Food intake, preference patterns and digestion coefficients in captive giraffe (giraffa camelopardalis) offered a tannin-containing pelleted diet

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Abstract

We performed preference trials with 3 adult captive giraffes and a group of 3 juveniles in which the animals could choose between a regular pelleted feed and a pelleted feed of the same composition with an addition of 3 % (original weight) tannic acid. One animal completely refused the new diet item, another animal and the juvenile group ate the new diet item in varying amounts, and one animal ingested increasing amounts of the tannic acid item until it had replaced the regular pellet in its diet nearly completely. However, after 8-16 days, the intake of the new diet item decreased again in those animals that accepted it. For the two adult animals which included the tannic acid containing feed in their diet, overall daily dry matter intake increased significantly by 0.9-1.2 kg. The new diet item had no discernable influence on apparent digestibility coefficients. Our results indicate that the outcome of preference trials depends to a great extent on individual preferences, and on the duration of the choice period. The increase in food intake may have been due to the inclusion of tannic acid, or may simply have been an effect of increased food variety.
FOOD INTAKE, PREFERENCE PATTERNS AND DIGESTION COEFFICIENTS IN CAPTIVE GIRAFFE (GIRAFFA CAMELOPARDALIS) OFFERED A TANNIN-CONTAINING PELLETED DIET

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Poster

Summary

We performed preference trials with 3 adult captive giraffes and a group of 3 juveniles in which the animals could choose between a regular pelleted feed and a pelleted feed of the same composition with an addition of 3 % (original weight) tannic acid. One animal completely refused the new diet item, another animal and the juvenile group ate the new diet item in varying amounts, and one animal ingested increasing amounts of the tannic acid item until it had replaced the regular pellet in its diet nearly completely. However, after 8 - 16 days, the intake of the new diet item decreased again in those animals that accepted it. For the two adult animals which included the tannic acid containing feed in their diet, overall daily dry matter intake increased significantly by 0.9 - 1.2 kg. The new diet item had no discernable influence on apparent digestibility coefficients. Our results indicate that the outcome of preference trials depends to a great extent on individual preferences, and on the duration of the choice period. The increase in food intake may have been due to the inclusion of tannic acid, or may simply have been an effect of increased food variety.

Introduction

The nutrition of captive giraffe (Giraffa camelopardalis) has become the subject of much recent research (FOWLER, 1978; PRINS and DOMHOF, 1984; BAER et al., 1985; HOFMANN and MATERN, 1988; JUNGE and BRADLEY; 1993; HATT et al., 1998; CLAUSS et al., 2000; CLAUSS et al., 2001; BALL et al., 2002), due mainly to a number of serious nutritional problems, such as calcium deficiency (GUCWINSKI and IPPEN, 1979), Vitamin E deficiency (BURTON and DIERENFELD, 1992), a presumed linolenic acid deficiency (CLAUSS et al., 2000), and most notably the "peracute mortality syndrome" (FOWLER, 1978; c.f. JUNGE and BRADLEY, 1993; CLAUSS et al., 2001). Recently, an explanation has been put forward that links the "peracute mortality syndrome" and several other reported digestive problems of captive giraffes to the unique morphophysiological design of browsing ruminants and the inadequacy of hay as a staple dietary item in captivity (CLAUSS et al., 2002a).

When giraffe suffer the "peracute mortality syndrome", low food intake has been suspected to be a major contributing cause (CLAUSS et al., 2001; CLAUSS et al., 2002a). Recently it has been reported that captive roe deer (Capreolus capreolus), small ruminant browsers, deliberately choose to include
tannins in their diet in preference trials (VERHEYDEN and TIXIER, 2000; CLAUSS et al., 2002b), and potentially positive effects of low-dose tannin ingestion for captive wild animals have been reviewed (CLAUSS, 2002). Therefore, we tested the effect of offering a tannin-containing diet to captive giraffe, especially on food intake. The animals used in this study included three of the same individuals for which a theoretically low food intake has been reported (CLAUSS et al., 2001).

The diet of free-ranging giraffe, like that of other browsing animals, contains significant amounts of tannins (COOPER and OWEN-SMITH, 1985; DU TOIT et al., 1990; FURSTENBURG and VAN HOVEN, 1994). In general, giraffe seem to avoid tannin concentrations above 5% of dry matter (COOPER and OWEN-SMITH, 1985; Furstenburg and Van Hoven, 1994); however, their reaction to different tannin concentrations below this threshold is unknown. It is important to note that the group of substances referred to as “tannins” comprises compounds of very varying chemical properties (e.g. HAGERMAN and BUTLER, 1991). The investigations on the natural forage of giraffes cited above measured condensed tannins only, whereas the preference trials reported for captive roe deer (see above) used hydrolysable tannins. Different kinds of tannins can cause different physiological effects, and animals will show different preference/avoidance patterns for different tannins (e.g. CLAUSEN et al., 1990). In this respect, our study, in which only one tannin was deliberately supplemented, has to be regarded as a pilot study, which nevertheless produced interesting results on preference and food intake patterns.

Methods

This study was conducted at Whipsnade Wild Animal Park (WWAP), Bedfordshire, UK, between 31.08. and 25.09.1999. Three adult captive reticulated giraffe and three juvenile animals were used. Body weights for the animals were estimated and ranged between 650 and 900 kg. However, the male Will died in August 2000 and was weighed after death. The carcass was approximately 750 kg instead of the estimated 900 kg (Table 1).

Tab. 1: Age, sex and estimated body weight (BW) of giraffes used in the feeding trials.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Age (years)</th>
<th>Sex</th>
<th>BW (kg)</th>
<th>metab. BW (kg 0.75)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellie</td>
<td>13</td>
<td>female, in lactation</td>
<td>700</td>
<td>136.09</td>
</tr>
<tr>
<td>Josie</td>
<td>11</td>
<td>female, pregnant</td>
<td>700</td>
<td>136.09</td>
</tr>
<tr>
<td>Will</td>
<td>11</td>
<td>male</td>
<td>900 (750)</td>
<td>164.32 (143.32)</td>
</tr>
<tr>
<td>Steffi</td>
<td>2.5</td>
<td>female</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Marcus</td>
<td>1.5</td>
<td>male</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Edmund</td>
<td>0.5</td>
<td>male</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1When Will died in August 2000 his carcass was weighed in pieces and added up to 705 kg. Body fluids and rumen contents lost before weighing were estimated to weigh approximately 45 kg, giving a total of approximately 750 kg.

The animals had access to troughs and racks only during closing hours, from about 5 pm till 9 am; during the day they spent their time either on a concrete yard or in a grass paddock. During the day, pre-weighed amounts of beech (Fagus sylvatica) browse were hand-fed individually to the animals. The adult animals were housed separately during closing hours; each animal was fed a diet of lucerne hay ad libitum, commercially available pellets (Mazuri Browser Breeder ad libitum and 200 g of Ele-Vit-E, Special Diets Services, Mazuri, Witham, Essex, UK), 1 kg of linseed extraction chips (Cargill Plc, Gladstone Dock, Bootle, UK) and 1 kg of beech browse. The three juveniles were kept together during
closing hours and were fed and treated in the calculations as a group. Water was provided *ad libitum*. The commercial pellets were fed from two troughs placed immediately side by side.

Tannic acid was obtained from Carl Roth GmbH, Karlsruhe, Germany. It was added to the Mazuri Browser Breeder pellets at 5% (original weight) by Special Diets Services, Witham, Essex, UK, and pelleted. The resulting pellets resembled the regular pellets in colour, size and texture, but differed significantly in smell and taste: the tannic acid pellets had, in comparison, a bitter, astringent, "woody" taste. In a preliminary trial, the giraffe did not accept the 5% tannin-pellets. Therefore, for the trial period, the tannin pellets were mixed with regular pellets so that the resulting tannic acid proportion in the whole ration was 3% (original weight). This mixture was placed in a trough next to a trough containing regular pellets only.

Individual daily intakes of all foodstuffs were recorded. Food placed in troughs was weighed and re-weighted the next day. All foodstuffs were sampled for nutritional analysis. Faecal samples were taken from each individual on a daily basis, immediately frozen, and later pooled for nutritional analysis. For 9 days, the animals were offered their regular diet. For the following 16 days, the animal were offered both the regular and the tannic acid-containing pellet mixture. Analyses for dry matter (DM), crude protein (CP), crude fat (CF), crude ash (CA), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were performed according to standard procedures as outlined by BAER et al. (1985). Hemicellulose (HC) and cellulose (C) were calculated as NDF minus ADF and ADF minus ADL, respectively. Nitrogen-free extracts (NFE) were calculated by subtracting CA, CP, CF, ADF from DM (PELLEW, 1984a). The energetic value of the ration, the basal metabolic rate and the maintenance and lactation requirement, the fecal output (FO) and the apparent digestibilities (aD) were calculated as previously described (CLAUSS et al., 2001), using ADL as an internal marker. For the calculation of digestibilities, a one-day delay period between food intake data and faecal sample utilized was allowed in order to accommodate for ingesta passage through the digestive tract. Three digestibilities were calculated:

1. using the average food intake of days 1 - 8 (tannin-free period) and the faecal pool samples of days 2 - 9.
2. using the average food intake of days 14 - 18 and the faecal pool samples of days 15-19.
3. using the average food intake of days 20 - 24 (tannin period) and the faecal pool samples of days 21 - 25.

Intake data for the different periods were compared using repeated-measures ANOVA for four animals (treating the average data of the juvenile group as a single animal) and 25 consecutive days. In order to test for a potential diet effect, a contrast was defined and tested between the mean intake before and after changing the diet. Student’s t-test was used in order to compare the diet effect separately for each animal. The significance level was generally set to α = 0.05. All statistical calculations were performed with SPSS 9.0 software (SPSS, Chicago, Ill.).

**Results**

The daily food intake of the three *ad libitum* diet items - the lucerne hay, the regular pellet and the tannin-containing pellet mix - is presented for the three adult individuals and the juvenile group in Fig. 1 - 4. The individual giraffe differed in their response to the introduction of the tannin pellets. Whereas Ellie almost completely refused the tannin pellets after tasting them on the first day (Fig. 1), Will showed a more versatile pattern (Fig. 2) with a peak consumption of tannin pellets after 8 days and a subsequent decrease in intake. The juvenile animals instantaneously accepted the tannin pellets (Fig. 3) and consumed them in quantities equal to or higher than the regular pellets for a period of 11 days, after which the intake of tannin pellets decreased again. Most interestingly, Josie increased the proportion of tannin pellets in her daily ration steadily (Fig. 4), until it equaled that of the regular pellets.
after 7 days. After 13 days, she hardly ingested any regular pellets at all and consumed the tannin pellets in quantities comparable to the amounts of regular pellet intake from the first part of the trial.

**Fig. 1 and 2:** Intake (in kg original weight) of lucerne hay, regular pellets and tannin pellet mix of the adult giraffe Ellie and Will.

**Fig. 3 and 4:** Intake (in kg original weight) of lucerne hay, regular pellets and tannin pellet mix of a group of three juvenile giraffes and the adult giraffe Josie. The monitoring of pellet intake was continued after the recording of lucerne hay intake was stopped.

Therefore, it was decided that her intake be monitored by the keepers for an additional 10 days after the termination of the scheduled trial. The peak consumption of tannin pellets occurred after 16 days and then decreased dramatically, with a compensatory increase of regular pellets.

The average daily total dry matter intake before (9 days) and after (16 days) the introduction of the tannin-containing pellet mix are presented in Fig. 5 - 6.

**Fig. 5 and 6:** Average daily food consumption (in kg dry matter) for the adult giraffe Ellie and the juvenile group, and for the adult giraffes Will and Josie.
No significant difference between the periods before and after changing the diet was found (repeated-measures design contrast: $p = 0.117$), which, however, might be due to the very small sample of only four cases. In the individual comparisons, there was no significant difference in daily dry matter intake between the two periods for Ellie ($t$-test, $p = 0.964$) and the group of juveniles ($p = 0.172$), but daily dry matter intake increased significantly in Will by 0.9 kg ($p = 0.001$) and Josie by 1.2 kg ($p = 0.001$) after the introduction of the tannin-containing pellet mix.

The digestibilities determined by the lignin method for the three adult animals did not differ distinctively between the feeding periods and ranged between 53 – 62 % for DM, 68 - 77 % for CP, 31 - 42 % for NDF and 31 - 41 % for ADF. Individual values for each animal, including digestibility coefficients for CA, CF, HC, C, NFE and GE are given in Table 2. The calculated minimal energy requirements (Table 3) were mostly met by the calculated energy intake (Table 2).

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**Tab. 2: Apparent digestibility coefficients for the three adult giraffes during different stages of the trial and calculated energy intake in MJ/d using the equations of Pellae (1984a) for the determination of gross energy (GE) and metabolizable energy (ME) of the diet. See Methods for abbreviations.**

<table>
<thead>
<tr>
<th>Digestibility %</th>
<th>Intake (MJ)</th>
</tr>
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<tbody>
<tr>
<td>DM</td>
<td>CA</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Ellie (1)</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Ellie (3)</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Will (1)</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Will (2)</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Will (3)</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Josie (1)</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Josie (2)</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Josie (3)</td>
<td>56</td>
</tr>
</tbody>
</table>

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**Tab. 3: Calculated energy requirements in MJ/d. The basal metabolic rate was determined conventionally as metabolic body weight* 293 kJ/d. As multiples of BMR the lowest factor of 1.33 and the lactation factor of 2.15 given by Pellae (1984b), the lowest factor given by Kirkwood (1996) for estimating the energy requirement of zoo animals of 1.5, and the conventional factor of 2 (e.g. Robbins, 1993) were used. For Will, values calculated with the body weight measured at death are given in brackets.**

<table>
<thead>
<tr>
<th></th>
<th>BMR</th>
<th>BMR*1.33</th>
<th>BMR*1.5</th>
<th>BMR*2</th>
<th>BMR*2.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellie</td>
<td>40</td>
<td>53</td>
<td>60</td>
<td>80</td>
<td>86</td>
</tr>
<tr>
<td>Will</td>
<td>48 (42)</td>
<td>64 (56)</td>
<td>72 (63)</td>
<td>96 (84)</td>
<td>-</td>
</tr>
<tr>
<td>Josie</td>
<td>40</td>
<td>53</td>
<td>60</td>
<td>80</td>
<td>-</td>
</tr>
</tbody>
</table>

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Discussion

The interpretation of results of any kind of feeding trials with a particular tannin substance always needs to be made with caution, because of the fact that the reaction of animals to a specific tannin may differ drastically from that to another tannin. Although the results of two adults and the juvenile group seemed to suggest a preference for a certain amount of tannic acid at first, this trend was reversed after 10 - 15 days. From these trials, one can only deduce that some giraffe choose to eat low levels of tannic acid, but that this preference fluctuates. The results also indicate that individual feeding preferences can make it difficult to determine species-specific ones. The animal Ellie might, for example be more cautious approaching new diet items. The variability of individual preferences could contribute to the fact that in ecological studies on many species, distinct choice patterns in relation to secondary plant compounds could not be demonstrated (reviewed in CLAUSS, 2002).

The outcome of preference trials of this kind depends not only on individual animal preferences, but also on the time period for which the trial is conducted. After the scheduled 2 weeks of preference trial, the animal Josie seemed to prefer the tannin pellet to the regular one (Fig. 3). The additional week of measurements, however, showed a drastic decline in her preference for the tannin pellet. Thus, any pattern – from a preference after 10 days to a rejection after a 2-week-period to an irregular fluctuation in preference – cannot be ruled out. Mid-term preference trials with tannin diets and captive roe deer showed similarly fluctuating patterns (CLAUSS et al., 2002b). Conventionally, preference trials with both domestic and zoo animals are carried out for much shorter periods of time (e.g. PROVENZA et al., 1990; KIRSCHNER et al., 1999; VERHEYDEN-TIXIER and DUNCAN, 2000; DE ROSA et al., 2002). In view of the individual differences, and the fluctuation of preference within individual animals, the results of short-duration preference trials have to be interpreted with caution, and should ideally be confirmed by long-term trials.

From the time necessary until a relative rejection of the tannic acid pellets occurred, one can assume that the proportions of tannic acid ingested did not cause instantaneous malaise in the giraffes. Would that have been the case, one would have expected a rejection of the tannin-containing pellet mix within the first few days (e.g. PROVENZA et al., 1990). On the other hand, one can only speculate if the observed pattern is the result of a delayed negative feedback, or the lack of positive reinforcement of the behavior. A tempting interpretation of the observed fluctuation in tannic acid intake is that the astringent, "woody" tannin taste and smell is habitually used by these captive animals to identify potentially beneficial diet items, i. e. browse, and that it takes a while to un-learn this association; when the animals realize that the digestive effect of the "tasty" food equals that of the regular food, the particular preference ceases. Given this concept, one would expect comparable intakes of both pelleted feeds in long-term preference trials. Another possible interpretation links our study with the preference trial performed with two captive giraffe by BAER et al. (1985). In that trial as well, the animal selected the pelleted food with the theoretically lesser nutritive value. The reaction of the giraffe might, in theory, be due to an avoidance of the regular pelleted food due to a hypothetical acidic state this feed induced in their rumen – consequently they shifted to food of a different taste. This new preference then was reversed again, in the case of the tannic acid pellets, when no difference in the acidic state of the forestomach ensued after ingestion.

Even in the animal with the highest intake of tannin pellets, Josie, there was no discernable negative effect on the digestive efficiency, which could be interpreted as an indication that the low level of tannins used in this study did not result in a direct digestion disturbance. In general, tannins are regarded to have negative effects on ruminant digestive processes (e.g. KUMAR and SINGH, 1984), albeit at higher concentrations that the one used in this study. At low doses, they might be advantageous due to several physiological mechanisms (CLAUSS, 2002). Browsing ruminants can defend themselves partly against dietary tannins by salivary tannin-binding proteins (AUSTIN et al.,
1989), and the anatomical correlates are the larger salivary glands of browsing ruminants as compared to grazers (HOFMANN, 1989).

Neither salivary tannin-binding proteins nor relatively large salivary glands have been demonstrated in giraffe so far, but HOFMANN (1973) mentions large parotid glands in one individual (without giving measurements). Although a preliminary study suggests some positive effects of low-dose tannic acid feeding in roe deer (CLAUSS et al., 2002c), potential positive effects for zoo animals remain to be demonstrated. The variety of naturally occurring tannins has to be taken further into account, and the mode of tannin application (as a special ingredient in pelleted feeds versus naturally tannin-containing feeds) must be further evaluated.

As in the preceding study (CLAUSS et al., 2001), the lactating female – in this case, Ellie, ingested enough food to meet even the calculated increased energy demands of lactation (Tables 2 and 3). In contrast, and based on his estimated body-weight (900kg), Will did not ingest enough food to meet the energy requirement calculated with the lowest BMR multiple provided by KIRKWOOD (1996) on the regular diet, but did so after the increase of intake due to the introduction of the new diet item. However, at necropsy in August 2000, Will weighed approximately 750 kg, and no weight loss had been apparent during the weeks before death. Therefore, it seems likely that his body weight had been overestimated consistently. If the 750 kg body-weight is used for the calculations, Will ingested enough energy to meet the energy requirements of a BMR multiple of 1.5, but not of 2. At necropsy, he did not show signs of fat atrophy and had moderate amounts of kidney fat, suggesting that his energy intake had been adequate, even if not enough to build up significant omental and pericardial fat stores. On the regular diet, Josie's energy intake balanced her calculated requirement if the BMR multiple of 1.5 was used; after the increase of food intake due to the introduction of the new diet item, her energy intake increased up to the point where a theoretical requirement, calculated with the "rule-of-thumb" BMR multiple of 2, was met. As stated in the earlier investigation, the energy intake on the regular diet, with respect to the high incidence of the "peracute mortality syndrome" in captive giraffes and potentially increased heat losses in giraffes (CLAUSS et al., 1999), is not reassuring. In this regard, the increase in energy intake after the introduction of the new diet item could be welcome. Thus, an increase in food ingestion could be a desired effect in many captive giraffe groups. With regards to the increased food consumption during the preference trial period, one should not focus on a potential effect of the tannin pellet, but rather on a general effect of food variety. Food variety is known to increase intake in other herbivore species and humans (REID and JUNG, 1965; MIQUELLE and JORDAN, 1979; LUNDBERG et al., 1990; BOYD et al., 1996; STUBBS et al., 2001; KLUMPE et al., 2002). If the relative food intake of this and the previous study are compared for the same individuals (Table 4), it becomes evident that (a) lactating females had a drastically higher food intake than their conspecifics and (b) that the addition of a new diet item – more browse or the tannin-containing pellets – led to an increase of food intake.

**Tab. 4:** Comparative intake data (DM as % of body weight) for the three adult giraffes used in this study as compared to data from the same individuals determined in a previous study (CLAUSS et al., 2001). Note that in 1998, Josie was in lactation, whereas in 1999, Ellie was in lactation. For Will, values in brackets represent calculations with his actual body weight measured at death in August 2000.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ellie</td>
<td>1.20</td>
<td>1.28</td>
<td>1.55*</td>
<td>1.55*</td>
</tr>
<tr>
<td>Josie</td>
<td>1.81*</td>
<td>-</td>
<td>1.17</td>
<td>1.34</td>
</tr>
<tr>
<td>Will</td>
<td>0.97 (1.16)</td>
<td>1.02 (1.22)</td>
<td>0.95 (1.14)</td>
<td>1.05 (1.26)</td>
</tr>
</tbody>
</table>

* female in lactation

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Further studies with different feeds should be carried out with captive giraffe in this respect. If an increase of food intake is a management objective, one should rather use structured feeds instead of pelleted ones. Given the susceptibility of captive giraffe to rumen acidosis (CLAUSS et al., 2002a), an increase in the intake of pelleted or concentrate feeds has to be regarded with scepticism. In this study, the increase in pelleted food intake by the giraffe was accompanied by an increase in oral stereotypies (HUMMEL et al., 2002).

Acknowledgements

We thank N. Lindsay for his support of the investigation, all of the keepers on the Africa section, Whipsnade Wild Animal Park for their constant help and good humour, and Special Diets Services, Witham, Essex, UK for the preparation of the tannic acid containing pelleted diet. M. Clauss acknowledges the kind support of G.-L. d’ Alterio and E. Williams during this project.

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