

**Se midieron los volumenes y las tasas de reposición del líquido de los pre-estómagos en cuatro dromedarios adultos fistulados mantenidos al pasto en las sabanas arbustivas con plantas espinosas del Kenya. Se determinaron simultaneamente las concentraciones de minerales y su reposición en los compartimientos C1 (panza) y C2 (redecilla). Se efectuaron los estudios durante la estación húmeda y durante la estación seca al observar los comportamientos alimenticios para**

**seasons but the fluid turnover rates were much lower in the dry season. The mineral concentration profiles of Na, K, Ca, Mg and inorganic phosphate over the day differed according to different dietary intake and probably saliva production. The daily turnover in the forestomach of all five minerals was reduced in the dry season.** *Key words* : Camel - *Camelus dromedarius* - Grazing - Forestomach fluid volumes - Fluid turnover - Mineral concentrations - Mineral pools - Mineral turnover - Kenya.

**evidenciar las dietas. No eran diferentes los volumenes del liquido del pre-estómago entre ambas estaciones sino las tasas de reposición del liquido eran mucho inferiores durante la estación seca. Las concentraciones de minerales Na, K, Ca, Mg y de fósforo inorgánico variaban durante el dia según las varias dietas y verosimilmente la producción de saliva. La reposición diaria de los cinco minerales en los pre-estómagos disminuyó durante la estación seca.** *Palabras claves* : Dromedario - *Camelus dromedarius* - Minerales - Concentración - Liquido biológico - Pastoreo - Pre-estómago - Kenya.

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