PHYSIOLOGY

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Energy and Fibre Intake in a Group of Captive Giraffe (Giraffa camelopardalis) Offered Increasing Amounts of Browse


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With 3 figures and 5 tables

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Summary
We investigated the effect of diet on intake of energy and fibre in a group of three captive adult giraffe by weighing offered diet items and leftovers for 7 days after an adaptation period of 7 days. Digestion coefficients were calculated using, as internal marker, the acid detergent lignin content of a faecal sample pooled from subsamples taken during the last 5 days of intake measurement. Two lucerne hay-only diets of differing quality (L1, L2) were fed, as well as the regular diet of lucerne hay and concentrates (L2C), and the regular diet supplemented with 3 or 6 kg of edible, fresh browse material (L2CB3, L2CB6). The proportion of roughage in the ingested diets L2CB6 (45 ± 5% dry matter), L2CB3 (35 ± 3%) and L2C (37 ± 10%) did not differ significantly. Digestible energy intake was low on the hay-only diets [L1: 0.28 ± 0.06 MJ/kg body weight (BW)\(^{0.75}\); L2: 0.33 ± 0.10 MJ/kg BW\(^{0.75}\)] and increased from L2C (0.60 ± 0.13 MJ/kg BW\(^{0.75}\)) to a significant increase with L2CB3 (0.72 ± 0.17 MJ/kg BW\(^{0.75}\)); no further increase was obvious for L2CB6 (0.63 ± 0.15MJ/kg BW\(^{0.75}\)). The results confirm that giraffes are unlikely to meet energy requirements on lucerne hay-only diets. In a feeding scenario where both lucerne hay and the concentrate component of the diet are fed ad libitum, the animals tended to exchange hay for browse when browse was added. Only the higher level of browse supplementation led to a potentially beneficial increase in fibre intake. Whether additional browse supplementation will lead to increased intakes in a feeding scenario with restricted concentrate provision can be suspected but remains to be demonstrated.

Introduction
Among the charismatic herbivores kept in zoos, the giraffe (Giraffa camelopardalis) remains a species whose nutritional management is still considered to be a challenge. Many captive animals die because of chronic energy deficit (Potter and Clauss, 2005), most likely due to the insufficient intake of the staple roughage component of the diet. Foose (1982) recorded a surprisingly low intake of either grass hay or lucerne hay in captive giraffes even when offered ad libitum, leading to an evident energy deficit and to a disruption of the study, and Gutzwiler (1984) similarly measured a low roughage intake in another group of captive animals. In several studies, where the food intake or energy intake of captive giraffes on a conventional zoo diet was calculated, the animals were considered to be in low to marginal energy supply (Gutzwiler, 1984; Clauss et al., 2001; Potter and Clauss, 2005). Krumbiegel (1971) stated that in captive animals, the fleshy, fat neck so typical of free-ranging individuals is rarely observed. The birth weight of free-ranging giraffes is recorded to average 70 kg (Dagg and Foster, 1976), whereas it is 50–60 kg in captivity (Fowler and Boever, 1986). As the nutritional state of the mother animal is one of the determinants of the birth weight of its offspring, this comparison is a further indication of a less than optimal energy supply.

In a pioneering survey on giraffe nutrition, Fowler (1978) recommends that diets in captivity should consist of 10–25% browse material. However, the logistics of zoo management and the facilities often do not allow the provision of browse material in such amounts. Additionally, as hay is usually fed ad libitum with no control of the actual intake, feeding recommendations that give proportional values are difficult to adhere to. Lintzenich and Ward (1997) recommend that roughage should represent 60–70% of the diet of large herbivores such as giraffes. With the exception of Hummel et al. (2003), none of the quantified giraffe maintenance diets reported in the literature achieve such a high proportion of roughage (Gutzwiler, 1984; Prins and Domhof, 1984; Baer et al., 1985; Hatt et al., 1998; Dingelreiter, 2000; Clauss et al., 2001, 2003a; Kearney et al., 2003; Potter and Clauss, 2005). A high roughage proportion will be prophylactic against the
Table 2. Food components used in feeding trials with giraffes (Giraffa camelopardalis). In previous studies (Clauss et al., 2001, 2003a), this study was performed at the Whipsnade Wild Animal Park, UK. Three adult giraffes were used (Table 1), two of which had already participated in previous studies (Ellie, Josie). The animals were habitually fed a diet of lucerne hay, commercially available pellets (Mazuri Browser Breeder and Ele-Vit-E; Special Diets Services, Mazuri, Witham, Essex, UK) and linseed extraction chips (Unitrition, Selby, UK). Water was provided ad libitum. The animals were housed separately except for 6 h/day, when they had access to a concrete yard or grass paddock, depending on weather conditions. During this time, no food was offered (except when hand-feeding browse during the respective trial periods), but mineral licks and water were available.

Each animal was tested on five different diets (Table 2). The linseed chips and vitamin E supplement were given throughout all trials. Two diets consisted of lucerne hay, using two lucerne hays of similar nutrient content (Table 3) but different sensory quality. One lucerne hay (L1) consisted of rough, brittle stems with a limited proportion of leaf material visible. In contrast, the other hay (L2) was soft to touch, with seemingly higher proportion of leaves. This second hay had obviously been harvested at an earlier stage, dried artificially and was highly condensed when packed. It is assumed that this processing resulted in an increased softness of L2, even though chemical analysis suggested that both types of lucerne hay were of similar quality. L2 was used in the three other treatments, during which the staple concentrate item (Mazuri Browser Breeder) was also fed ad libitum (L2C, L2CB3, L2CB6). In two of these trials, beech browse (Fagus sylvatica) was supplemented at respective amounts of 3 or 6 kg of fresh, edible beech browse per animal.

It had been the objective of this study to supply these three giraffes with the highest amount of browse possible that could be accurately measured. In order to ensure accurate measuring, browse material was hand-clipped from branches, so that only edible material (leaves and fine twigs) was weighed. In a previous study (Clauss et al., 2001), the provision of 3 kg of browse to one, and 1 kg to the other animals, had already been a challenging task. In a test run, it was determined that the simultaneous provision of 6 kg of browse per day to each of the three animals was the maximum feasible amount, the provision of which for two complete weeks represented a high demand on the keeping personnel, the gardeners and the acting investigator (DS). Clipped browse was partially fed by hand during the day to individuals, with the rest of the material put into the hay racks on top of the lucerne hay.

Each diet was fed for 2 weeks. Individual daily intake of all foodstuffs was recorded according to Clauss et al. (2001) during the second week, and approximately five faecal samples were taken per animal and day during the last 5 days of the second week, and were later pooled into one pool sample per animal and feeding period. Analyses of feeds and faeces were performed in duplicate according to standard methods as referred to in Clauss et al. (2001), and included dry matter (DM), ash, crude fibre (CF), ether extract (EE), crude protein (CP), neutral detergent fibre (NDF; including amylase incubation), acid detergent fibre (ADF), and acid detergent lignin (ADL). Additionally, gross energy (GE) was determined using bomb calorimetry (IKA-Calorimeter C 7000; IKA, Staufen, Germany). Digestibility coefficients were calculated using ADL as an internal marker as described in Clauss et al. (2001).

For comparative purposes, data on Ellie, Josie and one additional animal (Will) who had been maintained at the same institution, from Clauss et al. (2001, 2002) was included in the presentation of results. These animals had also received rations of lucerne hay and concentrates of the same brand (Mazuri Browser Breeder) ad libitum, similar allowances of vitamin E

### Table 1. Giraffes (Giraffa camelopardalis) used in this study including body mass estimates

<table>
<thead>
<tr>
<th>Animal</th>
<th>Age (years)</th>
<th>Sex/state</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jamie</td>
<td>2.5</td>
<td>Male</td>
<td>650</td>
</tr>
<tr>
<td>Josie</td>
<td>14</td>
<td>Female/end of lactation</td>
<td>650</td>
</tr>
<tr>
<td>Ellie</td>
<td>16</td>
<td>Female/end of lactation</td>
<td>700</td>
</tr>
</tbody>
</table>

### Table 2. Food components used in feeding trials with giraffes (Giraffa camelopardalis) (weights as fed in kg)

<table>
<thead>
<tr>
<th>Trial code</th>
<th>L1 L2</th>
<th>Browser Breeder pellet</th>
<th>Beech browse</th>
<th>Linseed extraction chips</th>
<th>Vitamin E supplement</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>ad lib.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
</tr>
<tr>
<td>L2</td>
<td>–</td>
<td>ad lib.</td>
<td>–</td>
<td>–</td>
<td>0.5</td>
</tr>
<tr>
<td>L2C</td>
<td>–</td>
<td>ad lib.</td>
<td>ad lib.</td>
<td>–</td>
<td>0.5</td>
</tr>
<tr>
<td>L2CB3</td>
<td>–</td>
<td>ad lib.</td>
<td>ad lib.</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>L2CB6</td>
<td>–</td>
<td>ad lib.</td>
<td>ad lib.</td>
<td>6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

L1/L2, lucerne hay ad lib.; C, concentrates ad lib.; B, browse (with number indicating the amount of browse in kg); ad lib., ad libitum.
pellets and linseed chips, and 1 kg of fresh edible beech browse. Additional browse levels (B2; B3 for Will) had been achieved by adding another kilogram of sycamore (Acer pseudoplatanus), and for Will also of hazel (Corylus avellana) browse. These data were not included in the statistical analyses.

Differences in nutrient composition between diets, as well as differences in DM and energy intake and nutrient digestibilities were tested with a one factor repeated measures ANOVA with post hoc (Dunn/Bonferroni) tests. For these parameters, averages of all three animals were compared between treatments. For the evaluation of DM intake, data for the seven individual collection days per treatment were used for all animals. In order to exclude the effect of the different intake level between the animals, digestible energy intake (DEI, MJ/kg\(^{0.75}\) metabolic body weight) was additionally evaluated by setting DEI at L2C, the usually fed ration, to 100% and calculating DEI for each animal and treatment in % to this value; the resulting averages of each treatment were then additionally evaluated by ANOVA and post hoc tests. All calculations were performed using the StatView 5.0 (SAS Institut, Wangen/Dübendorf, Switzerland) software.

### Results

There were no obvious changes in body condition during the course of the study. There were significant differences in diet nutrient composition between the lucerne-only diets and the diets including concentrates (Table 4); the hay-only diets had higher levels of NDF, ADF and ADL and lower levels of CP. Nutrient composition of ingested diets L2C, L2CB3 and L2CB6 were relatively uniform, with NDF contents of 36.8–37.9%, ADF contents of 23.9–25.5% and CP contents of 14.7–15.2% on a DM basis. Between these three diets, there was only a significant difference in the ADL composition, with increasing ADL content with increasing browse supplementation. In Jamie, the intake of roughage (lucerne and browse added together) increased with increasing browse supplementation (Fig. 1). In Josie, this effect was only noticeable on L2CB6 (40% versus 32% on L2C), whereas this level of supplementation did not lead to changes in Ellie (50% versus 48% on L2C). In general, the proportion of roughage in the overall diet did not differ significantly between the diets including concentrates (Table 4). Overall DM intake was lowest on the hay-only diets and increased with L2C to L2CB3 (Fig. 2, Table 5). There was no increase in DM intake on

<table>
<thead>
<tr>
<th>Nutrient (% DM)</th>
<th>L1</th>
<th>L2</th>
<th>L2C</th>
<th>L2CB3</th>
<th>L2CB6</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>13.8 ± 0.3(^a)</td>
<td>13.9 ± 0.2(^a)</td>
<td>15.2 ± 0.5(^b)</td>
<td>15.0 ± 0.2(^b)</td>
<td>14.7 ± 0.1(^b)</td>
</tr>
<tr>
<td>NDF</td>
<td>44.7 ± 0.3(^a)</td>
<td>44.7 ± 0.2(^a)</td>
<td>37.3 ± 1.5(^b)</td>
<td>36.8 ± 0.6(^b)</td>
<td>37.9 ± 0.7(^b)</td>
</tr>
<tr>
<td>ADF</td>
<td>33.4 ± 0.4(^a)</td>
<td>33.8 ± 0.3(^a)</td>
<td>25.4 ± 1.7(^b)</td>
<td>23.9 ± 0.6(^b)</td>
<td>24.2 ± 0.7(^b)</td>
</tr>
<tr>
<td>ADL</td>
<td>7.2 ± 0.1(^a)</td>
<td>7.0 ± 0.1(^a)</td>
<td>3.6 ± 0.6(^b)</td>
<td>3.9 ± 0.3(^b)</td>
<td>5.1 ± 0.5(^a)</td>
</tr>
<tr>
<td>Roughage</td>
<td>89 ± 2(^a)</td>
<td>91 ± 2(^a)</td>
<td>37 ± 10(^b)</td>
<td>35 ± 3(^b)</td>
<td>45 ± 5(^b)</td>
</tr>
</tbody>
</table>

Mean values within rows with different superscripts differ significantly. See Tables 2 and 3 for abbreviations.

Fig. 1. Proportion of different feeds of the total ingested diet (in % dry matter) in the giraffes (Giraffa camelopardalis) of this study (Jamie, Josie, Ellie). Data for Josie and Ellie on L2CB1 and L2CB2 from Clauss et al. (2001). Data for Will from Clauss et al. (2001, 2002). The pellet category comprises all concentrates or supplements.
There were significant differences in intake levels between treatments (ANOVA: d.f. = 4, F = 77.8, P < 0.001); apart from treatments L1 and L2, and treatments L2CB3 and L2CB6, all other differences between treatment pairs proved significant at post hoc tests (indicated in Table 5). Digestibility coefficients were, with the exception of NDF, low for the hay-only diets in all animals, highest in L2C, and decreased with increasing browse supplementation; significant differences existed between treatments for ADF (ANOVA: d.f. = 4, F = 6.6, P = 0.007) and GE (ANOVA: d.f. = 4, F = 6.2, P = 0.009) (see Table 5). Digestible energy intake (DEI; as MJ/kg0.75 metabolic body weight) was significantly different between treatments (ANOVA: d.f. = 4, F = 7.2, P = 0.006), with post hoc tests showing significant differences between L1 and L2CB3, and L2 and L2CB3 (Table 5). If DEI of each treatment was expressed in relation to DEI on the usually fed diet, L2C, then significant differences between treatments were detected as well (ANOVA: d.f. = 4, F = 357.8, P < 0.001), with post hoc tests showing significant differences between all pairs of treatments except for L1 and L2, and L2C and L2CB6 (Table 5).

Discussion

Studies with giraffe are generally hampered by the low sample size, estimated body weights, and by the large inter-individual difference in food choice and food intake, making universal conclusions for the feeding of the species difficult. The female Ellie, who ingested a higher proportion of lucerne hay in this study than Josie, had already ingested a higher proportion of hay in a previous comparison between these animals (Clauss et al., 2001; c.f. Fig. 1). On diet L2C, the proportion of roughage of the total DM intake ranged from 30% to 48% in this study, from 25% to 51% in Clauss et al. (2001), from 21% to 30% in Clauss et al. (2002), or even as dramatically as from 8% to 40% in Kearney et al. (2003). Given these differences in individual food choice, it is remarkable that the high browse supplementation of diet L2CB6 narrowed the observed range of roughage intake in this study to 40–50%. Hatt et al. (1998) measured a remarkably constant roughage intake of 47–48% in a group of six giraffes offered a clover hay and browse, on a feeding regime where concentrates were restricted. Differences between facilities, and between individuals, are likely to be influenced by the type of roughage offered, and by the availability of concentrate feeds.

Table 5. Dry matter intake (DMI, kg), apparent digestibility coefficients (aD, %), calculated with ADL as internal marker, digestible energy intake (DEI in MJ/kg0.75 metabolic body weight) and relative DEI (in % of DEI on diet L2C) for the different diets consumed by giraffes (Giraffa camelopardalis)

<table>
<thead>
<tr>
<th>Diet</th>
<th>L1</th>
<th>L2</th>
<th>L2C</th>
<th>L2CB3</th>
<th>L2CB6</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI</td>
<td>5.6 ± 0.9a</td>
<td>6.5 ± 1.4a</td>
<td>8.9 ± 1.9b</td>
<td>10.5 ± 1.8c</td>
<td>10.1 ± 1.6c</td>
</tr>
<tr>
<td>aD OM</td>
<td>43 ± 2</td>
<td>44 ± 4</td>
<td>55 ± 7</td>
<td>53 ± 2</td>
<td>47 ± 5</td>
</tr>
<tr>
<td>aD NDF</td>
<td>29 ± 3</td>
<td>36 ± 2</td>
<td>36 ± 5</td>
<td>30 ± 4</td>
<td>31 ± 5</td>
</tr>
<tr>
<td>aD ADF</td>
<td>33 ± 1a</td>
<td>40 ± 2ab</td>
<td>45 ± 5b</td>
<td>38 ± 3ab</td>
<td>34 ± 3a</td>
</tr>
<tr>
<td>aD GE</td>
<td>39 ± 2a</td>
<td>39 ± 5a</td>
<td>52 ± 8b</td>
<td>51 ± 3ab</td>
<td>46 ± 4ab</td>
</tr>
<tr>
<td>DEI</td>
<td>0.28 ± 0.06a</td>
<td>0.33 ± 0.10a</td>
<td>0.60 ± 0.13b</td>
<td>0.72 ± 0.17b</td>
<td>0.63 ± 0.15b</td>
</tr>
<tr>
<td>DEI (%L2C)</td>
<td>47 ± 2a</td>
<td>54 ± 5a</td>
<td>100b</td>
<td>119 ± 4c</td>
<td>105 ± 4b</td>
</tr>
</tbody>
</table>

Mean values within rows with different superscripts differ significantly. See Tables 2 and 3 for abbreviations.
Energy and Fibre Intake in Captive Giraffe

The explanation for the comparatively low proportion of roughage in overall intake in the animals used during our studies is the fact that, as in Kearney et al. (2003), the concentrate ingredient of the diet was offered ad libitum. Given the high fibre content of this component (Table 3), this practice does not decrease overall ration fibre contents below levels considered critical for ruminal acidosis, such as NDF or ADF levels of 28% and 21% DM, respectively, for dairy cattle (Kamphues et al., 2004) (Table 4). However, the lack of structured roughage material in the resulting rations could still be regarded as critical, and is probably also linked to the high frequency of oral stereotypies observed in these animals (Veasey et al., 1996; Hummel et al., 2002; Schaub et al., 2004). The presence of a subclinical rumen acidosis, which could have explained oral stereotypies with the aim to increase saliva production, cannot be ruled out. However, no correlation was found in the investigated giraffes between percentage of pellets (10–70%) in diet and amount of oral stereotypies, and no influence of browse supplementation on the frequency of oral stereotypies was observed (Schaub et al., 2004) in contrast to Koene and Visser (1996), but in the latter study, browse was not offered in edible portions but as branches/twigs that required more extensive manipulation. Given the presence of the ad libitum pelleted diet, browse supplementation did not increase roughage intake over more than 50% of total DM intake in this study, because, as already observed by Koene and Visser (1996), the offering of browse led to a decreased intake of lucerne hay. This effect had not been noticed by Claus et al. (2001) when increasing fresh browse supplementation from 1 to 2 or 3 kg (c.f. Fig. 1). The effect of increased browse supplementation to a diet with a restricted concentrate component remains to be demonstrated.

Different methods have been used to estimate the energy requirements and energy provision of captive giraffes. Using the allometric Kleiber equation, the basal metabolic rate (BMR) is calculated by the formula BMR = 293 kJ/kg BW^{0.75} day. As the BMR does not include all the maintenance requirements, BMR is usually multiplied by a factor between 1.5 and 2 to calculate maintenance metabolizable energy (ME) requirements in captivity (Kirkwood, 1991, 1996; Robbins, 1993). This translates into a maintenance requirement between 0.44 and 0.59 MJ ME/kg BW^{0.75}/day and up to 0.63 MJ ME/kg BW^{0.75}/day for lactation (BMR * 2.15 according to Pellow, 1984). In two captive female giraffes, based on intake and body weight data, Potter and Clauss (2005) roughly estimated an ME requirement of 0.52–0.61 MJ/kg BW^{0.75}/day, which corresponds well with the theoretical range. As the proportion of ME in dietary DE has not been determined in giraffes, a literature value (Robbins, 1993: ME is 85% of DE in cattle) was used for the transfer calculation. This then translates into a maintenance requirement between 0.52 and 0.69 MJ DE/kg BW^{0.75}/day, and of 0.74 MJ DE/kg BW^{0.75}/day for lactation. Although there is a certain degree of uncertainty in these calculations because of the fact that the correct values for the factors used have not been investigated in giraffes, the major uncertainty is derived from the estimation of DE or ME intake based on feed-intake data, in animals whose body weight is estimated. In this study, DE intake was determined using GE contents of feeds and faeces, with ADL as an internal digestion marker. In other studies, ME content of giraffe diets was estimated by standard equations derived from cattle (Clauss et al., 2001) or by in vitro digestion results, again based on cattle standards (Potter and Clauss, 2005). Evidently, a correct determination of DE using total faecal collection, combined with actual weighing of the animals, would be of great value further studies on giraffes.

In Fig. 3, the theoretical DE requirement range is compared with the DE intake of the three giraffes of this study. Evidently, energy requirements were not met on the lucerne hay-only diets. This finding confirms the observation of Foose (1982) that giraffe will not thrive on a hay-only ration, similar to other browsers such as moose (Alces alces) (Bo and Hjeljord, 1991; Schwartz and Hundertmark, 1993), in contrast to cattle or sheep. DM and energy intake was maximal on L2CB3, indicating that the addition of browse is an important stimulus, and maybe a mediator, for optimal food intake in giraffe.

The amounts of browse fed during this study, 3 and 6 kg of browse, corresponded to a proportion of browse in the total DM intake of 13–18% and 26–35%, respectively, surpassing even the recommendation of Fowler (1978) of 10–25%. Given the observation that the addition of 6 kg browse did not significantly increase DM intake any further in two animals, it could be argued that surpassing a proportion of 30% (DM basis) is unlikely to have energetic effects in giraffe husbandry. Yet such an amount of browse will already be challenging for many facilities. Using the equation for beech browse from Clauss et al. (2003b), 3 or 6 kg DM of browse would correspond to seven or 14 branches of 25 mm diameter (total fresh weight: 9.2 or 18.4 kg) or 2.5 and five branches of 50 mm diameter (total fresh weight: 17 or 34 kg) per animal – a considerable effort if one wants to feed a whole group.

This study suggests that additional browse feeding will have an influence on the energy provision in captive giraffes, and maybe also on the ration adequacy in terms of overall roughage proportion. The results on the different lucerne hays, combined with the findings of increased roughage intake on clover hay from Hatt et al. (1998) and on high-quality lucerne hay from Hummel et al. (2003) underline the importance of roughage quality (c.f. Ulrey, 1997) for the feeding of large browsing herbivores.

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References


