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Feeding practices for captive giraffes (*Giraffa camelopardalis*) in Europe: a survey in EEP zoos

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Abstract
As with other browsing ruminants, the nutrition of giraffes (*Giraffa camelopardalis*) can be challenging. Feeding browse in very large amounts is not feasible. Therefore, substitutes need to be provided that have to meet requirements and the species' digestive capacity to the greatest possible extent. To achieve a comprehensive overview of current giraffe feeding practice in Europe, a survey was conducted among 153 member zoos of the European Endangered Species Programme. Information from 81 returned questionnaires showed a considerable variety of feeds being provided in varying proportions. The use of lucerne hay (89% of zoos) and fresh browse as trees or branches (96% of zoos) was more common than stated in previous studies. The use of a pelleted compound feed was almost standard practice, but many diets additionally contained cereal grains, as concentrate feeds high in rapidly fermentable starch. Eighty-five percent of the zoos reported feeding fresh fruits and vegetables, even though this is not recommended due to high sugar contents with a potentially negative influence on ruminal fermentation. The estimated non-forage proportion (sum of concentrate feeds and fresh fruits and vegetables) in the overall dietary dry matter (DM) was 37% in summer and 43% in winter (median), which is in accordance with recommendations. However, a considerable range of non-forage proportions was found, with 43% of the zoos providing amounts that were likely to be exceeding 50% of the potential daily DM intake. Data on dietary proportions revealed a geographical variation, with zoos from Western Europe showing the lowest and zoos from Eastern Europe showing the highest proportion of concentrate feeds in rations. An index of feeding appropriateness, oriented towards conformity with feeding recommendations, may be useful to evaluate and improve feeding management precisely and individually, as room for improvement was revealed for half of the participating zoos.

Introduction

The European Endangered Species Programme (EEP) for the giraffe (*Giraffa camelopardalis*) unites 153 giraffe facilities and increasing numbers of animals have been registered during the last decade (Jebram 2012). Nevertheless, giraffe husbandry poses challenges and the European Association of Zoos and Aquaria (EAZA) has published husbandry and management guidelines (EAZA Giraffe EEPs 2006). The feeding of giraffes is a matter of particular interest in these recommendations, since multiple husbandry problems in giraffes are reported to be nutrition related (e.g. Bashaw et al. 2001; Clauss et al. 2006; Hummel et al. 2006a). Giraffes are classified as browsing ruminants (Van Soest 1988; Hofmann 1989), which are generally considered to be more challenging to feed in captivity compared to grazing ruminants (Clauss et al. 2003; Clauss and Dierenfeld 2007). On the one hand, being a ruminant implies a forage fibre requirement to maintain efficient rumen function (Van Soest 1994). On the other hand, forages or fibrous feeds should match the digestive physiological adaptations of browsers against the background of chemical and structural particularities of browse compared to temperate grasses (Bailey 1964; Bailey and Ulyatt 1970; Robbins and Moen 1975; Demment and Van Soest 1985; Spalinger et al. 1986). Year-round feeding of browse in large amounts is logistically demanding in temperate zones with a period of dormant vegetation. Appropriate substitutes need to be combined in proper ratios to meet nutrient and energy requirements and to prevent pathological consequences (Potter and Clauss 2005; Clauss et al. 2006) or behavioural disturbances (Hummel et al. 2006a). The main focus in feeding instructions is on providing rations with sufficient amounts of palatable high quality forage (at least 50% of diet dry matter [DM]; Schmidt and Barbiers 2005; Hummel and Clauss 2006). In several aspects, lucerne shows chemical and structural characteristics similar to browse (Hummel et al. 2006b, c), enables a comparably high forage intake in ruminants in general (Thornton and Minson 1973; Waghorn et al. 1989) and has been shown to be better accepted by giraffes than grasses (Foose 1982). In addition, browse should be supplied for nutrient supplementation and behavioural enrichment (Valdes and Schlegel 2012). As an additional fibre source, dehydrated lucerne pellets are recommended (Hummel and Clauss 2006). Energy-rich diet ingredients should be based on suitable compound feeds or components rich in easily digestible cell wall constituents, such as unmolassed sugar beet pulp. The use of cereal grains and commercial fruits and vegetables should be restricted to a minimum (Hummel and Clauss 2006). Due to high contents of starch and sugar (Schmidt et al., 2005), any over-use of such feeds increases the risk of nutrition-related disorders (Potter and Clauss 2005; Clauss et al. 2006; Hummel et al. 2006a).

Along with current reports on feeding practice in other browsing ruminants (Taylor et al. 2013; Wright et al. 2011), the last overview of giraffe nutrition was reported by Hummel et al. (2006d) for European zoos and by Sullivan et al. (2010) for North American institutions. Some potential for further improvements in feeding giraffes became apparent. The use of lucerne hay was confirmed to be common by Hummel et al. (2006d), but the use of non-forage feeds in amounts corresponding to an average proportion of 51% of DM intake was also found. Sullivan et al. (2010) found considerable variation in the offered forage-to-concentrate ratio (FC ratio; a range of 18 to 77% concentrate feed in the diet as fed) and only 65% of the facilities reported feeding browse. Almost one decade later, the present nutritional survey was conducted to (1) gain comprehensive knowledge of current feeding practice in European facilities and (2) evaluate developments and trends in giraffe nutrition. Additionally, (3) the location of zoos (west, north, east or south of Europe) and structure of herds (number and age of giraffes) were considered to evaluate potential geographic or group-specific effects on feeding practice among EEP member zoos.

Table 1. Database for estimation of dry matter intake (DMI) (g/kg $BW^{0.75}$/d) and dietary forage-to-concentrate ratio; based on DMI calculated for 97 giraffes in twelve German zoos.

		g DMI/kg $BW^{0.75}$/d		
Age	Status	Male	Female	Juvenile
>2.5 years	Maintenance	62	59	-
	Lactation month 1–6 p.p.	–	121	–
	Lactation month 7–9 p.p.	–	94	–
	Lactation month 9–12 p.p.	–	81	–
2.5–1.75 years	Growth	–	–	75
1.75–1.25 years	Growth	–	–	83
1.00–1.25 years	Growth	–	–	71
9–12 months	Growth	–	–	64
7–9 months	Growth	–	–	46
4–6 months	Growth	–	–	26
<4 months	n.c.	–	–	n.c.

kg $BW^{0.75}$ = metabolic body size; p.p. = post partum; n.c. = not considered.

Methods

Questionnaire

The survey was conducted using a questionnaire (see Appendix) that was sent to zoos (n = 153) that were members of the giraffe EEP. The questionnaire was divided into four sections: (1) general information on number, date of birth, sex and subspecies of animals in a facility, (2) information on forage feeding, (3) information on feeding of non-forage feeds (concentrate feeds: compound feeds, dehydrated lucerne pellets, straight feeding stuffs (single component feeds like cereal grain products or sugar beet pulp); produce (fresh fruits and vegetables)) and (4) additional information on general feeding practice. Questions in sections two and three needed to be answered separately for summer and winter. Zoos could give information on amounts of feed either referring to one individual or to the whole group of giraffes. Amounts were generally given as fed. For evaluating regional effects, participating zoos were sorted geographically into (1) Western Europe, (2) Northern Europe, (3) Eastern Europe, and (4) southern Europe including the Middle East.

Dry matter intake and forage-to-concentrate ratio

Offered amounts of feed were standardised from volumes to weights if necessary (Madgwick and Satoo 1975; BVL 2002; Hatt and Clauss 2006; Spiekers et al. 2009; Mosig 2012) and converted into DM, using standard data collections on animal feeds (Universität Hohenheim – Dokumentationsstelle 1997; DLG 2010; Agroscope 2013). Body weights (BW) were estimated using the data collected on BW development in giraffes by Reason and Laird (2004). Theoretical DM intake (DMI) related to metabolic body size (kg $BW^{0.75}$) was estimated using our own data on DMI in giraffes (Table 1), prepared from DMI documentation in 12 German zoos based on metabolisable energy (ME) requirement and the individual status (lactation, growth) of each animal. This data base was within the range of values published on DMI in giraffes (Prins and Domhof 1984; Baer et al. 1985; Hatt et al. 1998; Dinglreiter 2000; Clauss et al. 2001). If not declared otherwise, amounts of concentrate feeds and produce offered were assumed to be completely consumed (as done by, for example, Hummel et al. 2006d), resulting in the estimated non-forage proportion, which was used to calculate the potential FC ratio.

The classification of dehydrated lucerne pellets and the pelleted "browse-based" product as non-forage feeds was done with reference to their different physical structure and irrespective of potential similarities in nutrient composition with lucerne hay or dried browse.

Index of feeding appropriateness

A scoring system was developed to assign an index of feeding appropriateness (IFA) to every facility by using the equation:

$$\text{IFA} = (2 \cdot a) + (2 \cdot b) + c + \sum d + \sum([\text{\% of respective concentrate feed in the concentrate portion in DM}/100] \cdot e) + \sum f \text{ (Table 2).}$$

Scores included in the index calculation encoded respective non-forage proportions (a; minimum [min.] -4, maximum [max.] 4 points), produce proportions (b; min. -4, max. 4 points), feeding frequencies of non-forage feeds per day (c, min. -1, max. 1 point), types of main forage in the diet (d; min. -1, max. 3 points), composition of the concentrate portion (e; min.-2, max. 2 points) and feeding of additional forage (f; min. 0, max.2 points). Due to the high relevance of FC ratio in ruminant nutrition, variables a and b were multiplied by two in the index equation. Section d refers to the proportion of a respective concentrate feed in the whole portion of concentrates in DM. Each bullet point in sections d, e, and f is counted individually. An increasing IFA represented

Table 2. Index variables and scoring system for calculating the index of feeding appropriateness (IFA)[1].

Variable	-2 points	-1 point	1 point	2 points
Percentage of non-forage feeds (a) and produce (b) in diet DM	>70% >5%	50–70% 2–5%	30–50% 0.1–2%	<30% 0%
Feeding of non-forage feeds per day (c)		1 time	≥2 times	
Types of main forage in the diet (d)		Grass hay	Lucerne hay *and/or* browse[2] seasonal	Browse[2] year-round
Composition of the concentrate portion (% of concentrate feed in the concentrate portion in DM) (e)		% of cereal grains/100		% of compound feed *and/or* dried lucerne meal products *and/or* beet pulp/100
Feeding of additional forage (f)			Fresh forage[3] *and/or* Browse ensiled/ frozen/dried	

[1]IFA = (2 · a) + (2 · b) + c + ∑d + ∑([% of respective concentrate feed in the concentrate portion in DM/100] · e) + ∑f, each bullet point in section d, e and f counts individually; ∑ = addition of scores for multiple bullet points; [2]Whole trees and branches; [3]Fresh lucerne, nettles, blackberry, thistles, rose leaves.

increasing feeding appropriateness (evaluation scale from -12 to 16 points). To evaluate the results, the scale was quartered (results ≤0 points, 1 to 6 points, 7 to 11 points and ≥12 points) and the mean index value was taken as the critical value.

Statistical evaluation

Due to extreme outliers, the proportions referring to the FC ratio were averaged by median, and first and third quartiles are given to show variances. Other values are presented as arithmetic mean with standard deviation (SD). Seasonal differences in forage and non-forage proportions were tested with the Tukey test and considered significant at p≤0.05. To evaluate potential geographic or group-specific effects (number and age of giraffes in a zoo), an analysis of variance was conducted with region, number of animals and mean age of animals per group as fixed effects and comparison of least squares means of the variables forage proportion and produce proportion using the Tukey test. Subsequently, a cluster analysis was conducted for the variables forage proportion and produce proportion (hierarchical method of Ward, 3 cluster-algorithm) and the geographical distribution of zoos and distribution of group-specific characteristics among the clusters was enumerated. Differences between the clusters were tested with a Student's t-test and considered significant at p≤0.05. For all variables, the respective mean values per zoo were used in the data base. The statistical tests were done using the program SAS 9.3 (SAS Institute Inc, Cary NC, USA).

Results

Zoo and group information

A response rate of 53% was achieved, representing 81 separately managed groups of giraffes from 22 countries. The participating zoos were located in Austria (1), Belgium (2), Czech Republic (4), Denmark (5), France (10), Germany (16), Hungary (2), Ireland (2), Israel (2), Italy (2), Lithuania (1), the Netherlands (8), Poland (3), Portugal (1), Serbia (1), Slovakia (1) Slovenia (1), Spain (3), Sweden (2), Switzerland (1), the United Arab Emirates (1) and United Kingdom (12). The geographical distribution of the responding zoos was representative for the geographical distribution of all EEP member zoos contacted with 65% respondents from Western Europe, 9% from Northern Europe, 16% from Eastern Europe and 10% from Southern Europe including Middle East. The groups of giraffes consisted of a mean of 6 (± 3 SD; range 1–18) individuals which were a mean of 8 (± 2.7 SD; range 3.8–14.3) years old.

Diet composition

Lucerne hay was fed in 89% of the facilities, with 96% of those using it year-round and 4% during winter time. Grass hay was fed in 27% of the facilities (only seasonally in 18% of those) and grass-clover hay was used in 2% of the zoos. During summer, fresh lucerne and fresh grass was provided in 17% and 30% of the facilities, respectively. One facility provided fresh lucerne and grass year-long. In 2% of the facilities molassed lucerne hay was fed; grass haylage, lucerne silage, chopped lucerne hay or grass silage was used in single zoos only. Ninety-six percent of the participating facilities stated that they fed fresh browse, 86% of those during summer (as leafy twigs and trees) and winter (as twigs and trees without leaves). Frozen browse (9%), browse silage (7%) and dried browse (31%) were used in the zoos as forage sources during winter; the latter was also fed year-round in four and during summer in one facility. Thirty-one different types of browse were supplied in the zoos. Willow was most commonly used (81% of the facilities) followed by birch (51%), beech (44%), oak (44%), ash (41%), hazelnut (39%), robinia (35%), maple (22%), various types of berries (18%), fruit trees (15%) and hawthorn (13%). Additionally, nettles (6% of the facilities), blackberry, thistles and rose leaves (single facilities only) were provided as fresh summer forage. Seven percent of the zoos provided whole maize plants or maize stover during the growing season. Forages were fed in various combinations (Table 3), with the combination of preserved lucerne supplemented with browse, or preserved lucerne supplemented with fresh forage and browse being the most common combinations. Lucerne-free forage portions were fed in 8% of the zoos, with either grass hay/haylage or grass-clover hay being the main forage source. Two facilities did not provide any browse.

All responding zoos fed some concentrate. Almost all (96%) of the facilities stated that they used compound feed; 50% of the products were declared to be specific for browsers or giraffes. Dehydrated lucerne pellets were provided in 30% and a pelleted "browse-based" product in 11% of the facilities. In 19% of the facilities sugar beet pulp was used. Energy-rich cereal grain products (wheat flakes, oat flakes, barley flour, corn meal, broken corn, whole corn) and fibre-rich cereal grain products (crushed oats, wheat bran, oat bran) were part of the diet in 33% of the

Table 3. Combinations of forage fed in the percentage of respondent zoos.

Lucerne hay/ chopped/ ensiled/molassed	Grass hay/ haylage/silage	Grass-clover hay	Fresh forage (lucerne, grass,nettles, blackberry, thistle, rose leaves)	Browse fresh/ frozen/dried/ensiled	Fed in % of zoos
*				*	40
*			*	*	26
*	*		*	*	19
	*		*	*	5
*	*			*	4
	*			*	2
*					1
*	*		*		1
		*		*	1
*		*	*	*	1

zoos, with 26% of those feeding energy-rich, 37% combining energy- and fibre-rich and 37% feeding only fibre-rich cereal grain products. Nine percent of the respondents fed soybean meal and 16% fed linseed as supplement. Additionally, “giraffe cereals” and a “pasture mix” were used, each in one case. Regarding combinations of concentrate feeds (Table 4), the exclusive use of compound feed was most common (26% of the zoos). The next most frequent combinations were feeding of compound feed with cereal grains (14%), with dehydrated lucerne pellets (12%), with a pelleted “browse-based” product (7%) or with sugar beet pulp (7%). The remaining 30% of the zoos provided further combinations resulting in mixtures of up to five ingredients. Forty percent of the zoos provided concentrate feeds once per day, 52% twice, and 7% three times, while one facility stated that it fed concentrate feeds five times per day.

Of all participating zoos, 85% made use of produce in their giraffe diet. Fifty-three percent of those provided both fruits and vegetables, 46% vegetables only and 1% fruits only. Except for five facilities, all zoos stated that they fed produce year-round. In the produce-feeding zoos, apples (59%) and bananas (26%) were most commonly fed, followed by citrus fruits (9%) and others (7%). The following types of vegetables were used: carrots (77%), cabbage and celery (30% each), onions and beetroot (29% each), salads (26%), kohlrabi (19%), herbs (10%), radish, leek and potatoes (9% each), fennel and chard (6% each), celeriac, chicory and peppers (4% each), tomatoes, cucumber, maize cob, scallions, endive and zucchini(courgette) (3% each) and pumpkin, spinach, aubergine, fodder beet, garlic, cole and turnips (each in single facilities). Produce was fed once per day in 43% and twice per day in 49% of the zoos. Three zoos stated they fed fruits and vegetables three times per day and another three zoos provided them during training sessions.

Dry matter intake and forage-to-concentrate ratio

Thirty-eight percent of the respondents gave separate information for feeding of concentrates and produce in summer and winter season, respectively, but there was no statistically evident seasonal difference. During summer season a median content (1st quartile/3rd quartile) of 35% (23/50) of concentrates and 2.2% (0.5/4.2) of produce in diet DM was estimated. Accordingly, the median estimated forage content was 62% (48/72). During winter season an amount of 41% (28/57) of concentrates and 2.2% (0.6/4.5) of produce in diet DM was estimated and the median content of forage was 54% (41/69). A reasonable estimate

Table 4. Combinations of concentrate feeds fed in the percentage of respondent zoos.

Compound feed	Cereal grain products	Protein supplement	Dehydr. lucerne pellets	Browse-based product	Beet pulp	Linseed	Fed in % of zoos
*							26
*	*						14
*			*				12
*				*			7
*					*		7
*	*				*		4
*	*		*				4
*	*	*	*			*	4
*						*	4
*	*		*			*	2
*	*					*	2
				Combinations fed in single facilities			14

Table 5. Proportion of forage, concentrate and produce in diet dry matter (DM); based on reported amounts of non-forage feeds (concentrate and produce; 81 responding EEP zoos) and estimated proportion of forage derived from potential daily dry matter intake of the groups of giraffes during summer and winter season.

	% of dietary DM					
	Summer			Winter		
	Forage	Concentrate	Produce	Forage	Concentrate	Produce
Median	62	35	2.2	54	41	2.2
1st Quartile	48	23	0.5	41	28	0.6
3rd Quartile	72	50	4.2	69	57	4.5
Mean	58	39	2.8	53	44	2.9
SD	20	20	2.8	22	21	2.8
Minimum	2.2	2.9	0.0	2.2	10	0.0
Maximum	93	90	13	89	91	13

of DMI and FC ratio was not possible for six zoos due to feeding of concentrates or produce for ad libitum intake or at a level sufficient to meet energy requirements by concentrateand/or produce offers alone. Detailed information on estimated DMI and FC ratio is given in Table 5.

Influence on dietary proportions

Aalysis of variance showed that the location of zoos had a significant effect on the dietary forage ($p = 0.003$), concentrate ($p = 0.007$) and produce proportion ($p = 0.020$), with rations from Western European zoos containing more forage ($p = 0.009$) and less concentrate ($p = 0.028$) than rations from Eastern European zoos. The number or age of animals per group showed no effect on dietary proportion. The cluster analysis revealed clusters according to low, medium or high dietary proportion of forage ($p < 0.001$) or concentrate ($p < 0.001$), but produce proportions did not differ between the clusters ($p > 0.300$). The number and age of animals per group were likewise not different between the clusters (Table 6). The distribution of zoos among the clusters could be allocated based on their geographical location (Table 7).

Table 6. Proportion of forage, concentrate and produce, number of animals and age of animals in the clusters (mean ± SD; minimum/maximum); significant differences ($p < 0.05$) between clusters are labelled with different letters in the same line.

	Cluster 1 (n = 11)	Cluster 2 (n = 32)	Cluster 3 (n = 33)
Forage (% of diet DM)	20.8^{a} ±11 2.2/45.7	59.5^{b} ±8.1 33.0/62.1	73.9^{c} ±7.9 62.3/89.5
Concentrate (% of diet DM)	75.5^{a} ±12 46.4/90.3	48.0^{b} ±7.7 36.1/61.6	23.2^{c} ±8.0 7.8/34.0
Produce (% of diet DM)	3.8 ±2.9 0.4/7.9	2.5 ±2.7 0/10.5	2.8 ±2.8 0/13.0
Animals (number)	5.3 ±2.7 1/10	5.9 ±2.9 2/15	5.5 ±3.6 2/18
Age (years)	8.8 ±3.2 4.4/13.9	8.5 ±2.7 3.8/14.3	7.3 ±2.4 3.9/14.3

Particular differences between Western and Eastern European zoos became clear, with 54% of Western European and only 15% of Eastern European zoos being summarised in cluster 3 (high forage proportion).

Index of feeding appropriateness

A mean index value (± SD) of 6 points (±5) was observed with a minimum score of -4 and a maximum score of 14 points. In a quartered scale, 13 facilities achieved a value ≤0, 31 facilities achieved 1 to 6 points, 31 facilities achieved 7 to 11 points and six facilities reached ≥ 12 points. Taking the overall mean of 6 index points as critical value, 54% of the zoos were in the lower and 46% in the upper half of the scale. IFA results higher than 6 points were achieved by 59% of the Western European zoos, 38% of the Northern European zoos, 23% of the Eastern European zoos and 11 % of the zoos from Southern Europe including Middle East (Table 8).

Discussion

The results of the present survey showed that feeding of giraffes in Europe is in fact characterised by considerable variety, as previously determined for other captive browsing ruminants (Clauss et al. 2002; Wright et al. 2001; Taylor et al. 2013). An established use of preserved lucerne in 91% of all participating facilities, for the most part as lucerne hay (89%), exceeds the number of zoos feeding lucerne hay (81%) in the report by Hummel et al. (2006d) (Table 9). In contrast, the use of grass hay decreased; less zoos made use of grass hay but more fed the recommended lucerne hay. Furthermore, some zoos fed grass-clover hay that might likewise be more suitable for giraffes than pure grass hay due to similar patterns in fibre fractions compared to lucerne or browse species (Jayanegara et al. 2011). During summer, 52% of the zoos in our study used fresh forage, which is comparable to the percentage of zoos feeding fresh forage in the survey by Hummel et al. (2006d). Fresh forage did not undergo any conservation process, and thus nutrient characteristics and energy content are higher compared to the dried or ensiled product. However, in the former study exclusively fresh grass was used, while 19% of the zoos currently state that they feed fresh lucerne. Like its dried counterpart, fresh lucerne is regarded as more appropriate for giraffes than pure grass (Hummel and Clauss 2006). Furthermore, fresh nettles, thistles, blackberry and rose leaves were used in at least 12% of the facilities. These unconventional fodder plants can also be good quality complementary forage for giraffes due to similar chemical

Table 7. Distribution of zoos in the three clusters according to geographical location (cluster 1 = high concentrate proportion; cluster 2 = medium concentrate proportion; cluster 3 = low concentrate proportion).

	Cluster 1 (n = 11)	Cluster 2 (n = 32)	Cluster 3 (n = 33)
% of Western European zoos	8	38	54
% of Northern European zoos	25	75	0
% of Eastern European zoos	39	46	15
% of Southern European zoos incl. Middle East	12	44	44

characteristics compared to lucerne and high nutritive values (Hummel et al. 2009; Nijboer pers. comm.).

The number of zoos that provided some browse with the diet, especially during winter, increased compared to the survey by Hummel et al. (2006d) (84%) and the study of Sullivan et al. (2010) (65%); fresh branches and/or trees were commonly used in 96% of the current zoos, and dried or ensiled browse was also fed in several facilities. Three facilities stated that they feed fresh browse since the giraffes are able to browse from natural vegetation around the enclosure. Individual cases may differ, but vegetation in or around giraffes' enclosures is typically cropped in a short time and does not appear sufficient to provide a quantitatively relevant intake of browse. While this may still be advantageous for giraffe activity budgets, foraging would be reduced to extensive searching for browse over fences instead of actual feed intake. To prevent oral stereotypies (Koene and Visser 1999; Bashaw et al. 2001; Hummel et al. 2006a) and maximise browse intake, an additional supply of browse should be considered essential in the nutrition of browsing ruminants irrespective of the natural browse availability around an enclosure.

Feeding concentrate feeds is an efficient and easy way to supply energy and nutrients of constant quality (Sullivan et al. 2010). To improve feeding of concentrates, composition and amounts supplied need to be considered. Fortunately, the use of compound feeds has become more common in European zoos during the last few years. It can be assumed that these products are mostly suitable to meet the animals' demands with a higher suitability and safety regarding rumen physiology as compared to pure cereal grain products. Starch as a rapidly fermentable carbohydrate is characterised by a high acidogenicity value, indicating the potential to trigger unphysiological conditions in the rumen (Menke and Steingass 1988; Van Soest et al. 1991; Odongo et al. 2006). Therefore, the use of fibre-rich non-forage feeds like unmolassed sugar beet pulp or dehydrated lucerne pellets is additionally recommended (Hummel and Clauss 2006). In particular, unmolassed sugar beet pulp has been reviewed as a suitable energy source for browsers (Hummel et al. 2003; Kearny, 2005). Instead of starch it contains pectins as an easily fermentable component of the cell wall, which shows a higher cation exchange capacity and more even gas production during fermentation (Van Soest et al. 1991; Jeroch et al. 1993). Nevertheless, only 16 facilities made use of it.

Whether or to what extent the feeding of produce is really required for large herbivores has been discussed repeatedly (Oftedal et al. 1996; Hummel et al. 2003; Clauss and Hatt 2006; Hummel and Clauss 2006). Due to high amounts of rapidly fermentable sugar, produce shows an immediate, explosive fermentation, which can potentially trigger acidotic conditions in the rumen (Van Soest 1987; Oftedal et al. 1996). This was recently shown to be the case in various zoo ruminant species fed diets high in easily fermentable carbohydrates (Schilcher et al. 2013; Ritz et al. 2014). In the present survey, 85% of the participating facilities made use of produce as a more or less relevant diet component. Twenty-six percent exceeded the recommendation of at most 1% fruits in dietary DM; 16% exceeded the recommendation of at most 4% vegetables in dietary DM (Hummel and Clauss 2006). Obviously the use of commercial fruits and vegetables is still common, even though from a purely nutritional point of view, it should not be considered as a desirable or even necessary part of the diet. The main reason for feeding fruits and vegetables is probably their high palatability, which makes produce useful during training and medical treatments.

The distribution of concentrate portions over the day is important for ruminal conditions. It must be noted that 35% of the zoos provided non-forage feeds in one large portion per day, which increases the probability of a considerable pH drop in the rumen (Hummel et al. 2006b). Feeding of concentrates (including produce) in smaller portions has beneficial effects on rumen pH (Kaufmann 1976) and the time span for food consumption can be elongated. Therefore, feeding of non-forage feeds in at least two portions and with a maximum time lag between feeding times is recommended (Hummel and Clauss 2006).

The present study estimated a non-forage proportion of 37% in summer diets and 43% in winter diets (median). Correspondingly, the amount of forage was above the limit of 50% of dietary DM (Table 5) and in line with EAZA recommendations (Hummel and Clauss 2006). Therefore, the current potential FC ratio has improved in contrast to former results by Hummel et al. (2006d), who estimated a non-forage proportion of 51%) and is in line with the results of Sullivan et al. (2010), who estimated a non-forage proportion of 44%. At the same time a very large variance in potential FC ratio, similar to the results of Sullivan et al. (2010), was observed, showing that giraffe feeding in European zoos is still of considerable heterogeneity. The estimated proportion

Table 8. Distribution of zoos (% of zoos) in scoring ranges in the evaluation of feeding practice using an index of feeding appropriateness (IFA) (increasing value = increasing feeding appropriateness; evaluation scale = -12 to 16 points).

IFA scoring range	All regions	Western Europe	Northern Europe	Eastern Europe	Southern Europe incl. Middle East
≤0 points	16	10	12	46	11
1 to 6 points	38	31	50	31	78
7 to 11 points	38	47	38	23	11
≥12 points	8	12	0	0	0

Table 9. Feeding of forage as found by Hummel et al. (2006d) compared to information from the participating zoos in the present study.

	Hummel et al. (2006d)	Present study
Grass/lucerne		
Lucerne hay	81%	89%
Grass hay	40%	27%
Ensiled lucerne/grass	—	4%
Browse		
Fresh browse (trees and branches)	80%	96%
Dried/ensiled/frozen browse	4%	47%
Fresh forage		
Grass	53%	31%
Lucerne	—	19%
Nettles, thistles, blackberry, rose leaves	—	12%

of concentrates was a decisive variable for distance calculation in the cluster analysis, whereas no difference was found for the proportion of dietary produce. Obviously the use of fruits and vegetables is independent from other diet characteristics and evenly represented across zoos, whereas the quantitative use of concentrate feeds varied between zoos.

The calculation of the potential FC ratio was done assuming the complete intake of concentrates and produce as supplied. Therefore, an overestimation of the respective amount of non-forage proportion in certain diets was possible, if the amount of concentrate and/or produce was particularly high and potentially not completely consumed by the animals. This could lead to questionable results regarding extreme outliers (Table 5). Nevertheless, in these cases concentrates and/or produce would have been provided more or less for ad libitum intake, which is critical. Regulation of DMI in ruminants is described as happening due to energetic satiety in easily digestible diets with energetic density (Conrad 1966; Waldo 1986; Jung and Allen 1995). Increasing dietary energy values due to high amounts of concentrate and produce may therefore adversely affect forage intake, resulting in the consumption of a lower forage proportion.

The IFA shows that 54% of all participating EEP member zoos did not reach a score higher than 6, and therefore there is potential for improvement in feeding management. On the other hand, approximately half of the zoos showed an adequately calculated proportion of non-forage feeds in the diet and an extended use of various forage sources. On a quartered scale, six zoos from Western Europe achieved ≥12 index points. These zoos stood out for an adequate non-forage proportion, the choice of recommended concentrate feeds and an ambitious use of preserved browse and additional fresh forage in the diet.

Regarding the regional distribution of zoos in the clusters (Table 7) it was noticeable that zoos from Eastern Europe were mainly summarised in Cluster 1 (high concentrate proportion) and Cluster 2 (medium concentrate proportion,) whereas zoos from Western Europe were mainly summarised in Cluster 2 and Cluster 3 (medium and low concentrate proportion). Apparently feeding concentrate in high amounts was more common in Eastern European zoos. Supplementary feeding of high energy feeds could rather be assumed for Northern European facilities due to potentially higher energy requirements for thermoregulation in the boreal area, which was not confirmed tough. Looking at the IFA results, and thus feeding practice as a whole, more than half of the zoos from Western Europe and a comparatively high number of zoos from Northern Europe reached the upper half of the scale, indicating a high level of feeding appropriateness. Due to considerable amounts of non-forage feeds, many zoos from Eastern Europe could not reach a value greater than six index points. Based on the IFA results, feeding practices in zoos from Southern Europe including the Middle East appeared less positive than in the cluster analysis. Even though these zoos showed medium to high forage proportions, feeding practice lacked concordance with recommendations, as grass hay and/ or cereal grains were part of the diet in 90% of the facilities. Furthermore, the use of additional fresh forage was practised in only one zoo from Southern Europe including Middle East. The results of the cluster analysis and the index evaluation should be taken as a clear indication of differences in feeding practice across Europe, with higher improvement potential being visible in zoos from Eastern and Southern Europe including Middle East. This raised the question of reasons for geographical differences in feeding practice. As precondition for improvement, it would be highly desirable to further investigate if tradition, finances, management or even some climatic causes were of reason here. An IFA as developed in this study may be a useful tool to identify striking and improvable factors in practical feeding management of giraffe facilities, as strength and weaknesses become more clearly visible by scoring individual factors orientated on feeding recommendations.

Conclusions

The motivation of numerous zoos to participate in the survey with personal queries and suggestions mirrored the high interest in issues of giraffe feeding in European facilities. A large number of feedstuffs and combinations of feedstuffs were documented and proportions of feeds varied considerably. Preferable trends and desirable developments were clearly visible, but improvement opportunities were also obvious, as in former investigations.

The use of lucerne hay provided for ad libitum intake was nearly standard in the participating facilities and a higher percentage than in a previous survey supplied browse year-round. The use of fresh forage or preserved browse might be possible for more zoos if unconventional fodder such as nettles or dried browse was used.

As recommended, the estimated forage proportion represented more than 50% of dietary DM. Nevertheless, the potential extent of non-forage feeds in the diets differed significantly, resulting in varying dietary proportions. Concentrates should be dosed and chosen with due care. The use of pelleted compound feeds, unmolassed sugar beet pulp and/or dehydrated lucerne pellets is recommended and at least the former was used extensively. The feeding of less cereal grain-based diets would be highly desirable.

Even though fresh fruits and vegetables should not be part of giraffes' diets, more than three-quarters of the zoos stated they used them regularly. In terms of rumen physiology, produce is not recommended for giraffes, and intake should be limited to specific purposes such as medical treatment.

Effects of the geographical location of zoos were shown for dietary proportions and IFA results, with zoos from Eastern and Southern Europe including Middle East revealing a higher potential for improvements than Western European zoos. The use and advancement of an index system to evaluate feeding appropriateness could help to identify weakness and strength in particular management aspects of single facilities.

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