Nitrogen metabolism and renal function in the dik-dik antelope (*Rhynchotragus kirkii*)

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Received 15 June 1999; accepted 7 December 1999

Abstract

Nitrogen metabolism and kidney function of the dik-dik antelope (*Rhynchotragus kirkii*) were studied under a range of controlled, experimental conditions and diets. Dik-dik antelope remained in nitrogen balance even when fed a diet low in protein and high in fibre. When fed a diet high in protein (20%) and water ad-libitum, 55.3% of the urea filtered by the kidney was reabsorbed. Limiting water intake increased urea reabsorption to 77.2%. The U/P urea concentrations were maintained at similar ratios on all diets, as well as during dehydration and solute loading. Minimum endogenous nitrogen excreted was 74 mg/kg^{0.75}/day. Dehydration (water deprivation) and solute loading (intraruminal infusion of 0.25 M NaCl) had varying effects on nitrogen metabolism. It is concluded that the metabolic nitrogen economy of the dik-dik antelope is qualitatively similar to that of other domestic and wild ruminants. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Dik-dik antelope; Dehydration; Kidney function; Nitrogen balance; Urea metabolism

1. Introduction

Dik-dik antelopes are small, wild ruminants that inhabit arid and semi-arid regions of East, Central and Southwest Africa (Estes, 1991). These antelope selectively feed on succulent, easily digestible and rapidly fermentable leaves and seeds with a high energy content when, during the rainy season, such forage is readily available (Hofmann, 1973; Maloiy, et al., 1988; Estes, 1991). However, during the dry season, dik-dik must thrive on forage of very poor nutritional value, often high in fibre and low in protein. Almost no information is available on the nutritional and physiological stress imposed upon these small desert ruminants when deprived of water, and only a limited number of studies have been reported when water is provided (Maloiy, 1973; Hoppe, 1977).

In the present study, nitrogen metabolism and the role played by the kidney in the regulation of metabolic nitrogen were studied in dik-dik antelope under a wide range of experimental conditions and varied dietary composition. Dik-dik antelope, like other domestic and wild ruminants, are able to utilize dietary urea for protein synthesis (Rugangazi and
Maloiy, 1988a, b). The purpose of these studies was to determine dietary nitrogen utilization by the dik-dik, under harsh nutritional conditions, and to compare these findings to those reported on other ruminant species. Aspects of nitrogen economy investigated were: daily nitrogen intake, excretion, and balance, and creatinine, urea and ammonia nitrogen metabolism. The amount of urea filtered and reabsorbed by the kidney, and changes in glomerular filtration rate were also investigated.

2. Materials and methods

Six adult dik-dik antelope (four females and two males) were used in this study. The dik-dik were wild antelope, purchased from a professional animal dealer, and maintained in captivity according to guidelines of the American Physiological Society (1986). The six dik-dik, with a mean body weight of 3.8 kg ±0.6 SEM (range of 2.8–4.7 kg), were allowed a 3–4 week captive environment and diet acclimation period before beginning the experiments. The diet provided during the acclimation period consisted of Grewia similis leaves and early weaning calf pellets (6.2% fibre and 20.1% crude protein, Unga Ltd, Nairobi). A mineral block and fresh water were also provided, ad libitum.

2.1. Housing

The six dik-dik antelope were dewormed and maintained in a group housing unit for 1 month before being transferred to their individual metabolic cages in an environmentally controlled research unit. The environmental units consisted of climatic chambers where the temperature and relative humidity were controlled at 22°C and 30% humidity, respectively. Each animal was individually housed in a metabolism cage which allowed automatic separation of urine and faeces. The base of each cage was fitted with a small rectangular metallic wire-mesh that provided for retention of the faeces, while allowing the urine to drop into a funnel shaped collection device fitted with glass urine collection units. The metabolic chambers were also fitted with separate containers, at the front of each cage, for providing food and water.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Dry matter (%)</th>
<th>Fibre (%)</th>
<th>Crude protein (%)</th>
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<tbody>
<tr>
<td>Star grass hay</td>
<td>86</td>
<td>28</td>
<td>7</td>
</tr>
<tr>
<td>Lucerne leaves</td>
<td>82</td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>Grewia similis leaves</td>
<td>92</td>
<td>12</td>
<td>14</td>
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</tbody>
</table>

2.2. Experimental diets

The composition of the three experimental diets fed the dik-dik antelope and expressed in terms of dry matter, crude protein and fibre content, are detailed in Table 1. Each dik-dik was fed its respective diet for a period of 14 days prior to the beginning of sample collection. Animals were continually fed their respective diets and maintained in individual metabolic chambers for a minimum of 10 days during sample collection. Diets and water were provided ad libitum during each experimental period, with food intake and faecal output recorded daily.

2.3. Renal function studies

After completion of the nitrogen balance studies, renal function studies were conducted on the four female dik-dik fed a diet of Grewia similis leaves and early weaning calf pellets. Each of the dik-dik antelope were fitted with an indwelling polythene catheter inserted into the jugular vein and another into the rumen-reticular compartment as previously described (Rugangazi and Maloiy, 1987, 1988a). A series of 6–10, 2 ml blood samples were withdrawn into a heparinized tube, centrifuged and the resulting plasma stored for later analysis. A Foley catheter was also inserted into the bladder of each female dik-dik for direct urine collection. Water was provided either ad libitum for the hydrated (control) and for the solute loading (0.25 M NaCl) experimental periods, or as a restricted water supply (dehydration studies). State of dehydration was defined as a loss of 10–15% of that animal’s initial body weight. The solute loading phase of the experiment was accomplished by the addition of NaCl intraruminally, as previously described by Rugangazi and Maloiy (1987, 1988a). All animals were weighed at the beginning and end of each
experimental period, using a model 235 Salter Spring Balance (25 kg capacity). Dehydrated dik-dik were weighed every second day, and sufficient water provided so as to maintain a limited fluid intake regulation of 10–15% body weight loss. Composite 10 g daily samples of feed, faecal material and urine were collected for proximate analysis, with the feed and faeces being refrigerated and urine being frozen at −20°C for later analysis.

2.4. Chemical analysis

Feed and faecal samples were dried to a constant weight in a forced air oven at 105°C for dry matter determination. Dried feed and faecal samples were then analyzed by proximate analysis. Urine and plasma samples collected during the study were analyzed in duplicate for osmolality, creatinine, urea-N and ammonia-N. Osmolality of the urine and plasma samples was determined by freezing point depression (Knauer Micro-osmometer). Creatinine concentration of the plasma and urine was determined by the Jaffe reaction, with the glomerular filtration rate (GFR) estimated using endogenous creatinine clearance. Total urinary nitrogen and urea concentrations were determined calorimetrically, following treatment with diacetylmonoxine, according to the methods of Foster and Hochholzer (1971). The nitrogen content of the feed and faecal samples was determined by micro-Kjeldahl methods.

2.5. Statistical analysis

Means and standard error of the means (SEM) were calculated for all experimental data. Student’s T-test was used to determine statistical differences between the data of the control (normal hydration) period and that of each treatment. Significant difference was set at the P<0.05 level. Linear regression analysis was used to establish the relationship between urine flow rate and filtered urea excreted (i.e. glomerular filtration rate) (Hall, 1984).

3. Results

When dik-dik antelope were fed the basal diet of Grewia similis leaves or the lucerne hay, the animals maintained a constant body mass. However, when these same animals were fed the star grass (Cynodon dactylon) hay, the dik-dik lost weight. One dik-dik had to be removed from the star grass hay feeding experiment when the animal’s condition deteriorated drastically.

Daily nitrogen intake and that which was lost or excreted in the urine and faeces when the dik-dik were fed the experimental diets is presented in Table 2. All animals were in a positive nitrogen balance, even when fed the low protein (i.e. star grass hay) diet. However, it was observed that when Grewia similis leaves or lucerne hay were fed the urine nitrogen loss (66%) was greater than that of faecal nitrogen loss (34%), while faecal nitrogen loss (56%) exceeded that of urinary loss (44%) for the star grass hay.

Urine urea-N concentration and urine osmolality of dehydrated and solute loaded dik-dik antelope are presented in Table 3. Dehydration resulted in a decrease in urine volume and an increase in osmolality, while solute loading resulted in an increase in the daily volume of urine excreted, and a decrease in urine osmolality, when compared to those same animals during the control period. Following dehydration 77.2% of the urea filtered by the glomerulus was reabsorbed within the nephron, providing for a 22.8% urea excretion loss (Table 4). Both dehydration and solute loading had a marked effect on urine flow, plasma urea concentration and on glomerular filtration (Table 5).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Metabolic nitrogen (g/day) for dik-dik antelope fed various dietary forages a</th>
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<tbody>
<tr>
<td></td>
<td>Body weight (kg)</td>
</tr>
<tr>
<td>Star grass hay</td>
<td>3.6±0.3</td>
</tr>
<tr>
<td>Lucerne leaves</td>
<td>3.9±0.3</td>
</tr>
<tr>
<td>Grewia similis leaves</td>
<td>4.2±0.2</td>
</tr>
</tbody>
</table>

a Values represent the mean ±SEM for six dik-dik antelope. Mean values with unlike letters are statistically different, P<0.05.
Fig. 1 shows the daily nitrogen intake and concentrations of nitrogen excreted in the urine as creatinine, urea-N and ammonia-N for dehydrated and solute loading in the dik-dik antelope. Dehydration resulted in both a reduced feed and nitrogen intake. Furthermore, a decrease in the urinary creatinine and urea-N excretion accompanied dehydration. Solute loading, on the other hand, resulted in an increase urea-N excretion.

Fig. 1. Mean ±SEM urinary nitrogen excretion in the form of creatinine, urea and ammonia as grams of nitrogen per day. Data are from 21 samples from each of the six dik-dik antelope fed a diet of *Grewia similis* leaves and early weaning calf pellets. Daily nitrogen intake during each experimental period was: control, 21.3; dehydration, 13.7; solute loading, 18.9 and water loading, 19.8 g/day.

4. Discussion

Previous studies have highlighted the efficient water conservation abilities and digestive efficiency of the dik-dik antelope under desert and harsh nutritional conditions (Maloiy, 1973; Hoppe, 1977). These earlier studies by Hoppe (1977) demonstrated that the
dik-dik antelope, like other East African herbivore (Arman and Hopcraft, 1975a, b), are able to efficiently digest low quality roughage, and can meet their energy demands under adverse nutritional conditions. Similarly, renal urea excretion has been investigated and reported (Rugangazi and Maloiy, 1987, 1988a, b). In addition, the physiology, nutrition and environmental biology of the dik-dik antelope has been reviewed (Maloiy et al., 1988). Reported studies (Rugangazi and Maloiy, 1988a, b) have indicated the ability of the dik-dik antelope to retain blood urea, and to recycle the urea through the digestive system for microbial synthesis of amino acids and proteins, particularly when fed diets of low protein content. These observations are supported by studies in other ruminant species including: the camel (Schmidt-Nielsen et al., 1957), Zebu cattle (Livingston et al., 1962; Elliot and Topps, 1963), red deer and sheep (Maloiy and Scott, 1969), white tail deer (Robbins et al., 1974), Nubian ibex (Choshniak and Arnon, 1985). The present study has demonstrated that the dik-dik antelope, when fed diets differing in protein content (6–20%), are able to remain in nitrogen balance. The minimum endogenous urinary nitrogen excreted by the dik-dik antelope is of a similar magnitude to that reported for the domestic sheep (Smuts and Marais, 1938) and the camel (Schmidt-Nielsen et al., 1957), and less than that reported for the goat (Hutchinson and Morris, 1936) (Table 6).

When dik-dik antelope were fed a roughage diet high in protein content (i.e. 20% crude protein) with a daily nitrogen intake of over 20 g/day, 66 and 33% of the total nitrogen excreted was lost in the urine and faeces, respectively. Over 55% of the urea filtered by the glomerulus was reabsorbed by the nephron when the dik-dik antelope were fed diets high in protein (i.e. 20%). Dehydration resulted in over 77% of the urea filtered by the glomerulus being reabsorbed in the nephron. Similar values on tubular reabsorption of urea were obtained for ibex fed hay and wheat straw (Choshniak and Arnon, 1985). The data would suggest that, like the camel (Schmidt-Nielsen et al., 1957; Yagil and Berlyne, 1977), the Nubian ibex (Choshniak and Arnon, 1985) and cattle (Livingston et al., 1962; Elliot and Topps, 1963; Dalton, 1968), the dik-dik antelope were able to recycle urea. The amount of urea recycled represents a means of conserving nitrogen and may contribute significantly to effective nitrogen metabolism of the dik-dik when consuming low quality forage. These studies suggest that the dik-dik antelope’s kidney plays an important role in both the conservation of urea and in nitrogen metabolism.

### References


