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Research article

Survey of husbandry and feeding management and potential influencing factors on the body condition score of zoo-housed giraffes *Giraffa camelopardalis* spp. in Europe and Northern America

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Abstract

Giraffes *Giraffa camelopardalis* spp. feed mainly on browse in the wild. The logistical challenges, especially in temperate climates, to provide these animals with fresh browse year-round have resulted in zoos resorting to alternative feeds. Amongst these, high-sugar or high-starch concentrates can lead to pathologies which may, in part, be recognised by a reduced body condition score (BCS). Questionnaire data were obtained from 125 European and North American zoos with information on the animal's identity, health status, husbandry conditions and diet. The feed was summarised by season and compared to the animals' BCS assessed from photographs. There were no relationships between BCS and group size, enclosure size or feeding frequency. Over 80% of zoos offered browse (fresh, dry, frozen or silage) to giraffes in summer and winter, but the amount varied from a small branch daily per animal to feeding for ad libitum consumption. In most zoos, lucerne was offered as hay or fresh, and was fed for ad libitum consumption in 66% of facilities. 98% of zoos offered a high-fibre pelleted feed, but only 6% provided this feed for ad libitum consumption. Cereals and low-fibre pellets were fed in varying quantities in 50% of zoos, and their use was negatively related to BCS. Offering higher amounts of a high-fibre pelleted diet had an optimising effect on the BCS, especially in senescent animals. Together with browse and lucerne, high-fibre herbivore pellets should form the continuously available staple diet of zoo-housed giraffes to maintain an optimal body condition score.

Introduction

As exclusive browsers, *Giraffa camelopardalis* spp. present a logistical and financial challenge to zoo nutritionists (Clauss and Dierenfeld 2008). Seasonal and regional availability, and difficulties in storing leaves and branches resulted in zoos historically using grass hay and concentrates as the mainstay of giraffe feeding rations (Hummel et al. 2006). The current feeding recommendation outlined in the 2006 EAZA (European Association of Zoos and Aquaria) husbandry guidelines consists of 50% alfalfa hay, 10% browse, 30% pelleted compound and the remaining 10% made up of linseed extraction chips and green leafy vegetables. The pelleted mix should be lucerne meal-based and contain around 18% protein, 5% fat, 40% neutral detergent fibre and little starch. Energy requirements for giraffes are only roughly defined, especially concerning additional requirements during pregnancy, lactation, or cold spells (Gussek et al. 2017). A negative energy balance can have detrimental consequences and could eventually result in serous fat atrophy (Potter and Clauss 2005). More than half of the giraffe deaths seen over two years in zoos in the United States and Canada were related to cold conditions (Gage 2013), emphasizing giraffes' potential susceptibility to cold stress (Clauss et al. 1999). While the diet on offer may be particularly important for the energy balance of giraffes, the impact of husbandry-related factors should not be overlooked. Keeper experience, social stress and underlying medical conditions such as hoof and limb disease could lead to a negative energy balance (Gage 2019).

Monitoring the animals' body condition is a practical approach to assess the energy status of and has been validated across many domestic (Dorsten and Cooper 2004; Kristensen et al. 2006; Dugdale et al. 2012) and non-domestic species (Reuter and Adcock 1998; Ezenwa et al. 2009; Schiffmann et al. 2018; Shirane et al. 2020). A method for photographic body condition scoring (BCS) has been developed as the first part of the present study (Clavadetscher et al. 2021), which compared scores between free-ranging and zoo-housed giraffes: The BCS of zoo-housed giraffes were generally higher than those of their wild counterparts at the end of the dry season, and also – though less distinctively – at the end of the wet season. Nevertheless, zoo giraffes are rarely reported to be obese, and BCS suggesting obesity were not recorded (Clavadetscher et al. 2021). This is in contrast with many other zoo animals in which obesity is considered prevalent (Cocks 2007; Heidegger et al. 2016; Schiffmann et al. 2017). Therefore, given the historical propensity of zoo giraffes for a negative energy balance and the absence of evidence for obesity, BCS in the upper range of the current scoring system (from 1-7) are considered positive.

While we expect zoos to continuously improve their husbandry, especially when compared to historical practices, this is rarely documented. As a rough indicator of husbandry success, survivorship of various zoo animals has been shown to increase over historical time (Wich et al. 2009; Jett and Ventre 2015; Havercamp et al. 2019; Roller et al. 2021; Scherer et al. 2023; Tidière et al. 2023; Wittwer et al. 2023), including in giraffes (Scherer et al. 2024). While one may assume a historical improvement in feeding practices in many zoo animal species (Fens and Clauss 2024; Figueroa et al. 2024), this has been documented in the European zoo giraffe population using surveys of two different decades (Hummel et al. 2006; Gussek et al. 2018). One aim of the present study was to assess whether the trend of improving giraffe diets to better represent current feeding recommendations is continuing. The second aim was to relate results on individual animals' BCS to the feeding and husbandry practices of their respective zoo in an exploratory manner, to identify potential factors that might contribute to improving the body condition of zoo giraffes.

Methods

With the support of the EEP (EAZA Ex situ program) studbook coordinator and the EAZA Antelope and Giraffid TAG research advisors, an electronic survey was sent out in 2019 to European and North American zoos with giraffes in their collections. The survey asked for general information on the animals (sex, age, reproductive status and medical history), on husbandry (enclosure size, outdoor access, ambient temperatures in summer and winter), and nutrition in summer and winter (amount per animal and frequency of feeding of hay and fresh greens, browse, and concentrates and produce). Additional questions were asked for details about feeding management, such as the number of feeders and the feed presentation. Information on body condition (scored according to Kearney and Ball (2001)) was asked for in a separate section in the survey, as well as medical records, pathology data and morphological data – where available. The complete survey is provided as supplementary material. The study complies with relevant guidelines for data handling and privacy.

While we received data on more than 500 animals from 125 European and North American institutions, the dataset for this analysis was restricted to 223 animals for which a photographic BCS hip (ranging from 1-7) could be established as presented in Clavadetscher et al. (2021). The photographic BCS of the hip region (i.e., the score based on the visual appearance of the hip area as viewed from behind the animal) yielded the best differentiation, so only these scores from Clavadetscher et al. (2021) were used in the present study. The age categories (juvenile, subadult, adult and senescent) from the previous study were adopted, but since juvenile animals are less dependent in terms of their BCS on husbandry and feeding management until weaning at around one year of age (Miho et al. 2020), the animals in that age class all were excluded from the analysis (n = 12).

The general feeding practices of the surveyed institutions were summarised to allow for comparison with surveys from previous years (Bashaw et al. 2001; Hummel et al. 2006; Sullivan et al. 2010; Berthomieu 2017; Gussek et al. 2017). The daily food intake per animal was estimated as follows. Feed quantities were transformed from a reported portion per animal or group into kilogram dry matter intake per kilogram metabolic body weight per day (kg DM/kg MBW/day). The dry matter content was either extracted from commercial labels, previous literature (Gussek 2016), or data collections on animal feeds (Agroscope 2023). As outlined by Clauss and Hummel (2017), first the metabolic body weight was calculated for each animal; subsequently, the MBW of all animals for which an amount of food had been reported was summed up, and then the amount of food was divided by the total MBW of all animals. To summarise the feeding ration, 'appropriate food' was defined as the normal ration without high carbohydrate items such as cereals or low-fibre pellets (grouped together in results for simplicity), root vegetables and fruit. Dried grass and lucerne ('hay') were summarised as roughages in contrast to browse. All pelleted diets with a crude fibre content ≥ 20% (as fed; according to the manufacturer's labelling) were defined as high-fibre pellets; other pellets were classified as 'low-fibre'. To estimate the proportion of roughages in the overall diet, we followed the approach of Flores-Miyamoto et al. (2005): The assumed daily dry matter intake (DMI) was set to 60 g DM/kg MBW/d based on an estimation from a detailed feed study of giraffes in German zoos (Gussek et al. 2018). The DMI that was not covered by pelleted feeds, cereals or fruit and vegetables (allocated to an individual as explained above) was assumed to be filled by roughages. This assumed amount was then also used to calculate the proportion of roughage in the overall diet.

Statistical analysis was performed in R Studio (Version 2022.12.0+353). Due to the non-parametric nature of BCS, they were summarised as median and quartiles. However, means and standard deviations are additionally reported for the convenience of the reader. Data were analysed using Spearman correlation for continuous variables (reported as rho and p) and, where applicable, Chi-square testing (reported as chi-square and P) for categorical variables. A P-value below 0.05 was considered significant; some P-values slightly above this threshold (between 0.05 and 0.07) are mentioned specifically in the results. Because of the exploratory nature of the study, no correction for multiple testing was applied.

Results

General husbandry

In total, 211 animals from 89 institutions were included, representing 13% and 52% of individual giraffes and zoos keeping giraffes, respectively, in North American and Europe in 2019. The study population consisted of animals from European (n=152) and Northern American zoos (n=59), and we received data for more female animals (n=129) than males (n=82). The photographic BCS divided by age category are summarised in Figure S1 and presented in detail in Clavadetscher et al. (2021). The most

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common subspecies reported was *Giraffa c. rothschildi* (37%), followed by *G. c. reticulata* (34%), hybrid animals (9%), *G. c. tippelskirchi* (7%), *G. c. camelopardalis* (5%), *G. c. antiquorum* (4%), and 1% each for *G. c. angolensis, G. c. giraffa* and non-specified subspecies. Subspecies did not differ in BCS (X^2=46.79, P=0.282; Table 1; Figure S1). The BCS did not show any sex differences, but among the adult female animals, reproductive status was linked to the BCS, with nulliparous animals having the highest and lactating animals the lowest BCS (X^2=29.55, P=0.013; Figure S1). Overall, the photographic BCS correlated significantly with the BCS given by the institutions in the survey (rho= 0.32, P<0.001; Table 1; Figure S1); however, this was not the case for subadult animals and adult males (Table 1). It must be noted that the correlation only occurred because of extreme animals; in the photographic BCS range of 4-7, the survey BCS had a median value of 5, indicating a lower degree of resolution in the survey answers (rho=0.14, P=0.084, Figure S1). The answers regarding the animals' medical conditions were very varied: in summary, this part was filled out for only 52 animals. Most mentioned were hoof abnormalities and conditions related to the gastrointestinal tract. The BCS for animals with any reported medical condition (3.8±1.5) were lower than for the putatively healthy animals (4.0±1.5; X^2 =2.59, P<0.001). While the 16 animals with reported hoof overgrowth had a numerically higher BCS (4.2±1.2) than the reference group of putatively healthy animals, the 16 animals with endoparasites or an abnormal faecal consistency had a similar BCS (4.0±1.4) to the reference animals, and the 8 animals with oral pathologies incl. dental disease had a lower BCS (3.6±1.6). Whether these findings were due to the medical condition, feeding and husbandry practices or age was beyond the scope of this study.

Over 76% of animals were kept in institutions with 20 or more years of experience keeping giraffes, and group size ranged from 1 to 13 animals (mean 5.6±3.2 animals). The indoor enclosures ranged from 59 m^2 to 2153 m^2 (mean 338±313 m^2). Totalling indoor and outdoor enclosures, most animals (n=207) had access to an area larger than 10000 m^2 (mean 40596±127824 m^2). Indoor and total area correlated to the group size (indoor: rho=0.53, P<0.001; total: rho=0.63, P<0.001, Table 2). Most institutions reported temperature ranges, but the mean barn temperature in winter was 17.8±3.1°C (Table 2). Housing giraffes in a mixed exhibit with other African species was very common (74% of institutions). The ten most mentioned species were zebra *Equus* spp. (40%), ostrich *Struthio camelus* (31%), eland *Taurotragus oryx* (17%), guinea fowl *Numidae* spp. (10%), oryx *Oryx* spp., (10%), impala *Aepyceros melampus* (6%), gazelle *Gazella* spp. (5%), nyala *Tragelaphus angasii* (4%), roan antelope *Hippotragus equinus* (2%), and addax *Addax nasomaculatus* (2%).

The BCS did not vary with institutional experience (X^2= 0.07, P=0.877; Table 2), group size (rho= 0.11 P=0.109; Table 2; Figure S1), other species on exhibit (X^2=8.22, P=0.387; Table 2), enclosure size (indoor: rho=0.06, P=0.328; total: rho=0.12, P=0.076; Table 2) or mean barn winter temperatures (rho=0.04, P= 0.574; Table 2). The number of feeders and the daily feedings did not correlate with the body condition of the animals, although there was a close-to-significant, positive correlation between the number of feeders and the BCS of senescent animals (rho=0.47, P=0.057; Table 2, Figure 1A).

Feeding regime

The feeding practices are summarised in Table 3 and show that 93% of zoos feed browse in the summer season, which decreased to 84% in the winter season. Over 90% of zoos offered lucerne as hay or fresh forage to the animals, and less than 35% provided grass (or the giraffes had access to fresh grass in the enclosure).

Table 1. Correlation of basic animal information (continent, subspecies, age, sex, reproductive status (for females only) and the body condition as scored by the institution) with the photographic BCS developed by Clavadetscher et al. (2021). The data are summarised for the whole survey population and displayed separately for subadult (less than 4 years old), adult females or males as well as senescent (over 20 years old) animals. The correlation is given as X^2 for categorical data and rho for quantitative data.

		Overall	Subadult	Adult female	Adult male	Senescent
	n	211	27	99	68	17
Continent	X^2	10.92	9.85	3.35	9.14	6.30
	P	0.091	0.0431	0.655	0.104	0.391
Subspecies	X^2	46.79	23.61	46.08	24.58	33.90
	P	0.282	0.260	0.100	0.906	0.285
Age	rho	-0.41	-0.46	-0.33	-0.10	-0.02
	P	<0.001	0.017	<0.001	0.439	0.939
Sex	X^2	3.98	0.70		2.96	1.95
	P	0.680	0.953		0.706	0.922
Reproductive status	X^2	na	na	29.546	na	na
	P			0.0132		
Survey BCS	rho	0.32	0.10	0.42	0.02	0.80
	P	<0.001	0.653	<0.001	0.857	<0.001

na: not applicable or sample size <10

Table 2. Correlation of exhibit information (experience of the institution, group size, housing in mixed exhibit, size of indoor enclosure and enclosure in total, average barn temperature in winter, number of feeders per animal, and the number of feedings per day) with the photographic BCS developed by Clavadetscher et al. (2021). The data are summarised for the whole survey population and displayed separately for subadult (less than 4 years old), adult females or males as well as senescent (over 20 years old) animals. The correlation is given as X^2 for categorical data and rho for quantitative data. The mean±standard deviation is given for enclosure size and barn temperature only.

		Overall	Subadult	Adult female	Adult male	Senescent
		211	27	99	68	17
Experience	X^2	0.073	15.176	22.726	18.647	na
	P	0.877	0.232	0.090	0.545	
Group size	rho	0.1107	0.2298	0.1359	0.0391	-0.3962
	p	0.109	0.249	0.180	0.752	0.115
Mixed exhibit	X^2	8.224	6.687	6.244	3.528	5.991
	P	0.222	0.153	0.283	0.619	0.424
Exhibit size indoors [m²]	rho	0.0638	-0.199	0.090	0.0276	-0.1317
	P	0.328	0.320	0.432	0.826	0.627
	mean±SD	Europe:	307±218	North America:	422±480	
Exhibit size total [m²]	rho	0.1232	0.0001	0.1137	0.058	-0.2641
	P	0.076	0.998	0.265	0.639	0.323
	mean±SD	Europe:	2844±81612	North America:	73500±203269	
Barn temperature in winter [°C]	rho	0.0392	-0.0146	0.0531	0.0216	0.1955
	P	0.574	0.942	0.602	0.863	0.452
	mean±SD	18±3				
Feeders per animal	rho	-0.1333	-0.1954	-0.1463	-0.0765	0.4699
	P	0.053	0.3286	0.148	0.535	0.057
Number of daily feedings	rho	-0.0194	0.1554	0.0203	-0.0506	-0.1891
	P	0.779	0.439	0.842	0.682	0.467

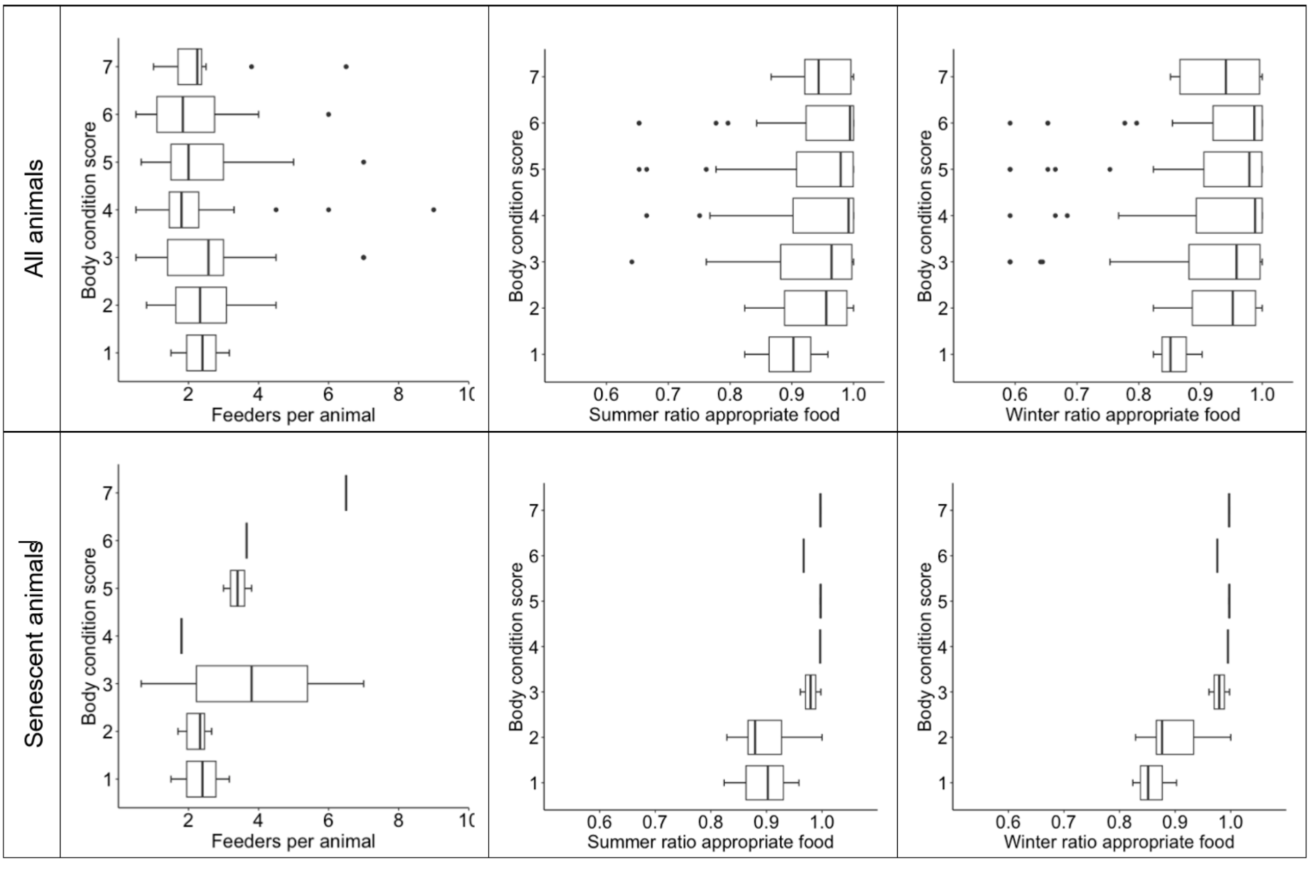

Figure 1. Boxplots summarizing the photographic BCS of zoo-housed giraffes (Clavadetscher et al. 2021) dependent on the number of feeder per animal and the percentage of appropriate food in the summer or winter feeding ration. Appropriate food is defined as ration without high carbohydrate items such as cereals, low-fibre pellets, root vegetables and fruit. The data are given separately for the senescent animals over 20 years of age for which the BCS showed a positive correlation for all parameters displayed here (see also Table 2 and 4).

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Table 3. Feeding practices for zoo-housed giraffes summarised by different surveys throughout the years. The percentage indicates the percentage of institutions feeding a certain diet item. Where available the data are split up into summer and winter feeding plans. For the current survey, the percentage of institutions feeding certain items for ad libitum consumption is given in square brackets.

		Bashaw et al. (2001)[2]	Sullivan et al. (2010)	Hummel et al. (2006)	Gussek et al. (2017)	Bertomieu (2017)	Current study [ad lib.]
Survey year		2001	2004	2004	2013	2016	2019
Geographical reach		North America	North America	Europe	Europe	Europe	Europe and North America
Number of institutions		49	41	70	81	63	89
Browse (fresh, dry, frozen or silage)	S	92%	65%	84%	96%	98%	93% [4%]
	W			53%	86%		84%
Lucerne (hay or fresh)	S	100%	100%	81%	89% (hay)	81%	90% [66%]
	W			43%			94% [67%]
Grass (hay or fresh[1])	S		n.s.	(fresh) 53%	29% (hay)	60%	35% [28%]
	W			n.s.			22% [15%]
High fibre pellets	S	n.s.	n.s.	n.s.	41%	80%	98% [6%]
	W						98% [7%]
Cereals/low fibre pellets	S		32%	n.s.	28%		52%
	W						50%
Fresh green vegetables	S	63%	n.s.	n.s.	85%	11%	48%
	W						52%
Root vegetables and fruits	S						67%
	W						66%

[1]including grazing opportunity, [2]Data including okapi *Okapia johnstoni* and giraffes (giraffes: n=214; okapi: n=29), S: summer, W: winter, n.s. not specified.

Most zoos offered the giraffes a specially formulated browser pellet, and 6% provided these pellets for ad libitum consumption. High starch concentrates ('cereals') were fed by 52% of zoos, and more than half additionally fed a defined amount of fruits and vegetables.

The percentage of appropriate food (= no cereals, no root/tuber vegetables, no fruit) was positively correlated to the BCS of senescent animals (summer: rho=0.54, P=0.026; winter: rho=0.58, P=0.014; Table 4; Figure 1) but not for the overall population. The amount of roughage (lucerne or grass hay) putatively ingested had a negative association with the BCS of the animals (summer: rho= -0.18, P=0.007; winter: rho=-0.11 P=0.102; Table 4; Figure S2), whereas the amount of browse showed a positive correlation with BCS in adult female giraffes in summer (rho=0.24, P=0.019; Table 4; Figure 2). The amount of high-fibre pellets was positively correlated to the BCS in both summer and winter (summer: rho=0.23, P<0.001; winter: rho=0.19, P=0.005; Table 4; Figure 2), whereas the amount of high starch concentrates ('cereals') was negatively related to the BCS in the giraffes (summer: rho=-0.16, P<0.019; winter: rho=-0.16, P=0.021; Table 4; Figure S2), especially in senescent animals (rho = -0.70, P=0.002; Table 4; Figure S2).

Discussion

The survey data from over 200 zoo-housed giraffes showed that the photographic body condition score correlates with some individual-related parameters (age, reproductive status) and with feeding practices, but not with any of the recorded husbandry parameters. The results do not question the fundamentality of providing lucerne hay to giraffes on an ad libitum basis with permanent access, and they support the concept that high-fibre pellets, roughages, browse and green leafy vegetables represent appropriate giraffe diet items, whereas high-starch products, commercial fruit and root/tuber vegetables do not. In particular, feeding giraffes high amounts of browse and high-fibre pellets is beneficial for the BCS, whereas the restriction of high-fibre pelleted feed (with a resulting calculated higher intake of roughages), and the use of cereals and other high starch products including cereal-based pellets, is associated with poorer body condition.

While these survey data offer valuable insight into the status of giraffe nutrition and husbandry, some limitations compared to experimental studies are evident: Survey data only represent a snapshot in time. An animal's body condition can change in

Table 4. Correlation of estimated feeding ratio with the photographic BCS developed by Clavadetscher et al. (2021). The data are summarised for the whole survey population and displayed separately for subadult (less than 4 years old), adult females or males as well as senescent (over 20 years old) animals.

			Overall	Subadult	Adult female	Adult male	Senescent
			211	27	99	68	17
Percentage appropriate food [%] Ration without high carbohydrate items°	S	rho	0.12	0.13	0.04	0.04	0.54
		P	0.073	0.510	0.705	0.777	0.026
	W	rho	0.11	0.01	0.01	0.04	0.58
		P	0.109	0.964	0.930	0.742	0.014
Roughage [kg DM/kg MBW] Lucerne and grass hay	S	rho	-0.19	-0.16	-0.21	-0.18	-0.47
		P	0.007	0.421	0.033	0.300	0.055
	W	rho	-0.11	-0.15	-0.09	-0.17	-0.35
		P	0.103	0.442	0.356	0.174	0.174
Browse [kg DM/kg MBW]	S	rho	0.07	0.12	0.24	-0.02	-0.14
		P	0.284	0.540	0.019	0.866	0.604
	W	rho	0.01	0.02	0.09	-0.01	-0.02
		P	0.985	0.939	0.381	0.990	0.929
High fibre pellets [kg DM/kg MBW]	S	rho	0.23	0.13	0.15	0.26	0.49
		P	<0.001	0.505	0.126	0.035	0.047
	W	rho	0.19	0.16	0.07	0.27	0.47
		P	0.005	0.426	0.475	0.028	0.056
Fresh greens [kg DM/kg MBW] Fresh lucerne, grass and leafy vegetables	S	rho	0.06	0.06	0.03	0.14	0.10
		P	0.400	0.783	0.756	0.262	0.714
	W	rho	0.08	0.12	0.09	0.12	0.11
		P	0.237	0.551	0.364	0.340	0.688
Cereals and low-fibre pellets [kg DM/kg MBW]	S	rho	-0.16	-0.54	-0.04	-0.10	-0.60
		P	0.019	0.003	0.674	0.434	0.011
	W	rho	-0.16	-0.26	-0.06	-0.10	-0.70
		P	0.021	0.193	0.562	0.400	0.002
Root vegetables and fruits [kg DM/kg MBW]	S	rho	-0.05	0.21	0.02	-0.04	-0.11
		P	0.478	0.295	0.853	0.733	0.664
	W	rho	0.01	0.042	0.09	-0.01	0.07
		P	0.996	0.835	0.353	0.976	0.785

°such as cereals, low-fibre pellets, root vegetables and fruit, S: summer, W: winter, kg DM/kg MBW: kilogram dry matter per kilogram metabolic body weight (max. 0.06)

the short term due to higher (i.e., disease, stress, pregnancy) or lower (i.e., confinement) energy requirements, but it usually develops over a more extended period. Determining the actual food intake of a single herbivorous animal of the size of a giraffe is a very time-consuming and work-intensive undertaking. It requires single-housing a social, stress-sensitive species, and weighing large quantities of supplied and discarded food (Clauss et al. 2001; Hatt et al. 2005; Gussek et al. 2018; Kearney et al. 2024). Some assumptions are made when transforming survey answers to kilograms of diet fed per metabolic weight: here, the feeds offered are presumed to be consumed in toto by the animals. For feed items provided for ad libitum consumption, it was hypothesised that giraffes would first eat the browse (Hatt et al. 2005), then cereal concentrates and any fruit and vegetables, followed by high-fibre pellets, lucerne hay and grass hay (Hummel and Clauss 2006). Bulk items such as vegetables and fruits were transformed into weight quantities after weighing representative samples of the corresponding items, assuming some uniformity. As mentioned earlier, these assumptions are standard practice (Flores-Miyamoto et al. 2005; Schiffmann et al. 2018) when analysing feeding rations but reduce the accuracy of the actual feed consumed by an individual giraffe.

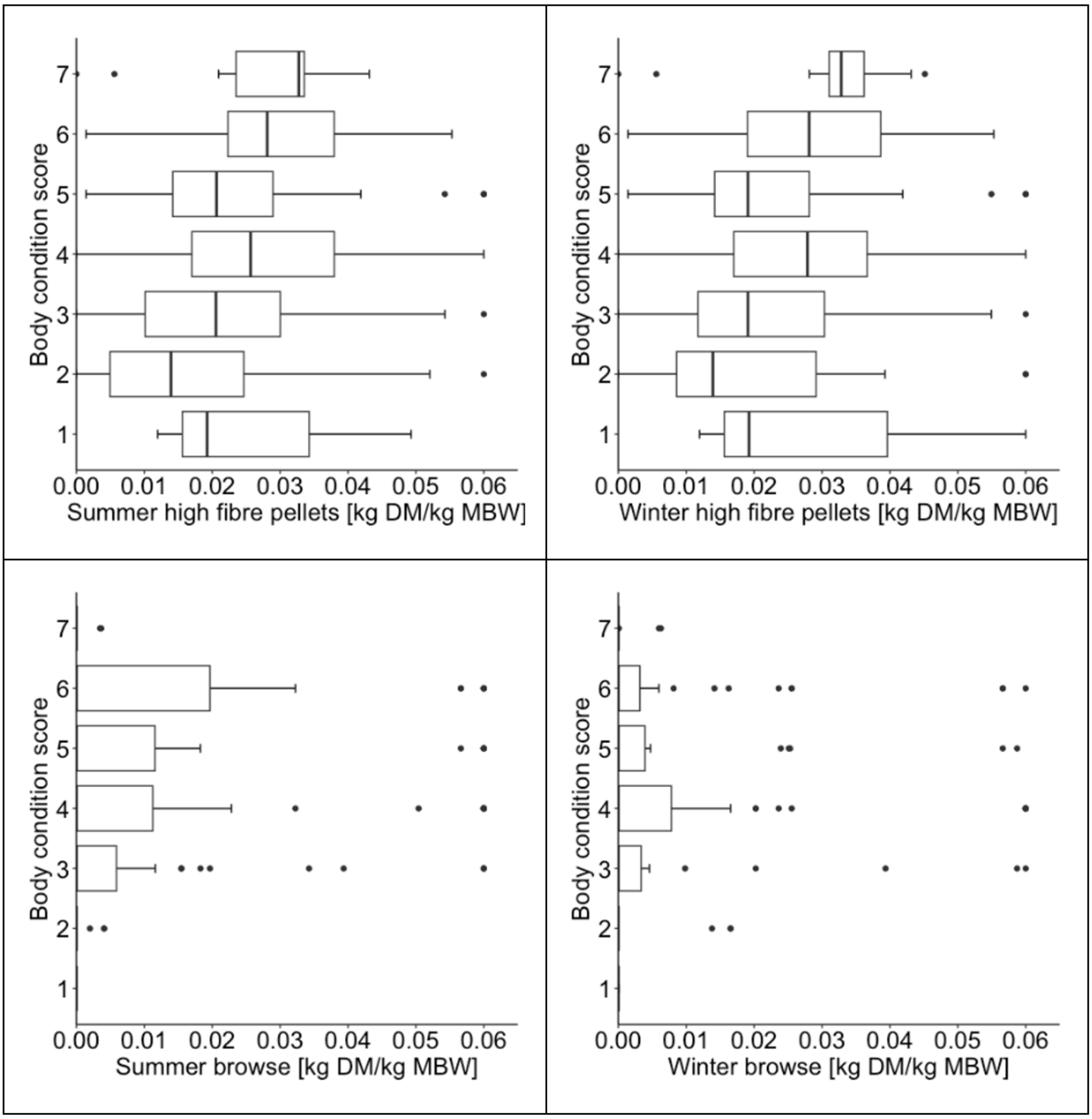

Figure 2. Boxplots summarizing the photographic BCS of zoo-housed giraffes (Clavadetscher et al. 2021) dependent on the estimated intake of high fibre pellets or browse per metabolic weight of the animal in summer and winter. See Table 4 for statistical analysis.

The photographic BCS did not correlate with any of the husbandry parameters analysed, such as keeper experience, group size, enclosure size, environmental temperatures, or number of daily feedings. The only exception was the (weak) association between the BCS and the number of feeders available for senescent animals. This is conveniently explained by speculating that older animals may be more easily kept from feeding stations by animals in prime age and hence benefit particularly from a higher number of possible feeding stations. Looking at the specific example of barn temperatures in winter, the husbandry manual recommends barn temperatures to be maintained around 20°C and with a minimum of 18°C (EAZA Giraffid EEP 2006). Lower temperatures are considered a significant risk factor for increased mortalities due to the fast depletion of energy reservoirs based on the high surface-to-volume ratio in giraffes (Potter and Clauss 2005; Gage 2013), and free access to warm indoor quarters is suggested as one cornerstone of zoo giraffe welfare (Rose 2023). Some giraffes were housed below the recommended temperature range according to the survey results, but the mean barn temperature in this study was 18°C. While current husbandry parameters did not influence the BCS, they can still cause detrimental effects on other aspects of giraffe health, such as hoof overgrowth or malformation due to pivoting in small spaces or inadequate substrate (Dadone et al. 2019), or oral stereotypies depending on the number, daily refilling and complexity of feeding stations (Fernandez et al. 2008; Depauw et al. 2023; Walldén 2023).

Comparing the current survey results with similar studies performed over the years across EEP-guided giraffe facilities, the feeding management has changed continuously (Table 3): The existing literature agrees that browse should be the mainstay of giraffe nutrition both for nutritional and behavioural benefits (Bashaw et al. 2001; Hatt et al. 2005; Clauss et al. 2007; Clauss and Dierenfeld 2008; Valdes and Schlegel 2012; Bertelsen 2015; Schüßler et al. 2017). Offering browse in addition to a diet of lucerne hay and a high-fibre pellet increased the voluntary energy intake in zoo giraffe (Hatt et al. 2005), which corresponds to the positive effect of browse provision on the body condition of adult females in the present study. The results by institution reflect the difficulties in obtaining browse, even though the percentage of zoos offering browse to giraffes has increased over the years. Differentiating between summer and winter, however, shows that less zoos can provide browse to the giraffes in winter, and only 4% of institutions state that they feed their giraffes with browse ad libitum in summer. To increase the availability of browse, many options have been suggested (Fidgett 2023), from storing fresh leaves as silage or hay to freezing branches (Hatt and Clauss 2006; Nijboer et al. 2006; Przybyło et al. 2020; Lasek et al. 2021). Collaborating with public park management agencies or gardening companies can also help to increase the supply while remaining mindful of toxic plants (Valdes and Schlegel 2012). While it is a common theme in communication within the zoo community that acquiring browse is difficult (M. Clauss, pers. obs.), it should be kept in mind that outside of this community, the decision to keep a species in the absence of capacities to provide its most natural food may be less easy to communicate.

With browse being limited, the main roughage on feeding plans for giraffes is lucerne, whereas grass plays only a minor role. The role of grass – fresh or dried – has been repeatedly discussed in giraffe nutrition (Hummel and Clauss 2006). Some of the chemical properties of grass, such as fibre components, fermentation characteristics and secondary plant compounds, are fundamentally different from browse (Clauss and Dierenfeld 2008). Grasses – including bamboo – are far higher in plant silicates that act as powerful abrasives, regardless of whether they are contained in fresh, ensiled or dried grass or other grass-related products such as grass meal, bran or hulls of cereals as ingredients in compound feed (Clauss et al. 2007; Müller et al. 2014; Martin et al. 2019). These phytoliths have been suspected to cause the abnormally high dental wear in zoo-housed giraffes compared to their wild counterparts (Clauss et al. 2007). Compared to previous surveys (Table 3), zoos seem to have adapted to these research findings as the number of institutions feeding grass in any form is markedly smaller. Hopefully, this number will further decrease in the near future. However, the inclusion of grass products or cereal hulls in pelleted compound feed marketed for giraffe is still common practice (M. Clauss, pers. obs.), and it is recommended that zoo managers base their choice of a pelleted product also on the absence of these ingredients.

Although chemically different from browse, alfalfa and lucerne more closely resemble browse regarding physical properties, and these are included in the feeding plans for giraffes across many institutions (Table 3), in accord with current recommendations (Hummel and Clauss 2006; Valdes and Schlegel 2012; Rose 2023). Feeding experiments, however, have suggested that giraffes cannot reach their energy requirements on a lucerne-hay-only diet (Hatt et al. 2005). This matches the observation of the present study that a higher estimated intake of roughage was associated with a reduced body condition overall (Table 4), with the evident conclusion – stated repeatedly in the zoo giraffe literature – that the additional provision of a pelleted compound feed is necessary (Hatt et al. 2005; Hummel and Clauss 2006; Valdes and Schlegel 2012; Rose 2023). Historically, tuber and root vegetables as well as fruits have been added to the diet plans of giraffe, even though it has been known for a long time that these products do not resemble natural diet items of this (or many other herbivore) species (Oftedal and Allen 1996; Schmidt et al. 2005; Clauss and Dierenfeld 2008; Schwitzer et al. 2009). For hoofstock like giraffes, the feeding of commercial fruit is clearly not recommended (Lintzenich and Ward 1997; Hummel and Clauss 2006). The fact that more than half of the responding zoos are feeding these items matches the observation of Fens and Clauss (2024) that, in spite of an absence of proven benefits and a number of nutritional, biological, didactic and financial reasons against the use of commercial fruit, some unspecified, potentially cultural motivation seems to induce many zoos to continue using these items.

Historically, any pelleted compound feed has been labelled 'concentrate', and associated feeding recommendations of several restricted, small portions distributed across the day reflect the perception that these feeds represent a danger to the health of the ruminant digestive system (e.g. Rose 2023). However, it is important to treat this group of feeds in a differentiated manner, which is why they were separated into high-fibre (and hence low-starch) and low-fibre (and hence typically high-starch) products in the present study.

Pelleted compound feeds consisting of mainly starchy ingredients, reminiscent of production animal feed used in agricultural settings, may be labelled 'concentrates', and warnings against the inherent danger of triggering acidosis are justified (Ritz et al. 2014). These energy-dense diets have been linked to numerous health conditions in giraffes, from rumen acidosis (Clauss et al. 2002) and laminitis (Hummel et al. 2006) to urolithiasis (Sullivan et al. 2010). Therefore, the finding that about half of the responding zoos still used this group of feeds and thus does not conform to current feeding recommendations is remarkable. The negative association of the proportion of this group of feeds with the body condition would, on the one hand, match the expected negative health effects; on the other hand, it might stem from the attempt to provide animals whose body condition deteriorated for other reasons with energy-dense feed. If this was the case, the use of these feeds evidently did not compensate for the low body condition across the population under study here.

By contrast, there has been a historical development of an increasing variety of pelleted compound feeds specifically designed for zoo herbivores, which are not based on starchy ingredients but on high-fibre products such as lucerne meal (Clauss and Dierenfeld 2008). To call these feeds 'concentrates' appears counter-productive, as they have been specifically designed to not have the negative effects of 'concentrates'. They contain high fibre levels and hence a low energy density that cannot be reconciled with the concept of a 'concentrate'. These fibre levels should, theoretically, preclude acidosis, and some of these feeds even contain a buffer substance such as sodium bicarbonate that provides an additional safety against acidosis (Clauss and Dierenfeld 2008). Due to their high fibre content and low energy density, one would not assume (nor want) a particularly eager consumption of these products, but a balanced choice between them and the forages provided in parallel. Therefore, rather than treating these compound feeds as items to be offered in limited amounts at specific time points (and hence make them 'valuable' to the animals), it might be considered more prudent to offer them continuously for ad libitum consumption and hence avoid a fast ingestion of large amounts in a short time period. In the present study, the amount of high-fibre compound feed offered was positively related

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to the giraffes' body condition, providing tentative empirical support for this feeding concept. Offering a high-fibre pelleted compound feed continuously for ad libitum consumption appears in contradiction with generic recommendations for the feeding of hoof stock stating that only 30-40% of the total dietary intake should consist of pellets (Lintzenich and Ward 1997); it must be remembered, however, that these recommendations are based on combinations of forages (hays) with a low-fibre, not a high-fibre pellet. For herbivores like giraffe, in which low body condition and difficulties in providing adequate forages are more relevant issues than obesity, permanent access to a safety feed (such as a high-fibre compound feed) appears a logical feeding approach. These feeds should be provided in ways that the giraffes cannot 'dip in' their snouts and grab larger amounts with their lips, but have to use their tongues to extract all of their food – not just some 'enrichment items' – from 'slow feeders' (Depauw et al. 2023; Walldén 2023). This does not only increase the behavioural value of the diet but also ensures an even food intake across the day.

Conclusions

Based on the findings of this study, continuous ad libitum access to high-fibre pellets might be the most beneficial change alongside maximising browse provision to increase the body condition of giraffes in managed care. An inherent benefit of high-fibre pellets is their year-round availability, standardised ingredients, and nutrients. If they are lucerne-based and do not contain grass products, bran or hulls of cereals, the dental abrasion should be similar to that of lucerne hay or browse. Obviously, a change to such a feeding regime should be slow and gradual, and should best include close monitoring and documentation, not only of weight and body condition changes but also of other welfare parameters. It would also be a chance to revisit how pellets are offered and instigate a feeding regime in which giraffe must use their tongue continuously, and not only for selected enrichment items.

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