Digestibility Trials in the Zoo Compared to Field Studies of White Rhinoceros

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Introduction

Digestive capabilities are at the basis of an animal's foraging strategies and behavioural ecology. Knowledge about them is thus important for management decisions, both in the field and in the zoo. The white rhino is a hindgut fermenter and one of the largest living pure grazers. Owen-Smith (1988) discussed some aspects of its nutritive performance in an ecological context, mostly based on data from Foose (1982). These data had been collected from zoo animals fed on grass or hay from temperate areas. The aim of our studies was a comparative investigation of food composition and digestion in free-ranging and zoo white rhinos, as a part of an interdisciplinary project on behavioural ecology and management of this species.

Material and Methods

The field study, was conducted during February and March 1999 on a private game farm in South Africa (Northwest Transvaal) where a healthy and increasing population of white rhinos lives. Three territorial males of this population were chosen for the study. Their tracks were followed together with an experienced game tracker to find the feeding sites. Per track 6-26 feeding sites were found. At each site, each grass species was identified and an amount equal to that, consumed by the individual was cut and collected. The sample therefore equalled the same quality and quantity of grass that the rhino had been eating at this feeding site. Owing to the mean retention time of ingesta, the respective animal was tracked again two days later to collect the faecal sample. From each rhino, samples were taken twice. All samples of the forage plants and faeces were subjected to nutritional analyses. The crude nutrients (Weender Analysis), the cell wall constituents (Van Soest), the gross energy and Calcium and Phosphorus were analysed (see Table 1).The apparent digestibility (aD) was estimated indirectly by the natural marker lignin with the following formula:

$$aD\,(\%) = 100 - (\text{marker}\,(\%)\text{ in the feed} / \text{marker}\,(\%)\text{ in the faeces}) \times (\text{nutrient}\,(\%)\text{ in the faeces} / \text{nutrient}\,(\%)\text{ in the feed}) \times 100$$

The digestibility trials were carried out with five white rhinos in the zoo of Erfurt, Germany. During the night the animals were separated into three groups: two females (born 1980

Table 1: Analysed parameters

Weender Analysis:	Dry Mater (DM) Crude Protein (CP) Crude Fiber (CF) Crude Fat Crude Ash	Calculated: ▸ Nitrogen free Extract (NfE) ▸ Organic Matter (OM)
Van Soest:: Cell wall constituents	NDF (neutral detergent fiber) ADF (acid detergent fiber) ADL (acid detergent lignin)	Calculated: ▸ Cellulose (C):ADF-ADL ▸ Hemicelluose(HC):NDF-ADF
Minerals:	Ca	P
Gross Energy:	(GE) by bomb calorimetry	

and 1970), two females (born 1996 and 1997) and one male (born 1981). During the day all five rhinos were kept together outside. The rhinos were fed with different diets out of grass and hay. Each was given for a period of 15 days. Food and faecal samples were collected daily (Food: day 1-15; Faecal: day 5-15). From each group ten percent of the faeces excreted during the night were collected. The samples were stored at –20°C. All samples were pooled for each group of animals and each diet. The nutrient composition (Table 1) of the pooled samples was analysed and the amounts apparently digested by the white rhinos were calculated like above described.
Additionally, the digestible energy (DE) in MJ/kg dry matter in the feed was estimated by a predictive equation for horses after Zeyner and Kienzle (2001):

$$DE \text{ in MJ/kg DM} = -3.66 + 0.11 \times CP + 0.421 \times CFat + 0.015 \times CF + 0.189 \times NfE$$

This equation is only permissible for feeds with a crude fiber content of less than 35 % DM and a crude fat content of up to 4% DM. These results were compared to those calculated by multiplying the GE content (in % of DM) of the diet by the experimental determined aD for GE.

Results

The nutrient composition of the different forages is shown in Table 2.

The South African grass (grass field) showed with 58 % dry mater (DM) of fresh weight (FW) a higher DM content than the German grass (grass zoo) fed in the zoo-study (33 % FW). The highest content of crude fiber (CF = 36 % DM) and the lowest of crude protein (CP = 4.7 % DM) was found in the field grass. The grass used in the zoo study contained 31 % CF and 7.5 % CP. The hay showed the best nutrient quality with 29 % CF and 13.2 % CP. There were only small differences between the three forages in their content of nitrogen free extract (NfE), organic matter (OM) and gross energy (GE). The amounts of the minerals Calcium and Phosphorus were notably lower in the African grass than in the German forages, but the relation between calcium and phosphorus is nearly equal (Table 2).

Table 2: Nutrient composition of different forages

Forage Composition	DM (%FW)	C F (%DM)	C P (%DM)	NfE (%DM)	O M (%DM)	GE (MJ/kg DM)	Ca (g/kg DM)	P (g/kg DM)
grass field	58	36	4.7	50	92	18.3	2.4	1.0
grass zoo	33	31	7.5	49	88	17.9	6.0	2.3
hay zoo	88	29	13.2	47	91	18.4	5.9	1.9

The contents of the fiber fractions determined by Van Soest are presented in Table 3. The African grass contained the highest amounts of the cell wall constituents (NDF), the lignocellulose fraction (ADF) and especially the cellulose (C) content.

Table 3: Cell wall composition of different forages

Forage Composition	NDF (% DM)	ADF (% DM)	C (% DM)	HC (% DM)	ADL (% DM)
grass field	75	43	36	32	6.8
grass zoo	66	37	30	29	6.7
hay zoo	65	33	28	32	5.5

The lignin content of the zoo hay was about 1 % lower than in the two grasses.
The values of the apparent digestibility were largely comparable (Fig. 1, Table 4).

The highest apparent digestibilities of each parameter were found in the zoo trial with the hay diet. The digestibility values from the South African grass are always higher than those from the zoo grass, with the exception of these from crude protein (Fig. 1, Table 4).

Fig. 1: apparent digestibility (aD) of the different foages in %

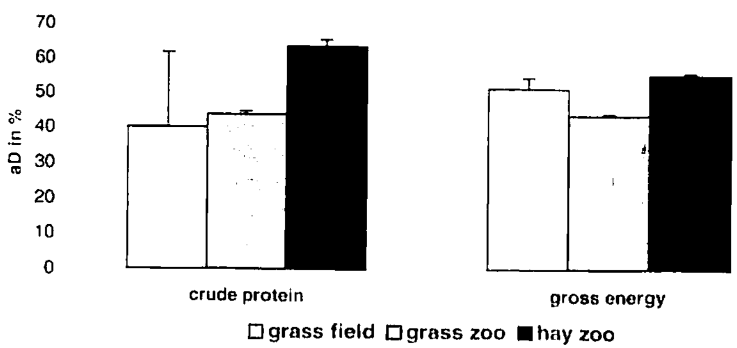

Table 4: apparent digestibility (aD) and the standard deviation (SD ±) of different forages in %

aD in %	n	DM	CF	CP	NfE	OM	GE
grass field	3	48	54	40	56	54	51
SD		± 5.1	± 3.9	± 21.5	± 3.2	± 3.5	± 3.2
grass zoo	3	41	40	44	54	47	44
SD		± 1.6	± 0.6	± 0.9	± 0.8	± 0.5	± 0.7
hay zoo	3	57	54	64	63	59	55
SD		± 2.2	± 1.6	± 1.9	± 1.2	± 1.0	± 0.7

Discussion

In the present investigation, the three different forages (grass field, grass zoo and hay zoo) showed different **nutrient compositions**.

The dry matter content of the field grass was higher than that of the zoo grass. This might be explained by the hot and dry climate in South Africa.

The highest amount of the cell wall components (see Table 3 and CF in Table2) was found in the African grass. In general, the cell wall tends to constitute a greater proportion of the dry matter of tropical versus temperate vegetation and older versus younger tissue (Foose, 1982). The grass of South Africa was collected at the end of the rainy season during February and March. Therefore it was in a mature vegetation stage. The grass fed to the rhinos in the zoo study also was in a mature stage. In contrast, the hay was made in an early vegetation stage. This explains why the hay contained the lowest amount of fiber.

Compared to field and zoo grass the hay contained the highest amount of protein. The nutrient composition of the three forages indicates, that the fiber content is negatively correlated with the protein content. Like commonly, in grasses the cell wall and protein contents are inversely related (Van Soest, 1982). Owen-Smith (1988) stresses, in discussing differences in protein balance, that tropical grasses, using the C_4-physiological pathway, in the dry season tend to have considerably lower protein values than temperate ones. Crude protein concentration in grasses eaten by white rhinos, as plotted by Owen-Smith (1988) lies between slightly below 5 % and almost 20 % and is slightly above a regression line of protein content in food against body mass. This regression, however, mostly is based on ruminants and extrapolated into megaherbivore range. Finally, it should be mentioned that theoretical calculations by Demment and Van Soest (1985) show no difference in the digestibility of cell wall components between grazing hindgut and foregut fermenters larger than 1200 kg.

The apparent digestibility values in our study were largely comparable between the different feeds, though the zoo hay showed slightly higher values than the zoo grass and the African grass (Fig. 1, Table 4). This differences in the digestibilities can be explained by the lower degree of lignification in the hay (Table 3). After Zeyner (1995) the nutrient digestibility is depressed by lignin. However, this does not explain why the field grass was digested better than the zoo grass, like it is shown in all parameters with the exception of crude protein (Table 4). Because of the high fiber content of the field grass one would expect a lower digestibility than the zoo grass. Since it is known that there is a negative correlation between the content of crude fiber and the digestibility of organic matter (Meyer, 1999), and of energy, dry matter, crude protein and NfE in horses (Fehrle, 1999). For this remarkable result that the field grass was better digested than the zoo grass, various reasons are possible. On the one hand there were methodical differences between the zoo and the field study . On the other hand it is imaginable that the rhinos are physiologically better adapted in their natural habitat and digest grass composed as African grass, in a more effective way.

The apparent digestibilities of crude protein for the three different forages are presented in Fig.1. The highest apparent digestibility was found during the zoo trial with the hay diet. This result could be expected due to the nutrient composition of the hay: high in protein, low in fiber. The high content of crude protein in the hay can cause a high apparent digestibility of protein, because the endogenous losses became relatively lower, if the protein intake is higher. The amounts of protein apparently digested from the two grasses were nearly the same.

Based on data from Foose (1982) Owen-Smith (1988) emphasises that white (and Indian) rhinos had higher values of cell wall digestion than horses (and elephants), but a little lower values than large grazing ruminants. This difference is particularly obvious when plotted against retention time. The retention time he used for white rhinos (between 48 and 72 hours, again based on Foose) is longer than the value of two days determined in our zoo pilot project and therefore used by us. It is perhaps remarkable that Owen-Smith's / Foose's diagram does not show differences between values for horses and ruminants around retention times of two days.

The digestibility values in rhinos in this study were similar to values determined in horses even indicating that the same systems of energy evaluating can be used. This encouraged us to apply a predictive equation for digestible energy in horse feed by Zeyner and Kienzle (2001). The differences between the calculated and estimated values did not exceed 10 %.

Further field studies will be necessary to determine possible seasonal variations in the natural forages of white rhinos (see chapter by Ganslosser this volume).

Summary

The nutrient composition of the African grass differed from the German grass and hay, especially in dry mater , crude fiber, protein and the cell wall compositions.

The apparent digestibility of the African and German forages were similar, although the compositions were different.

The results of the digestibility trials indicated that predictive equations for DE in horses can also be used for white rhinos.

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