40 apples a day doesn't keep the vet away...

A revision advice for the European nutrition guideline for okapis in captivity

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A revision advice for the European nutrition guideline for okapis in captivity

In cooperation with Joeke Nijboer, Rotterdam Zoo

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Prologue

As a completion for the study of Animal Management, a final thesis is performed focussing on the chosen majors within this study. In our case this involves ‘Companion Animal Management’ and ‘Wildlife Management’. This study will give an advice for the soon to be revised European nutrition guideline for okapis in captivity. First of all, this study is meant for those involved in creating the revised European nutrition guideline for okapis in captivity. Secondly, it is meant for those who are interested in the diet of okapis in nature and captivity, secondary plant components in the diet of the okapi, nutritionally related health problems in captivity and the present captive okapi diet in European zoos.

This final thesis is established with the help and effort of many people. We would like to take the opportunity to thank those who were involved in this final thesis.
First of all, our supervisors Tjalling Huisman and Alice Buijsert from Van Hall Larenstein in Leeuwarden and Joeke Nijboer from Rotterdam Zoo in Rotterdam. Kristin Leus, Bruno van Puijenbroeck, Francis Vercammen and Patrick Immens from Antwerp Zoo and Jurgen Hummel for involving us in this okapi project and giving us more background information. Dick Kuiper and Fred Wichers for helping us with the hay and concentrate analysis at Van Hall Larenstein. And everyone who cooperated with the questionnaire held for this final thesis.

Last but certainly not least, we would like to thank each other for keeping up the good spirit.

Dafna Azulai & Kim Engelhart
Leeuwarden, March 2007

Summary

Keeping exotic species in captivity, like the okapi (*Okapia johnstoni*), is often problematic, especially concerning their nutrient requirements, since these per se have not been studied. The association of diets of okapis and some health problems in captivity has often been speculated. In 1998 a research on okapi nutrition was held in several European zoos which have okapis in their collection. Among other information, the results of this research were used to establish the European nutrition guideline for okapis in captivity in 2001. Since 1998 more insight has been gained concerning okapi nutrition. Therefore the main objective of this final thesis assignment was to create an advice to improve the diet for okapis in captivity, using insights gained after 1998.

In order to realize this objective, the following main question has been answered;

- In what way do the feeding practices need to be altered in order to meet the nutritional requirements for okapi's in captivity?

The sub questions which are relevant in this case are;

- What is the nutritional and ingredient composition of the diet for okapis in the wild?
- What is the current nutritional and ingredient composition of the diet for okapis in captivity and what are the main differences from the known diet in the wild?
- How can the differences between the natural diet and the diet in captivity for okapis be used in order to explain occurring health problems among okapis in captivity?

Okapis appear to be very selective browsers in nature. The nutritional composition of the diet of okapis in nature contains 44,7% NDF, 34,8% ADF and 15,3-16,4% CP on dry matter (DM) basis, within a diet that consists of more than 150 types of browse species. A lot of browse species contain secondary plant components which seem to have no negative effects in nature, but when single browse species are offered in a very high amount in captivity, their secondary plant compounds can cause damage or even become lethal.

In 1998, the okapi diets in captivity mainly consisted of fruits & vegetables and Lucerne hay and the average nutritional composition of the diets consisted of 15,4% CP, 24,8% NDF and 15,3% ADF. Following from post-mortem reports, some common health problems with okapis in captivity were noticed. These health problems seem to be nutritionally related and comprise rumen acidosis, laminitis, kidney damages, glucosuria and obstructions of the gastrointestinal tract.

In order to get information about the current okapi feeding (practices), a questionnaire (2006) has been send to all 18 European zoos that have okapis in their collection. The 12 returned questionnaires showed that 8 zoos were satisfied with the nutrition guidelines of 2001. Also the okapi diets still mainly consist of Lucerne hay and fruits & vegetables and the average nutritional composition of the okapi diets contain 16,5% CP, 33,1% NDF and 21,3% ADF. The most common health problem with okapis appears to be hoof problems. Finally most zoos were satisfied with the Body Condition Score (BCS) system and most okapis (34 out of 42) were scored with a BCS of 3 on a scale of 1 to 5.

When discussing the results from the questionnaire and the literature research, it appears that most zoos do not follow the nutrition guidelines of 2001 concerning both the recommended ingredient composition and the nutritional composition of the diet, even not the zoos that were satisfied with these nutrition guidelines.

The main differences between the natural diet and the captive diet are the NDF and ADF percentages and the high amounts of fruits & vegetables and Lucerne hay in the captive diet. Also a possible relation could be found concerning zoos that experience(d) hoof problems with their okapis. These zoos offer more fruits & vegetables and concentrates (which means a higher level of easy digestible carbohydrates) compared with zoos that don't experience(d) hoof problems with their okapis. Also the okapis with hoof problems had a higher average age than the okapis without hoof problems. Finally, a possible relation was speculated between the type of browse offered in captivity and the appearance of kidney damages (by willow) and obstructions of the G.I. tract (by *Robinia pseudoacacia*).

From these results and the discussion, the following new advice resulted:

- Fruits and vegetables are reduced to 0 percent of the total diet.
- A minimum of 15% browse in the DM diet should be offered and at least two different browse species every day.
- A minimum of 55% Lucerne hay in the DM diet should be offered.
- A maximum of 30% concentrates and beet pulp of the total DM diet should be offered. Concentrates and unmolassed beet pulp should be fed in a ratio respectively 1:1,5, which translates into respectively 10-12% concentrates and 18% unmolassed beet pulp.

Content

Chapter 1, Introduction

1.1 Keeping okapis in captivity

Feeding exotic species in captivity, like the okapi (*Okapia johnstoni*), is often problematic, since their nutrient requirements have not been studied. This is partly because there is little knowledge about these subjects and partly because of practical limitations. (Leus et al, 1996; Hummel et al, 2003; SSP Feeding guidelines, Crissey et al, 2001). The association of diets of okapis and some health problems in captivity have often been speculated (Dierenfeld, 1996).

One way to improve the wellbeing of okapis in captivity is to keep improving the diet of these animals in order to meet their specific nutritional requirements. These nutritional requirements are derived from the information available from the feeding ecology of okapis in the wild, as well as physiological parameters, domestic animal nutrient requirements, related species nutrient requirements, nutrient content of ingested food and physiological assessment data (Body Condition Score) (Jansen and Nijboer, 2003).
At this moment, 54 okapis are held in 18 different zoos across Europe.
(Leus, International Okapi Studbook, August 2006). From the position of the European Endangered Species Program (EEP) it is advantageous to set up one general nutrition guideline for a species. This contributes to a part of the EEP objective for the future management of the EEP species, in this case the okapi. (http://www.eaza.net/EEP)

1.2 European nutrition guideline of 2001 for okapis in captivity

In 1998, a research on okapi nutrition was done (Boon et al) among several European zoos that have okapis in their collection which was supervised by Joeke Nijboer. All these zoos are participants of the EEP for okapis. The zoos that participated were situated in Berlin, Basel, Wuppertal, Cologne, Stuttgart, Antwerp, Winchester and Rotterdam. Among other information and data, the results of this research were used to establish the European nutrition guideline for okapis in captivity in 2001 (Boon et al., 1998, Crissey et al., 2001).

The following diet was recommended:

Table 1: *Recommended nutrient profile (DM basis) for okapi diets in captivity*

Nutrient	Value range
Protein %	17-20
NDF %	20-35
ADF %	13-18
Calcium %	0,7-0,97
Phosphorus %	0,36-0,40
Magnesium %	0,18-0,24
Potassium %	1,6-1,8
Zinc mg/kg	54-68
Copper mg/kg	10-12

(Feeding guideline for okapis, Crissey et al., 2001)

1.3 Health problems with okapis

Since 1998, further research has been performed focusing on the different aspects of okapis in the wild as well as in captivity. One of these aspects are health problems that occur to okapis in captivity (Post mortem reports European okapis until 2006, Antwerp Zoo archives; Hummel, 2003). These health problems are possibly nutritionally related and comprise:

- Kidney abnormalities e.g. tubulointerstitial nephropathy, following from post-mortem reports. Salicylic acid is an anti-nutritive substance, which can be present in certain plant parts from e.g. willow (*Salix sp.*). Okapis from German zoos that have been examined during autopsy and showed tubulointerstitial nephropathy, had access to feed containing leaves and twigs of willows. An accumulation of salicylic acid has therefore been considered as a possible cause of tubulointerstitial nephropathy (Haenichen, 2001).

- Glucosuria; a high level of glucose in the urine of healthy adult okapis has been reported in 1980 (Glatston and Smith, 1980). In 2003, a routine urine analysis has been carried out on eleven healthy okapis with varying urine glucose results. The appearance of glucosuria in apparently healthy okapis remains unexplained (Vercammen, et al., 2003).

- Rumen acidosis; a diet including little fiber and high amounts of easily digestible carbohydrates may lead to digestive problems in ruminants. Rumen acidosis is one of these problems, causing damage to the rumen mucosa or even death of the animal (Hummel, 2003).

- Obstructions of the gastrointestinal tract and bezoars; due to highly lignified forage, the okapi can get problems digesting its food. This may cause the obstructions in the rumen. (Crissey, et al., 1999).

- Laminitis; like many other captive ungulates, the okapi regularly experiences hoof problems, like laminitis. This is a serious problem since okapis can not easily be trimmed without using anesthesia and complications may occur during anesthesia, which can result in mortality (Sikarskie et al., 1988, Leus and Puijenbroeck, 2000).

Amongst other subjects, this report intends to combine all the insights in the relation of these health problems to nutrition, along with its cause(s), effects and more important, its prevention, gained from literature since 1998. With this knowledge, diet adjustments can be proposed to the current feeding situation in European zoos, possibly contributing to a revised European nutrition guideline for okapis in captivity.

1.4 Objectives and research questions

As mentioned earlier, one way to improve the wellbeing of okapis in captivity is to keep improving the diet of these animals in order to meet their nutritional requirements. This means that all of the information gained from research, questionnaires focusing on the okapi and every related aspect needs to be combined again to form a revised European nutrition guideline for okapis in captivity.

Therefore the main objective of this final thesis assignment is;

- Creating an advice for the improvement of the European diet for okapis in captivity, using insights gained after 1998.

In order to realize this objective, the following main question needs to be answered;

- In what way do the current feeding practices in European zoos need to be altered in order to meet the nutritional requirements for okapis in captivity?

The sub questions that are relevant in this case are;

- What is the ingredient and nutritional composition of the diet for okapis in the wild?
- What is the current ingredient and nutritional composition of the European diet for okapis in captivity and what are the main differences from the diet in the wild and the nutrition guideline of 2001?
- How can the differences between the natural diet and the diet in captivity for okapis be used in order to explain occurring health problems among okapis in captivity?

1.5. Contents of this report

This report consists of 7 chapters. After Chapter 1, this introduction, Chapter 2 will cover literature research about the wild situation of the okapi, covering a description of the okapi and an ingredient and nutritional composition of the okapis' natural diet. Chapter 2 will also cover the captive situation of the okapi with the ingredient and nutritional composition of the okapis' current diet in captivity and nutritionally related health problems of the okapi. Chapter 3 will cover the methods used during this research in order to answer the sub-questions and eventually the main question. In Chapter 4, the results of the questionnaire (November 2006) are shown, Chapter 5 will cover the discussion, where several possible relations between the results will be proposed and discussed. Chapter 6 and 7 will cover respectively the conclusion and the recommendations to revise the nutrition guideline of 2001. The appendices (See enclosed CD-Rom) will cover documents and data that are too extensive for the report itself.

Chapter 2, The okapi

The first part of this chapter focuses on the situation and diet of the okapi in the wild. The second part will deal with the situation and diet of the okapi in captivity. This will give a good view of the differences between these two situations, especially concerning the diet. After that, information will be given concerning secondary plant components, and finally an attempt is made to find a relation between some frequently occurring health problems with okapis in captivity and nutrition.

2.1 The okapi in the wild

This part will start with a description of the okapi; its taxonomy, general characteristics, reproduction, a description of the gastrointestinal tract and the okapi's digestive strategy. After that will be proceeded with the known diet composition of the okapi in the wild, divided into ingredient and nutrient composition.

Description of the okapi

The okapi (*Okapia johnstoni*) is one of the few large ungulates living in the Ituri rainforest of the Democratic Republic of Congo (former Zaire). Because of the remoteness of their habitat, as well as their elusive behaviour, the species was only discovered in the beginning of the 20th century by Sir Harry Johnston. Their natural habitat consists of dense lowland rainforest. Okapis appear to be very selective browsers with a preference for high quality, fresh foliage tips from certain light dependent plants and trees mostly found in tree-fall gaps or along the edges of larger clearings (Hart and Hart, 1988). The prehensile tongue of the okapi, allows it to browse on the more highly digestible portions of plants. The okapi is a ruminant; its digestive tract consists of a voluminous, highly compartmentalized stomach, which allows fermentation and digestion of roughage (Stevens and Hume, 1995, Crissey et al., 1999). The natural population is estimated on 25.000 individuals. The okapis' conservation status is determined at a lower risk. (**http://www.sandiegozoo.org/animalbytes/t-okapi.html**)

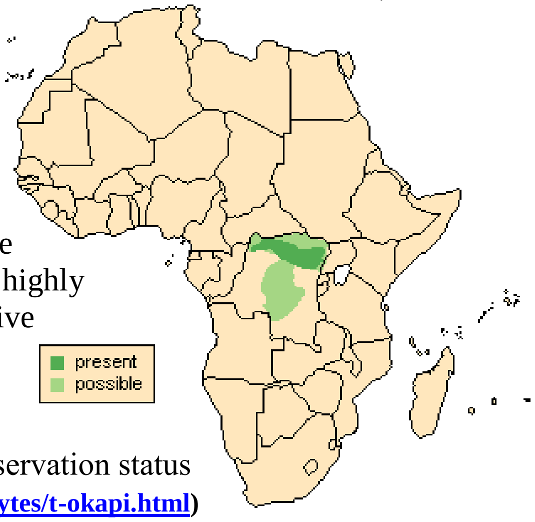

Figure 1. Okapi habitat
(source picture: **http://www.ultimateungulate.com/Artiodactyla/Okapia_johnstoni.html**)

Taxonomy of the okapi

Kingdom:	Animalia	(Animals)
Phylum:	Chordata	(Higher animals)
Class:	Mammalia	(Mammals)
Order:	Artiodactyla	(Even-toed ungulates)
Family:	Giraffidae	(Giraffes)
Genus:	*Okapia*	
Species:	*johnstoni*	

(http://www.ultimateungulate.com/Artiodactyla/Okapia_johnstoni.html)

General characteristics

The velvet-like coat is generally dark chestnut-brown or purplish red in colour, with a distinctive pattern of horizontal stripes, much like those of a zebra, on the upper legs. The lower legs are white, with dark patches at the joints. The horse-like head is generally lighter in colour, with a black muzzle, and is supported by a thick neck. The ears are large, and the black tongue is long and prehensile. The body is sloped, with the forequarters much higher than the rear. Males have two skin covered 'horns' or knobs on the forehead which develop between one and five years of age.

Fig. 2: Okapi, Rotterdam Zoo
(© Dafna Azulai, 2006)

Head and body length is about 200-210 cm (6.6-7 ft.), shoulder height is 150-170 cm (5-5.6 ft.) and tail length measures up to 30-42 cm (12-16.8 in.). Females are larger than males and they weigh more. Males weigh 440 to 660 pounds (200 to 300 kilograms) and females weigh 495 to 770 pounds (225 to 350 kilograms).

**(http://www.sandiegozoo.org/animalbytes/t-okapi.html/
http://www.ultimateungulate.com/Artiodactyla/Okapia_johnstoni.html)**

Reproduction

Okapis are found alone, in pairs or in small family parties, but never in herds. Young are born from August to October, which is the period of maximum rainfall. Expectant mothers retreat into dense forest to give birth, after which the newborn lies hidden for several days. The head and body length of the single offspring is 79 cm and it weighs 16 kg. at birth. The young start to nurse within six to twelve hours. The young do not seem to imprint on their mothers, and have been observed nursing from two different females. According to Gijzen and Smet (1974), estimated gestation is 425 to 491 days.

Females attain sexual maturity at the age of 1 year and 7 months. The lifespan of an okapi can be over 30 years in captivity (Nowak et al., 4th edition).

The digestive tract of the okapi

The digestive tract of the okapi is characterised by several morphological parameters. In a study by Clauss et al. (2006), anatomical measurements were performed on a euthanized okapi in captivity and supplemented with and compared to further information on two okapi forestomachs and other anatomical data on okapis from literature. This study describes that the digestive tract contains a comparatively small reticulorumen (wet contents 9,8% of body weight) with weak rumen pillars (thickness being 7-10 mm). The reticular honeycomb structure is quite shallow with reticular crest height being 1-2 mm. The omasum is stated to appear small for a ruminant, measuring a curvature of 28-33 cm, and long papillae cunguiculiformes have been found in one forestomach. These long papillae have not always been a consistent finding. The ratio of the length of the small and large intestine was low, 1.3-1.8. The liver was relatively large, weighing 3,6 kg, which is 1,56% of body weight. The protozoa in the forestomach consist mainly of the *Entodinium* species.
All of the parameters mentioned above apply to the classification of a browser as according to Hofmann (1989).

The digestive strategy of the okapi

From the early seventies onwards, research was published on the digestive strategies of ruminants by R.R. Hofmann. He discovered that there are physiological and anatomical adjustments of the digestive tract that influence the food preference of ruminants. The differences can be seen in the capacity of cell-wall digestion, the feed passage rate and the forage- and cud chewing frequency. According to Hofmann, ruminants can be divided into three groups; the browser (concentrate selector), the grazer (bulk and roughage feeders) and the intermediate (mixed feeders).
All of the parameters mentioned under “The digestive tract of the okapi” above were compared to the ruminant feeding type classification by Hofmann (1989), and conclusively it places the okapi in the ruminant feeding type of a typical selective browser.
In foregut fermenters, the retention of food in the digestive tract takes a long time, explaining why the digestibility of their food is so high (Hummel et al., 2003). The okapi is also a foregut fermenter, but the smaller rumen of okapis should allow indigestible food particles to flow more rapidly through the tract than average for foregut fermenters. This more rapid flow should promote a higher food intake (Shipley, 1999). Foregut fermenters are also able to make more efficient use of the bacteria in their fermentation chamber because this is situated in front of the real stomach and small intestine (Hummel et al., 2003). The small forestomach capacity and the lack of strong reticulorumen muscles could explain why okapis avoid grass forage under natural conditions (Clauss et al. 2003).

Ingredient and nutritional composition of the okapis' natural diet

The exact ingredient and nutritional composition of the natural diet of an okapi is still not completely known. According to Hart et al. (1989), the diet of a wild okapi is composed almost entirely of the leaves of dicotyledenous plants of the shady forest understory. Research has been done by Hart et al. (1989) to determine the composition of the natural diet of the okapi by following the animal(s) in their natural habitat and noting every single species of browse consumed by the okapi. About 150 species of plants are known to be browsed in total (See appendix 1 for a selection of these species), approximately 30-35 different species are eaten per day. This feeding strategy prevents the same types of secondary plant components from building up in the organs of the okapi. Okapis have not been observed eating fruits.

As mentioned earlier, okapis are very selective feeders and diets are very diverse, with no species comprising over 20% at any time of the year. Most browse species contain less cell wall, and fibers within their cell wall are more lignified and indigestible than grass. Browse species tend to have more phenols, including tannins which can reduce protein digestibility, terpenes that can reduce dry matter digestibility, and toxins such as alkaloids (Robbins, 1993). Wild okapis are known to consume foliage with a high phenolic content, and okapis often have dark reddish urine, associated with high phenolic intake (n.n.).
The only known nutritional composition of the okapis' natural diet is listed below in table 2:

Table 2: *Diet composition of okapis in the wild on dry matter basis*

Analysis	**Hart, 1989**
Intake	23,5 kg
DM Intake	4,1 kg (17,4%)
DM Intake as % of bodyweight	1,6-2,4%
	Percentage
NDF	44,7
ADF	34,8
ADL	19,3
CP	15,3-16,4
Available protein	12,0-12,9

(Feeding guideline proposal for okapis, Crissey et al., 2001)

In another research, Hart et al. used 8 to 10 okapis taken from the wild which were held in the IZCN Station d'Épulu, Congo, where they were used in preference trials and intake and digestion tests. Foliage preference was researched by offering these okapis 12 to 15 types of browse at a time in cafetaria style. Five common forest monocotyledonous species (grasses) were also used, all of which are avoided by okapi in the wild (Hart et al., 1989).

(Some) of the browse species have been nutritionally analysed and outcomes averaged to get an idea of the nutritional composition of the okapis' natural diet. Nutritional analyses were conducted on 16 dicot foliage species (See table 3). This showed that strongly preferred foliage had the lowest average neutral detergent fibre (NDF) and acid detergent fibre (ADF) values, while both avoided dicots and monocots had the highest levels. Also the soft, young leaves were more preferred than the hardened, fully expanded leaves. In dicot foliage, the lignin levels were negatively correlated with preference.

Total crude protein (CP) levels were not correlated with preference. Daily dry matter (DM) intake of the experimental diets averaged 2% of body weight. Plant cell wall (NDF) intake averaged almost 2 kg per day, while total CP levels averaged 0.56 kg per day. Overall apparent DM digestibility ranged from 67 to 72 % across experimental animals. Digestibility was correlated with body size, with the two smaller sub adult animals included in this study having lower apparent DM digestion than larger individuals. Digestibility of plant cell wall (NDF) ranged from 53 to 57 percent, while that of the fermentable components, hemi cellulose (average 77%) and cellulose (average 70%) was higher (Hart et al., 1989).

Table 3: *Nutritional composition of foliage used in captive okapi preference trials*

Species	**Preferences**	**DM**	**Ash**	**CP**	**NDF**	**ADF**	**ADF-CP**	**LIG**
Rinorea oblongifolia	++	30,8	8,4	16,1	44,2	31,8	2	7,9
Tremma guineensis	++	29,3	11,5	21,4	29,2	25,1	2,1	6,3
Macaranga monandra	++	37,6	7,7	17,5	31,7	26,6	2,6	6,1
Aidia micrantha	++	34,4	8,4	14,5	43	38,6	4,9	19,2
Ricinodendron heudelotii	++	23	11	30,3	26,7	23,2	1,9	6,3
Macaranga spinosa	++	39,9	5	15,2	29,2	23,8	1,9	5,4
Diospyros bipendensis	+	36,3	7,2	19	45,7	35,1	1,8	13
Manniophyton fulvum	+	30	6	15,1	45,8	39,1	2,9	13,7
Cleistanthus michelsoni	+	44	4,7	11,6	46,6	38,3	2,7	14
Celtis mildbraedii	+	36,1	10,9	25,8	46,5	33,1	2,5	10,3
Trichilia rubescens	+	28,2	6,6	13,2	40,3	38,4	4,1	20,5
Pseuderanthemum ludovicianum	+	13,9	14,2	29,9	35,5	25,6	2,4	5,9
Albizia gummifera	0	33,2	4,5	27	60,1	51,2	7,7	28,7
Drypetes sp 1	0	29,9	10	15,1	61,2	45	5,6	17,3
Ageloea macrophylla	0	38,9	4,8	17,2	45,6	52,9	5,8	23
Dasylepsis seretii	0	33,5	8,5	13	52,5	39,6	2,5	11,3

Composition given in percentage dry matter basis. Values shown are mean.
DM= Total Dry Matter
CP= Crude Protein (Total Nitrogen x 6,25)
NDF= Neutral Detergent Fiber
ADF= Acid Detergent Fiber
ADF-CP= Acid Detergent Fiber bound Crude Protein
LIG= Lignin
(Hart et al, 1989)

The mean nutritional values for the preferred and avoided species are shown in table 4 below.

Table 4: *Foliage preferences of captive okapi: Average nutritional composition*

Selection	**Nr. Plant Species**	**DM**	**Ash**	**Total CP**	**NDF**	**ADF**	**ADF-CP**	**LIG**	**Free CP ADF**
Strong Preference	6	32,5	8,7	19,1	34	28,1	2,4	8,5	0,65
Variable preference	6	31,4	8,3	19,1	43,4	35	2,7	12,9	0,51
Avoided	4	33,6	7	18,1	59,8	47,1	5,4	20,1	0,27
Avoided monocots	5	22,4	8,7	16,6	69,9	41,5	3,3	9,1	0,32

Composition given in percentage dry matter basis. Values shown are mean.
DM= Total Dry Matter
CP= Crude Protein (Total Nitrogen x 6,25)
NDF= Neutral Detergent Fiber
ADF= Acid Detergent Fiber
ADF-CP= Acid Detergent Fiber bound Crude Protein
LIG= Lignin
Free CP= CP minus ADF-CP
(Hart et al., 1989)

2.2 Secondary plant components of willow (*Salicadeae*) and the possible effects on okapis

The majority of European zoos offer their okapis different species of plants and trees as browse. Willow is one of the main browse species that are offered to okapis in zoos (Resulting from questionnaire 2006). Willow belongs to the family of *Salicadeae* and the genus *Salix* consists of 44 specimens and many hybrids (Palo, 1984). A closer look at the different secondary plant components within the family of *Salicadeae* is needed in order to gain insight in the influences of these components in okapis. Certain secondary plant components characteristic to the willow are suspected of causing negative effects on the digestive tract and health of okapis, such as chronic tubulointerstitial nephropathy and renal lesions (Haenichen et al., 2001). Because most of the studies on secondary plant components and their effects on animals are not directly related to the okapi itself, focus will also be on studies performed on other (related) ruminants or other mammals.

Secondary plant components in the willow family Salicadeae

Secondary plant components are used by plants as chemical defense mechanisms (van Genderen, 1997). Secondary plant components can be divided into three groups; the terpenes, the nitrogenous compounds and the phenols (Kool & Smit, 2000, Taiz & Zieger, 1991). The terpenes and nitrogenous compounds will not be dealt with in this chapter, because they do not occur in the family of *Salicadeae* (Van Genderen et al, 1997). Salicaceous plants produce a wide variety of phenols such as phenolic glycosides (salycilates), together with a high concentration of condensed tannins (Julkunen-Tiitto and Sorsa, 2001). Phenolic glycosides and tannins are characteristic to the family of *Salicaceae*, since they are present in all species of willow to a certain degree (van Genderen et al, 1997).

Phenolic glycosides

Phenolic glycosides in willows function as defense mechanisms against herbivores and pathogens. Phenolic glycosides characteristic to willows are salicin and salicortin. **Salicin** is the glycoside of salicylic alcohol and saligenin and the derived salicylates. Another related phenolic glycoside is an ester of salicin; **salicortin**. Salicortin and its derivates are labile compounds that degrade immediately when cell compartmentalization is ruptured, producing salicin and 6-hydroxycyclohexenon under the influence of esterase (Ruuhola et al., 2003). Other phenolic substances are salicylaldehyde, gentisine-alcohol and gentisinic acid. All of these phenolic components occur in bark as well as twigs and leaves of all species in the family, but often in small amounts and never as the main glycosides (Palo, 1984).

Negative effects of phenolic glycosides

In general, growth of herbivores appears to be reduced by phenolic glycosides, such as salicylates, in three ways: by feeding deterrence, by reducing the nutritive value of plant parts or through toxicity (Ruuhola, Julkunen-Tiitto and Vainiotalo, 2003).

For the salicylate salicin, it is known that it causes a bitter taste and it is considered toxic. It disrupts the function of the mitochondria in the cell. A threshold value for toxicity in okapis is still unknown (Ruuhola, Julkunen-Tiitto and Vainiotalo, 2003).

Tannins

Tannins are naturally occurring plant water-soluble polyphenols that can have a large influence on the nutritive value of browse. **Hydrolysable tannins** (HT's) and **condensed tannins** (CT's, also known as proanthocyanidins; PA's) are the two major classes of tannins. Although both groups of tannins resemble each other in the way they function, the effects of hydrolysable tannins on the digestion of proteins is often less severe than those effects of condensed tannins. Hydrolysable tannins are also known to be toxic (Kool & Smit, 2000, van Genderen, 1997).

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Hydrolysable tannins

Hydrolysable tannins (HT's) are polymers of gallic or ellagic acid esterfied to a core molecule, commonly glucose or a polyphenol such as catechin. They are more susceptible to enzymatic and non-enzymatic hydrolysis than condensed tannins (Reed, 1994, Min & Hart, 2003). Microbial tannases that hydrolyze galloyl esters are present in the rumen. The gallic acid released due to hydrolization is further metabolized by microbes to pyrogallol and other low-molecular-weight phenols that are absorbed from the rumen (Reed, 1994, Min & Hart, 2003).
HT's do not affect the protein digestibility in ruminants (Reed, 1994, Min & Hart, 2003). However, the microbial and acid-hydrolysis of hydrolyzed tannins in the gut produces metabolites that have anti-microbial activity and toxicity in the liver (Reed, 1994, Min & Hart, 2003). Hydrolysable tannins are therefore considered to be toxic to ruminants. The major lesions associated with HT poisoning are hemorrhagic gastroenteritis, necrosis of the liver and kidney damage with proximal tubular necrosis (Reed, 1994, Min & Hart, 2003)

Condensed tannins

Condensed tannins (CT's) are flavonoid polymers. Condensed tannins have a large number of free phenolic hydroxyl groups that form strong hydrogen bonds with numerous types of molecules such as carbohydrates, proteins, polysaccharides, nucleic acids and minerals (Palo, 1984/1985, Reed, 1994, Min & Hart, 2003). These tannins may also complex with proteins through hydrophobic bonding. Although CT's interact with carbohydrates (especially starch) as well as proteins, their affinity for carbohydrates seems to be much less than for proteins (Palo 1984/1985). These tannin-protein complexes are stable over the pH range of 3,5-7 and dissociate at pH <3 and > 8,5 (Teferedegne, 2000, Barry a& McNabb, 1999). The tannin-protein complex decreases the fermentation (degradability) of forage proteins in the rumen, thereby increasing the amount of protein available for abomasal and intestinal digestion (Reed, 1994, Min & Hart, 2003, Palo 1984/1985), whilst free CT's can react with and inactivate microbial enzymes, explaining why high levels of free CT's reduce rumen carbohydrate digestion (Barry & Manley, 1986). The decreased degradability can lead to inefficient enzyme digestion of the protein in the small intestine when the complex fails to dissociate (Reed, 1994, Min & Hart, 2003, Palo 1984/1985).
Furthermore, CT's are considered to be non-toxic to ruminants because they are not absorbed, but they are associated with lesions of the gut mucosa which could decrease absorption of other nutrients such as essential amino acids when present at high concentrations (Reed, 1994, Min & Hart, 2003, Palo 1984/1985).

Other negative effects of tannins

Detrimental nutritional effects occur to ruminants when the amount of tannins within the digested food exceeds the level of 5% of the dry matter of the digested food (Kool & Smit, 2000). High concentrations of tannins can cause a decline in growth because of a combination of reduced intake and low true digestibility of protein as well as irritation and damages to the digestive tract (Reed, 1994). As mentioned above, tannins may reduce cell wall digestibility by binding bacterial enzymes and/or form indigestible complexes with cell wall carbohydrates. The formation of complexes between tannins and salivary glycoproteins may increase salivation and decrease palatability (Reed, 1994). When levels exceed 9%, tannins in the diet can become lethal (Reed, 1994).

Positive effects of tannins

There are several mechanisms by which tannins in browse may increase the efficiency of protein utilization by ruminants. All of these effects are based on hypotheses and need to be further studied.

- Tannins can have a positive effect on the digestion of proteins. Because tannins have the ability to bind proteins and have an inhibiting effect on micro-organisms, CT-protein complexes are not part of ruminal degradation. After passing the rumen, the complexes are unstable at the acid pH of the abomasum. The proteins become available for digestion in the lower tract. Therefore, the percentage of proteins within the digestive tract increases (Clauss, 2006).
- Tannins may increase the efficiency of urea recycled to the rumen. Tannins lower the rate of protein degradation and deamination in the rumen and therefore lower ruminal NH_3. Tannins may increase the glycoprotein content and excretion of saliva, which could lead to more N recycled to the rumen (Reed, 1994).
- Tannins may increase microbial yield. Several researchers have observed increases in non-ammonia nitrogen (NAN) flows to the duodenum greater than N intake for forage legumes that contain tannins. Because N is not created in the rumen, part of the increased flow of NAN must be from endogenous sources that have been incorporated into the microbial fraction (Reed, 1994).

Influences on amounts and composition of secondary plant components

The composition of phenols and their amounts vary among the seasons, the different species of willow itself and also within the species for different plant parts, different sexes and different ages (Palo, 1994).
Seasonal changes in phenolic production are common in *Salix* species. The amount of phenolic glycosides in leaves is highest in spring and lowest in winter. This is opposite for bark. Bark generally shows higher phenolic concentrations and higher glycoside diversity than leaves. In leaves where glycosides occur, salicin and salicortin are most common. The substances also show diurnal variation, with higher values in early morning, decreasing during the day (Palo, 1984; van Genderen et al, 1997). The bark of willows can also contain a high amount of tannins. There is a rough distinction between willows of which the leaves contain a high amount of phenolic glycosides and a low amount of tannins and vice versa (Palo 1984/1985).
The chemistry of *Salix* is made more complex by the fact that female and male plants are different individuals, which is shown in the different chemistry of the two sexes (Palo, 1984/1985). Generally female plants show higher concentrations of phenolic glycosides in bark and leaves than males, only *Salix alba* shows the reverse. The production of phenols by the plant changes as it ages.

Overall, the levels of salicin and salicortin decrease with tree age (Palo 1984/1985). Nutritional quality of willow as browse is influenced by factors such as the period of harvesting and certain plant parts which are fed.

The secondary plant component values of certain species of willows and their separate plant parts are mentioned in table 5 below. The species of willows mentioned in this table are spread across Europe and can be part of the traditional main browse offered to okapis within European zoos.

Table 5: *Species of Salix spread across Europe and their amounts of secondary plant components*

	Phenolic glycosides in % DM			**Tannins in % DM**		
***Salix* species**	**Leaves**	**Twigs**	**Bark**	**Leaves**	**Twigs**	**Bark**
Salix caprea	**0,12**	-	-	**1,20 (2) +/- 0,45**	**1,47 (2)+/- 0,67**	-
Salix viminalis	**0,15**	-	-	-	-	-
Salix repens	**6,4**	-	-	-	-	-
Salix purpurea	**7,5**	-	-	-	-	-
Salix triandra	**0,2/ 0,78**	-	-	-	-	-
Salix dasyclados	**1,21**	-	-	-	-	-

(Palo, 1984; van Genderen et al, 1997; Kool & Smit, 2000)

Defense mechanisms of ruminants against the negative effects of secondary plant components

The negative effects described earlier are mentioned for ruminants in general, because for most of the effects of secondary plant components it is still unclear if they occur in okapis as well. The same is true for most of the defense mechanisms that ruminants have developed in order to reduce or undo the effects of these components. Large ruminants have several possibilities to protect themselves against poisoning (van Genderen, 1997):

- The distribution of toxic substances may affect food selection and feeding behavior of herbivores. Through negative experiences from eating certain plant species, animals will start to recognize and they tend to avoid plant parts rich in these substances, in spite of high nutritional content of the plant tissue (Palo, 1984, Kool & Smit, 2000).
- Accelerated transport through the digestive tract (e.g. diarrhea). The mucous membranes of the mouth, esophagus, rumen and intestines of vertebrates contain chemical sensors which “recognize” certain substances and initiate this reaction in order to make sure they leave the body as fast as possible (Kool & Smit, 2000).
- Detoxification and excretion of toxic substances through organ- and cell metabolism (Kool & Smit, 2000).
- The protective role of the rumen. Possible mechanisms of microbial defense against the negative effects of tannins are secretion of tannin binding polymers, synthesis of tannin-resistant enzymes and the biodegradation of tannins (Reed, 1994). The swallowed feed becomes a part of the fermentation process inside the ruminant. The plant parts are exposed to the influence of the anaerobe micro-organisms within the rumen and certain toxic substances can be broken down before they can reach the other parts of the digestive tract (Reed, 1994).
- Okapis, as well as other large herbivores, have the ability to immobilize tannins through detoxification mechanisms which produce CT-binding proline-rich salivary proteins (Reed, 1994, Hoffman 1989).

As mentioned earlier, wild okapis are known to consume foliage with a high phenolic content. One of the reasons that these animals can deal with the high amounts of phenols (phenolic glycosides and tannins) in nature is the fact that okapis are very selective feeders and their natural diet is very diverse. Because of this feeding strategy, the same types of phenols and other (toxic) secondary plant components do not built up inside the animal, preventing negative effects on health from occurring (Bruno van Puijenbroeck, pers. comm.).

2.3 The okapi in captivity

This part will focus on the diet composition of the okapi in captivity, divided into ingredient and nutritional composition based on data collected from a research held in 1998 (Boon et al.). Also, possible nutritionally related health problems occurring to okapis in captivity will be handled in this part.

Ingredient and nutrient composition of the okapis´ diet in captivity

Since okapis are only kept in zoos from the beginning of the 20th century, not much data is available about their diet and nutrient requirements in nature as well as in captivity. In 1998, students from Delft (supervised by Joeke Nijboer, nutritionist Rotterdam Zoo) visited 8 European zoos that had (and still have) okapis in their collection in order to gain more insight concerning the husbandry of okapis in European zoos. Among other husbandry issues, the diet of the okapis was recorded per zoo per okapi. In table 6 below the average ingredient composition of the 8 zoo diets is summarized on a fresh matter basis and on a dry matter (DM) basis.

Table 6: *Average ingredient composition of offered okapi diets in 8 European zoos that participated with the okapi research in 1998 (As fed on dry matter basis)*

Zoos	Fruits & Vegetables	Browse	Lucerne hay	Concentrates
Antwerp	38,1% (10,5% in DM)	0,9% (1,5% in DM)	44% (62,9% in DM)	17% (25,1% in DM)
Basel	27% (7,1% in DM)	0%	45,8% (57,5% in DM)	27,2% (35,3% in DM)
Berlin	31,3% (6,7% in DM)	0,5% (0,9% in DM)	38,2% (52,1% in DM)	30% (40,4% in DM)
Köln	44,8% (13,2% in DM)	7,6% (8,2% in DM)	26% (41,8% in DM)	21,6% (36,7% in DM)
Marwell	61,6% (22,2% in DM)	0%	17,8% (36,1% in DM)	20,6% (41,7% in DM)
Rotterdam	31,4% (7,1% in DM)	0,65% (0,4% in DM)	26,5% (35,8% in DM)	41,4% (56,7% in DM)
Stuttgart	56,7% (16,4% in DM)	1,4% (3,3% in DM)	14,5% (28,7% in DM)	27,4% (51,7% in DM)
Wuppertal	68,4% (24,7% in DM)	0,9% (1% in DM)	14% (33,2% in DM)	16,7% (41,1% in DM)
Average	44,9% (13,5% in DM)	1,5% (1,9% in DM)	28,4% (43,5% in DM)	25,2% (41,1% in DM)

DM = Dry Matter

All zoos feed more than 25% fruits and vegetables in the offered diet (fresh matter basis) and 5 zoos feed more than 25% concentrates in the offered diet (fresh matter basis). It is also remarkable that 2 zoos did not offer their okapis browse.

The average nutritional value of the intake mentioned in the previous table 6 is calculated and summarized below in table 7 per zoo:

Table 7: *Average nutritional value of okapi diets in 8 European zoos that participated with the okapi research in 1998*

Zoos	CP (%DM)	NDF (%DM)	ADF (%DM)	NFE (%DM)
Antwerp	16,7	31,8	19,9	42,3
Basel	**17,2**	**33,9**	**20,4**	<u>40</u>
Berlin	16,8	27,7	17,4	48,1
Köln	16,2	24,6	15,4	49,7
Marwell	<u>11,5</u>	<u>16,1</u>	<u>10,3</u>	**66,9**
Rotterdam	16,1	20,8	12,6	54,8
Stuttgart	15,9	19,9	11,5	55
Wuppertal	15,8	18,6	11,4	57,5
Average:	***15,8***	***24,2***	***14,9***	***51,8***

CP = Crude Protein
NDF = Neutral Detergent Fibre
ADF = Acid Detergent Fibre
NFE = Nitrogen Free Extract
DM = Dry Matter

Value = Highest value
<u>Value</u> = Lowest value

The results of the research in 1998 contributed to the first feeding guideline proposal for okapis; a joint European and North American project in 2001:

Table 8: *Recommended ingredient composition of the European okapi nutrition guideline 2001*

Ingredient	Recommended percentages as offered
Fruits & vegetables/ Browse:	0-25%
Prime quality alfalfa hay:	=>50%
Nutritionally complete pellets:	=>25%
Intake as % Body mass:	1,8% Dry matter diet (2-2,4% DM offered/body weight)

DM = Dry Matter

(Feeding guideline proposal for okapis, Crissey et al., 2001)

The additional comments in the feeding guideline for okapis state that fruits and vegetables are not required in the okapi diet and it does not seem to have apparent harmful effects unless provided at levels that would interfere with the consumption of the nutritionally important foods or at a level that would cause dilution of the nutrients in the total diet.
The feeding guideline also states that Lucerne hay will provide nutrients as well as fibre needed for gut function and that commercial concentrates, pellets and grain can provide the nutrients lacking in Lucerne hay.
Browse was considered an essential component of the diet that could actually replace some of the forage components if chemical composition was known and appropriate quantities were consumed. Finally, for lactating, growing and active okapis, a greater intake and additional quantities offered was recommended in the feeding guideline. (Feeding guideline proposal for okapis, Crissey et al., 2001)

The recommended nutritional composition of the okapi diet was also published in the okapi feeding guideline of 2001:

Table 9: *Recommended nutritional composition of the European okapi nutrition guideline 2001*

Nutrient	Concentration range dry matter basis
Protein, %	17-20
NDF, %	20-35
ADF, %	13-18
Calcium, %	0,70-0,97
Phosphorus, %	0,36-0,40
Iron, mg/kg	126-139
Zinc, mg/kg	54-68
Magnesium, %	0,18-0,24

NDF = Neutral Detergent Fibre
ADF = Acid Detergent Fibre
(Feeding guideline proposal for okapis, Crissey et al., 2001)

2.4 Nutritionally related health problems of the okapi

In this part five common health problems in captive okapis will be handled. These health problems were proposed by Joeke Nijboer (nutritionist Rotterdam Zoo) and followed from post-mortem reports. Focus will be on nutritionally relatedness of these health problems in order to give a new diet advice for the okapi diet in captivity.

Rumen acidosis

Not much research has been done on ruminal acidosis in captive wild ruminants. The only systematic investigation on the incidence of ruminal acidosis in captive wild ruminants remains the study of Marholdt (1991), who reported acidotic changes of the ruminal mucosa in more than 80% of all browsing ruminants investigated. The most probable reason for the sporadic reports on rumen acidosis in captive wild ruminants is that this disease is most likely to occur in its chronic form, which rarely is the immediate cause of death, and rarely looked for at necropsy (Clauss and Kiefer, 2003).

The okapis' natural diet consists of browse and vines, with a preference for young growth coming up in small rain forest gaps created by the falling of single trees (Hart, 1993). The okapis' characteristics of the morphology of its digestive tract and of food retention time fit into the picture of a typical browsing ruminant (Hummel et al., 2006).
In the nutrition of browsing ruminants in captivity, adequate nutrient digestibility and energy content of diet is debated. Problems related to energy provision and low forage intake have been reported for the okapi and other browsers like the giraffe, particularly during winter when browse is less available to zoos. Historic okapi diets usually consisted mainly of high amounts of easily digestible components like fruits, vegetables and milk. An okapi dating back to 1962 had a proportion of non-forage feeds of 75% altogether and finally died from rumen acidosis (Hummel et al., 2006).

A ruminant suffers from rumen acidosis when its ruminal pH drops below 5,5 (the normal physiologic nadir for ruminants). Ruminal pH drops below 5,5 when ruminants consume excessive amounts of easily digestible carbohydrates, mostly present in fruits, vegetables and concentrates. Low ruminal pH leads to inflammation of the ruminal epithelium, erosion, and ulceration of the ruminal epithelium. Any additional intake puts the ruminant at risk of subacute ruminal acidosis, because it results in the fermentation of carbohydrates into volatile fatty acids (VFA) in the cecum where they are absorbed passively across the rumen wall. The major VFA are acetate, propionate and butyrate. This passive absorption is enhanced by finger-like papillae. These ruminal papillae increase in length when ruminants are fed higher easily digestible carbohydrates diets and presumably increases ruminal surface area and absorptive capacity, which protects the animal from acid accumulation in the rumen. If the absorptive capacity of these cells is impaired (e.g. chronic rumenitis with fibrosis), it becomes much more difficult for the animal to maintain a stable ruminal pH following a meal. (http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/21704.htm&word=ruminal%2cacidosis)

Low ruminal pH also reduces the number of species of bacteria in the rumen. When fewer species of bacteria and protozoa are present, the ruminal bacteria are less stable and less able to maintain normal ruminal pH (pH > 5,5). Finally, intake depression is the ruminants' last resort for regulating ruminal pH. Inflammation of the ruminal epithelium (rumenitis) could cause pain and contribute to intake depression during subacute ruminal acidosis.

Due to inflammation of the ruminal epithelium, the ruminal epithelial cells are not protected by mucus ('slimy' coat), which make them more vulnerable to chemical damage by acids. (http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/21704.htm&word=ruminal%2cacidosis)
Therefore, the salicylic acid in willow, which is mostly offered to European okapi in captivity, might cause more damage and/or inflammation in the ruminal epithelial cells in okapis with rumen acidosis and may therefore worsen the symptoms of rumen acidosis.

Laminitis

Like many other captive ungulates, the okapi regularly experiences hoof problems. In captive European okapis, 23,5% needed hoof care (Leus and Puijenbroeck, 2000). These hoof problems should be considered a serious problem in captive ungulates.
Between 1993 and 2000, there were 20 anesthesia performed in which also foot care was needed in European okapi. Of these 20 performed anesthesia in European okapis, 80% were <u>only</u> anesthetized for foot care. This is a serious problem, since okapis can not easily be trimmed without using anesthesia and complications may occur during anesthesia, which can result in mortality (Sikarskie et al., 1988; Leus and Puijenbroeck, 2000).

In the following part, laminitis (*Pododermatitis aseptica diffusa*) in captive okapis will be discussed, while also looking for a nutritional relation for this problem. This particular hoof problem was proposed by Joeke Nijboer for further research because of its probable frequent occurrence in captive okapis.

<u>Characteristics of laminitis</u>

The layers of laminae (outer layer of the hoof) and papillae (inner layer of the hoof) are arranged in folds that act to absorb the impact of the hoof contacting the ground. Between these layers, there is a complex network of tiny blood vessels that are responsible for supplying the hoof and hoof horn with nutrients and removing waste produced during nutrient metabolism. When these vessels are damaged, the nutrient supply to these tissues is diminished, resulting in the production of poor quality horn, which is more susceptible to subsequent insults. The vessels can be damaged due to dilation of the hoof, which results in blood pooling in the hoof. The pooling blood increases blood pressure in the hoof, damaging the walls and vessels (Socha et al., 2005; Bell and Weary, 2002).

<u>Easily digestible carbohydrates</u>

Easily digestible carbohydrate overload in ruminants leads to acidosis in rumen contents. Acidosis leads to production of lactate, endotoxin, blood plasma histamine levels and severe signs of systemic histaminosis, which is one of the causes of laminitis. The mentioned substances are absorbed through the damaged rumen wall and damage capillary beds at predilection sites, the most important of which is the hoofs' blood vessels. This may be the underlying cause of a high proportion of laminitis observed in captive ungulates, like the okapi. Nowadays, it is very evident that feeding diets that result in a significant and prolonged drop in rumen pH (caused by a high amount of easily digestible carbohydrates in the diet) will result in a dramatic increase in laminitis cases. Therefore, management of acidosis is critical in preventing laminitis (Clauss and Kiefer, 2003).

In order to decrease the amount of easily digestible carbohydrates in the okapis' diet, it was proposed to replace a part of the concentrates with unmolassed sugar beet pulp (USBP). USBP has a high content of soluble and easily fermentable cell wall components, which are composed of pectin and easily digestible hemicellulose/cellulose in stead of easily digestible sugars and starch which are more present in fruits and concentrates. Therefore USBP can be considered a suitable substitute for concentrates. (Clauss and Kiefer, 2003)

Minerals

In cows, it is found that calcium and phosphorus are needed for normal hoof growth and integrity (Socha et al., 2005). Another nutritional factor that has been mentioned in correlation with health in hoofs is the biotin status of ruminants. Biotin plays an important role in hoof hardness and reserves are dramatically reduced during periods of stress and lameness. Biotin deficiency often seemed to lead to poor hoof health (Socha et al., 2005).
In 1998, Midla et al. evaluated biotin supplementation in cows and suggested that supplemental dietary biotin may have a beneficial effect on hoof health in intensively managed primiparous dairy cows (Socha et al., 2005). Biotin supplementation has also shown to improve horn quality in other domestic cattle and therefore may be beneficial for okapis too. In order to gain more insight in this, more serum surveys in okapis need to be performed (Socha et al., 2005).

Copper increases the strength of connective tissue and plays a role in the production of a healthy claw horn in cows. This is related to the copper enzyme, thiol oxidase, which increases the structural strength of horn. Cattle suffering from a subclinical copper deficiency are more susceptible to heel cracks, foot rot and sole abscesses (Socha et al., 2005). This may also influence the hoof health of okapis in captivity .
A report about hoof overgrowth in a copper deficient, free ranging moose population demonstrated differences in hoof copper content, this was also found in another research in giraffe, cattle and in Finnish moose.

As long as more systematic studies are missing, these reports remain anecdotal.
It also needs to be taken in account that neither biotin supplementation nor high copper supplementation can be expected to prevent damages to the hooves when an animal suffers from rumen acidosis (Clauss and Kiefer, 2005). Therefore focus should be on the prevention and appearance of rumen acidosis in okapis in order to prevent laminitis. .

Kidney abnormalities

The European center for okapi conservation and breeding is located in Antwerp (Belgium). For decades the center has collected the post-mortem reports of all captive okapis. Recently, post-mortem examinations were carried out on six okapis kept in four different German zoological parks (Haenichen et al. 2000). Renal tubular atrophy with cortical and medullary interstitial fibrosis with severe thickening of the basement membranes of atrophic tubules was found in six okapis. Focal glomerular atrophy, probably secondary to ischemic collapse of the glomerular capillary tuft, was also observed. Although the etiologies and pathogeneses of these nephropathies are unclear, primary damage of the tubular epithelium appears to be the most likely cause (Haenichen et al. 2000).

Thorough and comparative studies on the six okapis mentioned above, has led to speculate on a dietary-toxic origin, since the damages in the renal tubules are comparable with human analgesic nephropathy. However, papillary necrosis, considered to be a hallmark of this nephropathy caused by chronic abuse of nonsteroidal analgesics, was not present in the okapi. Another feature of analgesic nephropathy is a homogeneous thickening of capillary walls just beneath the epithelium in the renal pelvis, ureteral and bladder mucosa, which is considered highly characteristic. In the six examined okapis, such vascular lesions were limited to one case. However, this finding points to possible similarities to human analgesic nephropathy. Analgesic nephropathy is a type of toxic injury to the kidney. It is usually a result of prolonged or chronic ingestion of analgesics, like non-steroidal anti-inflammatory drugs (NSAIDs) including aspirin.

In this context it is noteworthy that in the German parks, the six okapis that were examined had access to feed containing leaves and twigs of willow (*Salix* sp.). A similar situation occurred at other European parks. Salix sp. contains salicylic acid (2-hydroxybenzoic acid). Salicylic acid is also present in aspirin for humans, and is known to cause toxic injuries to the kidneys by chronic ingestion. It is known that in humans a dose of 150 mg or more per kg body mass is toxic to the body and will cause damages. The exact damaging dose of aspirin (or salicylic acid) for the kidneys in okapis, human or other related species could not be found in literature. At the current state of knowledge, use of willow as appropriate okapi browse is not discouraged by the EEP. Nonetheless, salicylic acid should be considered a possible cause of tubular nephropathy in okapi, until proven otherwise (Haenichen et al. 2001; Hummel et al., 2006).

Glucosuria

In 1980, Glatston and Smith reported that urine of many healthy adult okapis could contain high amounts of glucose. Also Vercammen et al. (2003) reported that many European okapis seem to develop glucosuria. Recently, 18 out of 38 okapis (47%) housed in the United States were found to be glucosuric by dipstick analysis (Fleming et al., 2006) and it was concluded that glucosuria is a true finding in many apparently healthy okapi, but remains unexplained yet.

Glucosuria is an abnormal condition in mammals and can have an infectious, metabolic, inherited or familial etiology. Glucose in the urine causes osmotic production of urine by the kidneys and often occurs in those suffering from diabetes mellitus. Due to a lack of the hormone insulin, plasma glucose levels are above normal for ruminants. This could also be the case in okapis, because according to ISIS (International Species Information System, 2000), blood glucose values of captive okapis are higher (i.e. in adult males 139 +/- 49 mg/dl (0,13%) (n=64), in adult females 121 +/- 43 mg/dl (0,11%) (n=63)) than the values in domestic ruminants (i.e. in cows 57 +/- 7 mg/dl, in sheep 68 +/- 6 mg/dl, in goats 63 +/- 7 mg/dl). Unfortunately, due to lack of data of blood glucose levels in wild okapis, there is no reference to compare these blood glucose levels of captive okapis to. This means it is unknown if the blood glucose levels of the captive okapis are too high or normal for okapis (http://en.wikipedia.org/wiki/Glycosuria).

In the wild, okapis browse on more than 150 species of plants and prefer fast growing heliophilics (Hart et al. 1988). In the Epulu station, okapis are given leaves of approximately 35 different species ad libitum and are not given any fruit, vegetables, grass, hay or pellet, like the okapis in European zoos do. All adult animals (nine older than 8 years and two between 7 and 7.5 years old) were tested without glucosuria (Rosmarie Ruf, pers. comm.; Fleming et al., 2006). This suggests that there is a relation between the diet of captive okapis and the glucose found in the urine of these captive okapis.

The results in the report of Glatston and Smith (1980) for urine glucose levels in six adult okapis were not always positive for a given animal, but varied over time and thus may possibly be related to what has recently been eaten by the animal. This could mean that when an okapi is being tested for glucose in its urine and has recently eaten feedstuffs that contain high amounts of easily digestible carbohydrates (sugars), the urine will also contain high glucose levels.
In the White Oak Conservation Centre in Florida, urine samples of 10 okapis were collected between 07:00 and 08:00 hours during the first urination of the day, when the animal had not eaten yet. The urine of these okapis were tested and showed that urine glucose ranged from undetectable to 1 mg/dl of glucose, with seven okapi testing positive for glucosuria. (Fleming et al., 2006) since the okapis in the White Oak had not eaten before these glucose tests, it indicates that the high glucose in the urine of okapis can not (always) be explained by what has recently been eaten.

Okapis in European zoos are fed various fruits and vegetables (produce), mainly bananas, apples and carrots containing high amounts of easily digestible carbohydrates, like fructose, glucose and sucrose. Fermentation of fruits and vegetables is generally very fast and yield high metabolizable energy (ME) contents due to the high sugar content.

A fast fermentation and fast production of high amounts of short chain fatty acids might cause rumen acidosis (Vercammen et al., 2003; Schmidt et al, 2005; EEP questionnaire, okapi diets in zoos, 1997 and 2006).
It is known that ruminants maintain their blood glucose levels with the help of their microbial ruminal flora, much lower than monogastric animals, since the microbial ruminal flora use glucose as an energy source. When an okapi suffers from rumen acidosis, the microbial ruminal flora decreases and therefore less glucose will be used by the microbial ruminal flora. The overload of glucose can pass the rumen wall and end in the blood of the okapi. The overload of glucose in the okapis' blood will then finally end up in the urine of the okapi (Vercammen et al., 2003).

In domestic ruminants, glucosuria is infrequently diagnosed and not present unless the serum glucose renal threshold of 100-160 mg/dl has been reached (Fleming et al., 2006). Assuming the earlier mentioned blood glucose levels (ISIS, 2000) are normal for okapis, the high urine glucose levels can also be compared to symptoms of renal glucosuria. Renal glucosuria is a rare condition, in which the simple sugar glucose is extracted in the urine, despite normal or low blood glucose levels. With normal kidney (renal) function, glucose is excreted in the urine only when there are abnormally elevated levels of glucose in the blood. However, in those with renal glucosuria, glucose is abnormally eliminated in the urine due to improper functioning of the renal tubules. (http://en.wikipedia.org/wiki/Glucosuria)

When renal glucosuria occurs in humans as an isolated finding with otherwise normal kidney function, the condition is thought to have a genetic cause (http://en.wikipedia.org/wiki/Glycosuria). A genetic cause in okapis for probable (renal) glucosuria is unlikely as inbreeding is very low to absent in okapis with (n=11) or without (n=8) glucosuria (inbreeding coefficients ranging from 0.0000-0.0469 and from 0.0000-0.0704 respectively) (Vercammen et al., 2003).

According to the post-mortem reports of European okapis, almost every investigated okapi had kidney abnormalities, mostly in the renal tubules. (Post mortem reports European okapis until 2006, Antwerp Zoo archives). Also, differential diagnosis for glucosuria in mammals includes acute and chronic renal disease such as renal tubule disorders. This suggests that the high urine glucose levels of European captive okapis are (partly) due to tubular nephritis and are a true finding in captive okapis (Fleming et al., 2006).

Obstructions of the gastrointestinal tract

Obstructions of the gastrointestinal tract in ruminants can be caused by sudden change in the quantity and/or quality of the diet or possibly by eating forage material that have a rough, large particle size and a star character (**http://www.merckvetmanual.com**).
In nature, the okapi diet mainly consists of young foliage tips from more than 150 different plant and vine species (Hart et al., 1989). Also, the natural diet of an okapi consists of a low dry matter percentage of 17,4% (Hart et al., 1989), which probably makes the structure of these young foliage tips eaten in nature softer and are more easily ripped off from the plant, easily chewed on and swallowed compared with older, dried and/or frozen browse offered in captivity.
This offered browse in captivity usually contains more twigs than leaves. When this kind of browse is offered to okapis they will consume these twigs too, because the okapis do not need to tear the rough twigs of the plant, since these twigs has already been cut for them (Pers. Comm.. Bruno van Puijenbroeck).
It can be expected from the known diet in nature that the gastrointestinal tract of the okapi is not well suited for this kind of dry, star material offered in captivity. When the captive okapis consume this dry, star material, it may therefore cause obstructions in the gastrointestinal tract and result in odd faeces shapes e.g. chain-droppings.

Bezoars are one type of obstruction in the digestive system. These are foreign bodies in the gastrointestinal tract that increase in size by the accretion of non-absorbable food or fibers. Bezoars develop after ingestion of foreign material that accumulates in the gastrointestinal tract because of large particle size, indigestibility, gastric outlet obstruction, or intestinal stasis. Three types of bezoars are known to cause gastric outlet obstruction: phytobezoars, trichobezoars, and lactobezoars. Phytobezoars are the most common in ruminants and consist of undigested cellulose, lignin, hemicellulose, and fruit tannins derived from fruit and vegetable matter (**http://www.nlm.nih.gov/medlineplus/ency/article/001582.htm, http://lib.bioinfo.pl/pmid:4048035**).

Chapter 3, Methods

In this chapter every sub-question will be handled separately in order to show the methods that have been used to answer each sub-question. With the answers of these sub-questions, the main question will be answered: ‘In what way do the feeding practices need to be altered in order to meet the nutritional requirements for okapis in captivity?’
This study has been carried out between September 2006 and March 2007. Data have been gathered through literature study, a questionnaire, feed analysis of hay and concentrate samples that different European zoos have send along with the questionnaire and the computer program Zootrition V2.6.

3.1 What is the ingredient and nutritional composition of the diet for okapis in the wild?

This question has been answered through literature study.

Table 10: ***Sources of used literature and information for sub-question 3.1***

Literature and information	**Source**
Articles and data by John Hart	J. Nijboer and Antwerp Zoo archives
Article by Ellen Dierenfeld/Epulu station	J. Nijboer and Antwerp Zoo archives
Natural diet – browse list	J. Nijboer
Personal observations	B. van Puijenbroeck

3.2 What is the current ingredient and nutritional composition of the diet for okapis in captivity and what are the main differences from the diet in the wild?

This question has been answered with information obtained from the questionnaire (2006), Zootrition V2.6, ‘Zoo animal nutrition tables and guidelines’, by Jansen and Nijboer (2003) and a laboratory analysis on feed samples. To compare the captive diets with the natural diet, the information gathered to answer the previous sub-question (“What is the ingredient and nutritional composition of the diet for okapis in the wild?”) has been used as reference information for the natural diet.

<u>Questionnaire (See appendix 2)</u>
The questionnaire contained an introduction letter, studbook information (Kristin Leus, August 2006), if available: the data gathered from the research of 1998 (Boon et al.), the nutrition guideline of 2001 (feeding guideline for the okapi, Crissey et al., 2000), a body condition score (BCS, developed by Disney’s Animal Kingdom, 2005) and the questionnaire itself. The questionnaire has been send by email to persons in the European zoos that are involved in keeping okapis. This email-list has been provided by Kristin Leus (Former international studbook keeper for okapis).
The questionnaire consisted of four different parts: “Animals in your collection”, “Feeding”, “Health” and “Body Condition Score”.

In part one of the questionnaire, a table was given to note changes in the collection of okapis in each zoo. In part two, an opinion could be given about the nutrition guideline of 2001, the current feeding strategy of each zoo could be filled in, along with the diet adjustments for different life stages. Finally, okapi keepers could point out how they have obtained the filled-in information.
In part three, a table was given in which okapi keepers could point out the different health problems their okapis (have) experience(d). In part four, an opinion could be given about the Body Condition Score (BCS) that was enclosed in the questionnaire. Finally, keepers were asked to score their own okapis according to this scoring system.
At the end of the questionnaire, space has been left to offer the opportunity for keepers to add any remarks.

Answers from the questionnaire have been summarized in table A t/m N (See appendix 3). Answers to open questions have been categorized as much as possible. Each question in the questionnaire has been processed separately, except the first question about the studbook information. This question was meant to assure studbook data is still up to date.

Ingredient composition
The ingredient composition has been determined with the help of the questionnaire that has been send to all 18 European zoos that have okapis in their collection. The ingredient composition has been asked for in g. or kg. ingredient/okapi/week. This was done to make sure that ingredients that were not offered every day were taken in for analysis as well. Results of the analysis are shown per g. or kg. ingredient/okapi/day. This has been done to improve the usability of the recommended advice for the new nutrition guideline. If zoos did not specify the types of fruits and/or vegetables offered to their okapis in the questionnaire, apples and bananas were assumed for fruits and greens were used for vegetables. If the type(s) of browse were not specified in the questionnaire, willow was used for further analysis. An average of 3 kg per bundle of browse (fresh matter basis) has been used for processing the results (proposed by Joeke Nijboer). If the type of hay was not specified, Lucerne hay was assumed for further analysis. If types of concentrates were not specified in the questionnaire, horse pellets values were used (proposed by Joeke Nijboer).
Zoos were asked to specify the manner in which they obtained the diet information. This was done to learn more about the accuracy of the amounts given per feedstuff.

Processing the ingredient composition resulting from the questionnaire of 2006 to determine the nutritional composition of the captive diets
Calculating the nutritional composition was done by averaging the nutritional values per feed stuff, available from Zootrition V2.6 and ‘Zoo animal nutrition tables and guidelines, Jansen and Nijboer, 2003’. For every zoo diet, an Excel sheet was made in which the ingredients with their amounts (in kg) offered and averaged nutritional values were specified (See appendix 4).

The BMR (Basal Metabolic Rate) is calculated by using the Kleiber rule; 293 KJ * W (weight)^0,75 = MJ * 239 = kcal. The maintenance requirement is calculated by 1,5 – 2 * BMR = MJ * 239 = kcal.

Energy in kcal DM for the total offered diet per day per okapi is calculated by 3,5 kcal * x gr. protein + 8,5 kcal * x gr. fat + 3,5 kcal * gr. NFE. Dividing this outcome with the total offered gr. (DM) per zoo diet results in the energy in kcal/gr. DM per day per okapi for that specific zoo diet.

NFE was calculated by DM minus CP, NDF and Ash values.

All the values for ingredient and nutritional composition of the zoo diets will be based on an offered basis, not on an intake basis. Therefore all the amounts (in kg) are also given in percentages in order to make the values comparable with the natural diet, which is given on an as intake basis.

The nutritional composition data per zoo, resulting from the Excel sheet (See appendix 4), has been compared with the known nutritional composition data of the natural diet.

Hay and concentrate analysis (See appendix 5)
To get a more realistic impression of the nutritional composition and therefore the quality of the hay and concentrates that are offered in different European zoos, zoos were asked to send along 3 samples of hay (250 grams each) and 500 grams of concentrates with the questionnaire. These samples have been analyzed in the lab at Van Hall Larenstein in Leeuwarden.

The hay and concentrates were analyzed on Air Dry Matter (ADM), Dry Matter (DM), Ash, Crude Protein (CP), Crude Fibre (CF), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Calcium (Ca), Phosphate (P), Magnesium (Mg), Iron (Fe) and Zinc (Zn).

Methods used for analysis of ADM, DM, Ash and CP are described in "Chemische diervoederanalyse, 05077, Van Hall Larenstein". Methods used for analysis of CF, NDF and ADF are obtained from ANKOM Technology, 2005.

3.3 How can the differences between the natural diet and the diet in captivity for okapis be used in order to explain occurring health problems among okapis in captivity?

This question has been answered through literature study, post-mortem reports and results from the questionnaire of 2006.

Information on the occurring health problems glucosuria, hoof problems (laminitis), rumen acidosis, tubulointerstitial nephropathy and obstructions of the gastrointestinal tract (bezoars) has been taken primarily from literature. Studying these five specific health problems has been proposed by Joeke Nijboer. Further information on the occurrence of any of these health problems among okapis in European zoos has been obtained through the questionnaire of 2006.
Additional information on occurring health problems and causes of death among okapis has been obtained through post-mortem reports. For this study, Antwerp Zoo has given permission to read these reports.
The comparisons between the nutritional and ingredient composition of the natural diet and the captive diets that needed to be done in order to answer the second sub-question ("What is the current ingredient and nutritional composition of the diet for okapis in captivity and what are the main differences from the known diet in the wild?") have also been used in answering this sub-question. During the study for health problems among captive okapis, focus has been on the nutritional relatedness of these problems.

Therefore ingredient and nutritional compositions have been compared with the information gathered through literature study concerning the health problems in okapis to try and find relatedness.
Zoos were asked to give the weight of each individual okapi. Additionally, for the accuracy of the results and eventually for determining relations between weight, health and other variables, zoos were also asked to specify whether these weights were obtained through estimation or actual weighing.

Table 11: *Sources of used literature and information for sub-question 3.3*

Literature and information	**Source**
Hoof problems (Laminitis)	Internet (Merck, Google Scholar, Pubmed, Springerlink Wikipedia), J. Nijboer
Glucosuria	Internet (Merck, Google Scholar, Pubmed, Springerlink Wikipedia), J. Nijboer and Antwerp Zoo archive
Tubulointerstitial nephropathy	Internet (Merck, Google Scholar, Pubmed, Springerlink Wikipedia), J. Nijboer
Rumen acidosis	Internet (Merck, Google Scholar, Pubmed, Springerlink Wikipedia), J. Nijboer
Secondary plant components	Internet (Google Scholar, Pubmed, Springerlink), J. Nijboer and library of the Van Hall Institute
Natural diet	Internet (Google Scholar), J. Nijboer and Antwerp Zoo archive
Captive diet	J. Nijboer, Antwerp Zoo archive and library of the Van Hall Institute
Post mortem reports	Antwerp Zoo archive

The main question ("In what way do the current feeding practices in European zoos need to be altered in order to meet the nutritional requirements for okapis in captivity?") has been answered with the data gathered from answering the previous sub-questions. This data have been used in calculating the advice (For specific calculations, see appendix 6)

Chapter 4, Results

In this chapter, the results of the European okapi nutrition questionnaire 2006 will be presented. The results of this chapter can contribute to the revision advice for the European nutrition guideline for captive okapis.

The questionnaire (See appendix 2) was send to all 18 European zoos that have okapis in their collection. From these 18 questionnaires, 12 were returned.

As mentioned before, the questionnaire consisted of 4 parts; ‘Animals in your collection’, ‘Feeding’, ‘Health’ and ‘Body Condition Score’. The first part was only meant for checking the studbook data. This part will not be handled in this chapter. The results of the other 3 parts of the questionnaire are presented per question.

4.1 Feeding

This part of the questionnaire contained questions concerning the satisfaction of European zoos with the nutrition guideline of 2001, the individual and/or group feeding strategy for okapis in inside and outside enclosures, the diet offered, diet adjustments and in what way the diet information was obtained. With most of the questions in the questionnaire, space was left for zoos to give (additional) remarks. These remarks are presented in appendix 3.

Satisfaction with nutrition guideline 2001

Zoos were asked if they were satisfied with the nutrition guideline of 2001. The answers are summarized below:

Table 12: *Satisfaction with nutrition guideline 2001*

Satisfied?	Nr. of zoos
Yes	8
No	4

Zoos were also given the opportunity to give remarks about the guidelines. In general, 6 zoos proposed a more detailed nutrition guideline, which also has to be practical and useful for keepers themselves and 2 zoos proposed other values (Zoo 1: 1/3 pellets, 1/3 Lucerne, 1/3 browse and Zoo 2: 25% pellets has to be reduced to 15% pellets) for the given nutrition guideline of 2001 (See appendix 3, table A).

Table 13: *Applying nutrition guideline of 2001 according to zoo*

Use of nutrition guidelines	Nr. of zoos
Yes	4
No	8

From the 12 zoos, 4 zoos use the nutrition guideline that their zoo/nutrition advisor established itself.

Feeding strategy

In the second question of the 'Feeding' part of the questionnaire, zoos were asked to note down whether their okapis are fed individually or in groups in the inside and outside enclosures. These answers are summarized below in two separate tables:

Table 14: *Group or individual feeding, inside enclosures*

Group or individual feeding	Nr. of okapis
Individually	38
Together (2)	4
Trio (3)	0

Table 15: *Group or individual feeding, outside enclosures*

Group or individual feeding	Nr. of okapis
Individually (1)	23
Together (2)	10
Trio (3)	9

Three zoos feed all of their okapis separately in the inside as well in the outside enclosures. Six zoos feed all of their okapis separately in the inside enclosures, but together in the outside enclosures. Two zoos feed their okapis together in the inside enclosure of which one zoo also feeds its okapis together in the outside enclosure and one zoo does not feed its okapis in the outside enclosures. Furthermore, 1 zoo feeds its okapis separately in the inside enclosure and does not feed its okapis in the outside enclosures.
These results are also given per zoo in appendix 3, table B.

European okapi diets per zoo

The zoos were also asked to note down the diet they offer to their okapis. They were asked to specify the diet in grams per food item per individual okapi per week (See appendix 4). These answers were processed into useful comparable data (See Chapter 3, Methods).
The results for the ingredient composition that these zoos offer their okapis are summarized below in table 16 specified per zoo and feed category:

Table 16: *Average offered diet ingredient composition as fed per zoo (given in %)*

Zoos	Fruits&Veg. (% of total diet, as fed)	Browse (% of total diet, as fed)	Lucerne (% of total diet, as fed)	Concentrates (% of total diet, as fed)	Total kilograms /okapi/day (as fed)
Antwerp	16	10	52	28	5
Basel	20	**33**	33	11	9
Beauval	36	<u>0</u>	46	18	11
Chester	27	19	25	25	8
Frankfurt	<u>5</u>	16	**77**	<u>7</u>	11
Köln	18	6	50	31	<u>4</u>
Lisboa	10	20	46	22	11
London	13	13	39	**35**	11
Marwell	35	<u>3</u>	36	27	14
Rotterdam	23	10	49	18	8
Stuttgart	**48**	10	<u>22</u>	22	9
Wuppertal	37	18	29	15	**17**

<u>Data</u> = lowest value found for a specific feed category
Data = highest value found for a specific feed category

For 9 of the 12 zoos, Lucerne comprises the biggest part of the offered diet. For the other 3 zoos, the major part of the offered diet comprises fruits & vegetables.

The absolute amounts that are offered to the okapis per day per zoo are summarized below in table 17:

Table 17: *Diet ingredient composition as fed per zoo, offered per okapi per day (in kg)*

Zoos	**Fruits&veg. (kg of total diet as fed)**	**Browse (kg of total diet as fed)**	**Lucerne (kg of total diet as fed)**	**Concentrates (kg of total diet as fed)**	**Total kilograms /okapi/day (as fed)**
Antwerp	0,8	0,5	2,6	1,4	5
Basel	1,8	3	3	1	9
Beauval	4	<u>0</u>	5,1	2	11
Chester	2,2	1,5	<u>2</u>	2	8
Frankfurt	<u>0,55</u>	1,8	**8,5**	<u>0,8</u>	11
Köln	0,72	0,24	<u>2</u>	1,2	<u>4</u>
Lisboa	1,1	2,2	5,1	2,4	11
London	1,5	1,5	4,3	**4,1**	11
Marwell	4,9	0,42	5	3,8	14
Rotterdam	1,8	0,8	3,9	1,4	8
Stuttgart	4,3	0,9	<u>2</u>	2	9
Wuppertal	**6,3**	**3,1**	4,9	2,6	**17**

<u>Data</u> = lowest value found for a specific feed category
Data = highest value found for a specific feed category

In appendix 5, more detailed tables are given per zoo specifying food items per feed category.

When the percentages of the offered feed categories from table 16 are given in kg in table 17, some zoos appear to have other minimum and maximum values. When looking at the total kilograms fed in these 12 zoos, Wuppertal offers the largest amount of fresh food to their okapis (17 kg) and Köln the lowest amount (4 kg).

Nutritional value of okapi diets per zoo

Zoos were asked to note down the diet they offer to their okapis specified per ingredient per individual okapi per week. These ingredient data were processed into average nutritional data per zoo per okapi per day.
The nutritional values of the zoo diets are summarized in table 18 on the next page:

Table 18: *Average nutritional composition per zoo diet offered per okapi*

Nutritional values	**Antwerp**	**Basel**	**Beauval**	**Chester**	**Frankfurt**	**Köln**	**Lisboa**	**London**	**Marwell**	**Rotterdam**	**Stuttgart**	**Wuppertal**	**Average (Median)**
Total kg as fed	5	9	11	8	11	4	11	11	14	8	9	**17**	10,8 (10)
DM (%)	70,2	55,3	58,2	60,2	**78,4**	70,3	67,4	70,8	60,5	63	52,5	46,9	62,81 (61,75)
DM (kg)	3,53	4,98	5,82	4,81	**8,62**	2,81	7,41	8,17	8,46	5,04	4,72	7,97	6,7 (5,9)
Energy (kcal/g DM)	2,1	2	2,2	2,3	1,9	2,2	2,2	2,2	**2,9**	2,1	2,7	2,2	2,25 (2,2)
Energy (total kcal DM)	7432	9761	12618	11080	16244	6202	16195	18218	**24310**	10362	12867	17514	15085 (12743)
Ash (%DM)	9,8	8,9	8,8	7,5	9,5	9,2	**10,1**	8,2	6,7	9,2	7,1	8,7	8,642 (8,85)
CP (%DM)	17,5	16,0	16,5	14,6	**18,3**	16,9	17,7	18,1	14,4	17,1	13,7	17	16,48 (16,95)
NDF (%DM)	34,9	39,1	34,4	35,5	**41,8**	32,5	34,7	34	22,3	37,2	18,4	32,8	33,13 (34,65)
ADF (%DM)	22,1	26,1	21,8	24,5	**27**	20,1	22,2	21,3	14,3	23,8	12,2	20,5	21,32 (21,95)
NFE (%DM)	34,4	33,2	36,7	36,4	26,8	37,9	34,3	35,4	49	32,9	**56,9**	38,5	37,7 (35,9)
CF (%DM)	24,9	18,9	25,9	20,7	29,2	25,5	**31,8**	20	19,7	24,6	20,5	20,7	23,53 (24,75)
CFat (%DM)	3,4	2,8	3,6	6,1	3,6	3,4	4,3	4,3	**7,7**	3,6	3,9	3,0	4,14 (3,6)
Ca (%DM)	1,1	**1,25**	1,1	1,0	1,24	**1,1**	1,2	1,0	0,66	1,2	0,78	0,94	1,048 (1,1)
P (%DM)	0,37	0,38	0,34	0,37	0,32	0,4	0,36	**0,5**	0,27	0,38	0,25	0,3	0,35 (0,365)
Fe (mg/kg DM)	212,2	240,2	205,1	263,7	234,6	202,3	199,5	**256,1**	137,9	246,2	103,6	167,0	205,7 (208,7)
Zn (mg/kg DM)	64,9	**101,8**	43,3	76,9	47,8	57,6	60,0	90,7	26,8	74,6	20,5	33,4	58,2 (58,8)
Mg (%DM)	0,23	0,24	0,24	0,27	0,26	0,21	0,23	**0,28**	0,2	0,26	0,17	0,21	0,23 (0,235)

Legend table 18: from previous page:

DM (%) = Dry Matter percentage	Ca (%DM) = Calcium percentage
Ash (%DM) = Ash percentage	P (%DM) = Phosphorus percentage
CP (%DM) = Crude Protein percentage	Fe (%DM) = Iron percentage
NDF (%DM) = Neutral Detergent Fibre percentage	Zn (%DM) = Zinc percentage
ADF (%DM) = Acid Detergent Fibre percentage	Mg (%DM) = Magnesium percentage
NFE (%DM) = Nitrogen Free Extract percentage	value = lowest value found for a specific nutrient
CF (%DM) = Crude Fibre percentage	**value** = highest value found for a specific nutrient
CFat (%DM) = Crude Fat percentage	

The complete tables are given in appendix 4, where the ingredients are specified with their nutritional characteristics.

To make the results in table 18 more clarifying, they are summarized in the table below for the four most important nutritional values. Ranges were chosen for the most frequent values in order to clarify how many zoos feed below or above these common ranges.

Table 19: *Ranges of nutritional values for zoo diets*

Nutritional values	**Range**	**Nutritional values of zoo diets below range (nr of zoos)**	**Nutritional values of zoo diets within range (nr of zoos)**	**Nutritional values of zoo diets above range (nr of zoos)**
DM (%)	60,2 – 70,8	4	7	1
CP (%DM)	16,0 – 17,7	3	7	2
NDF (%DM)	32,5 – 37,2	2	8	2
ADF (%DM)	20,1 – 22,2	2	6	4
NFE (%DM)	34,3 – 38,5	3	7	2

The known nutritional values of the offered browse species in captivity are summarized below.

Table 20: *Nutritional values of offered browse species in captivity*

Browse species captive diet	**DM (%)**	**CP (%DM)**	**NDF (%DM)**	**ADF (%DM)**
Black willow (*Salix sp.*) (twigs&leaves)**	41	12,3	50,1	38,6
Dried ash (*Fraxinus sp.*) (twigs&leaves)*	100	17,1	-	-
Dried linden (*Tilia sp.*) (twigs&leaves)*	100	19,5	-	-
Dried raspberry (*Rubus idaeus*) (leaves)*	100	11,7	43,7	25,1
Beech (*Fagus sp.*) (twigs&leaves)*	40,7	8,7	74	58,8
Dried oak stick (*Quercus sp.*) (twigs&leaves)*	100	14	-	-
Silver maple (*Acer sp.*) (twigs&leaves)**	50,1	9,9	41,7	30,7
Acacia (*Robinia pseudoacacia)* (twigs&leaves) **	36,1	21,3	40,2	25,2
Average	**71**	**13,4**	**37,7**	**26**

DM = Dry Matter
CP = Crude Protein
NDF = Neutral detergent fibre
ADF = Acid detergent fibre

* = Zootrition V2.6
** = Zoo Animal Nutrition Tables and Guidelines (Jansen and Nijboer, 2003)

As table 20 shows, the NDF and ADF percentages of Beech are higher than the other browse species mentioned.

Diet adjustments for different life stages and/or body conditions

In the 'Feeding' part of the questionnaire, zoos were also asked to note down adjustments in the offered diet concerning different life stages and/or body conditions in their okapis. The results are summarized below in table 21 per life stage and/or body condition specified per zoo:

Table 21: *Adjustments of diet for different life stages and/or body conditions*

	Juvenile	Aged	Gestating	Lactating	Obese	Emaciated	Sick
Adjusted diet (nr. of zoos)	8	4	6	8	5	4	7
No adjusted diet (nr. of zoos)	4	8	6	4	7	8	5

Most zoos appear to have no specific diet adjustments for different life stages and/or body conditions. The most common comment for the juvenile life stage was that the feed will gradually be increased and when the young is fully weaned he receives 70-80% of the adult diet. For the life stage 'Aged' no adjustments were noted down for any zoo. For the life stage 'Gestating', 3 zoos would adjust their diet by increasing the amounts of concentrates, Lucerne and browse. For the life stage 'Lactating', 6 zoos would adjust their diet by again increasing the amounts of concentrates, Lucerne and browse offered. For the body condition 'Obese', 5 zoos would adjust their diet by decreasing the amounts of offered concentrates and Lucerne. For the body condition 'Emaciated', 3 zoos would adjust their diet by increasing the amount of offered concentrates, Lucerne and browse as long as the composition of the faeces remains normal. For the body condition 'Sick', 6 zoos would adjust their diet by recommendations of their veterinarian and by reducing the amounts of concentrates offered. All given remarks can be found in appendix 3, table C – I, given per life stage and/or body condition per zoo.

Strategy of collecting diet information

Zoos were asked to mention in what way they obtained the diet composition figures given in the questionnaires. The results are summarized below per zoo:

Table 22: *Strategies used for obtaining diet weight and composition*

Zoos	1.	2.	3.
Antwerp	X		
Basel		X	
Beauval	X	X	X
Chester	X		
Frankfurt	X		
Koln	X		
Lisboa	X		
London			X
Marwell			X
Rotterdam			X
Stuttgart			X
Wuppertal	X		
Total:	**7**	**2**	**5**

1 = Weighing all the feedstuffs offered
2 = Weighing all the feedstuffs offered and weighing back most of the feedstuffs left
3 = Estimating weights and amounts fed

The table above shows that most zoos weighed the ingredients. Only one zoo obtained its information by using all three options; option 1 for the pellets, option 2 for the Lucerne and option 3 for the vegetables and fruits. This zoo is also part of 5 zoos which estimate the amounts that are fed to the okapis. This can cause too many fluctuations in offered ingredient composition.

4.2 Health

This part of the questionnaire contained 1 question concerning a number of health problems with okapis in captivity. The additional remarks that zoos shared with us will not be handled with in this chapter, but can be found in appendix 3, table J.

Health problems

In this part, the zoos were asked to fill in which of the mentioned health problems in the questionnaire occurred or still occurs to their okapis. They were also asked to point out who diagnosed the health problem, the veterinarian, the keeper or somebody else. The results are given in the table below:

Table 23: *Health problems occurring per zoo per okapi*

Zoos	**Hoof problems**		**Obstruction of the G.I. tract***		**Obesity**		**Other (Diarrhoea)**	
Antwerp	Af	V&K						
Basel								
Beauval								
Chester								
Frankfurt	Am Am	V V	Am	V				
Koln								
Lisboa								
London	Am Af	K K						
Marwell	Af	K						
Rotterdam	Af Af	V V					Af Af	K K
Stuttgart	Am Af Af	K K K						
Wuppertal	Af	V&K	Af	V	Af Af Am	K K K		
Total	**12** (4 Am and 8 Af)		**2** (1 Am and 1 Af)		**3** (1 Am and 2 Af)		**2** (0 Am and 2 Af)	

Am= Adult male (>1 year)
Af= Adult female (>1 year)
Jm= Juvenile male (<1 year)
Jf= Juvenile female

V = diagnosed by Veterinarian
K = diagnosed by Keeper
V&K = diagnosed by Veterinarian and Keeper
* = Gastrointestinal tract

Of all health problems mentioned in the questionnaire, a total of 19 health problems were experienced by okapis (some okapis experience(d) more than 1 health problem). Which okapi experienced what health problem can be found in appendix 3, table J. Most okapis experience(d) hoof problems (12).

4.3 Body Condition Score

In this part of the questionnaire, 2 questions were asked concerning the satisfaction of zoos about the body condition scoring system of Disney's Animal Kingdom and the actual body condition scoring of the okapis in the different zoos with the weight mentioned per okapi.

Opinion on the body condition score (BCS) system developed by Disney's Animal Kingdom

The first question of this part of the questionnaire was about the body condition scoring system, developed by Disney's Animal Kingdom (2005), enclosed in the questionnaire (See appendix 2). Zoos were asked if they were satisfied with this scoring system as well as to comment on this scoring system. The results of this question are summarized below per zoo:

Table 24: *Opinion on the BCS system developed by Disney's Animal Kingdom*

Opinion BCS	Nr. of zoos
Satisfied	10
Not satisfied	2

No zoo gave motivated their satisfaction. The 2 zoos that were not satisfied with this BCS did motivate their opinion. The main reason for disagreement with this BCS system is the fact that the assessment is too general. For example, an okapi is ascribed one particular condition (emaciated, thin, good, fat or obese) while separate body parts could fit into different conditions. In appendix 3, table K, remarks can be found.

Body condition score

In this part of the questionnaire, zoos were asked to note down the weight of each of their okapis and score them, according to the scoring system developed by Disney's Animal Kingdom. The results of this weighing and scoring are given below:

Table 25: *Weight and Body Condition Score per zoo per okapi*

Zoo	Age	Sex	Weight (kg)	Body Condition Score
Antwerp	0 y, 8 m	Female	116	3
	15 y,7 m	Female	276	3
	9 y, 4 m	Female	264	2
	6 y, 6 m	Male	238	3
	2 y, 3 m	Female	242	3
Basel	6 y, 8 m	Female	ND	3
	8 y, 3 m	Male		3
Beauval	18 y, 6 m	Male	218	3
	3 y, 2 m	Male	275	3
Chester	2 y, 5 m	Male	220	4
	1 y, 7 m	Female	205	3
Frankfurt	18 y, 2 m	Male	250	4
	1 y, 11 m	Male	110	3
	3 y, 7 m	Female	230*	3
	3 y, 7 m	Female	220*	3
Köln	14 y, 3 m	Male	243	4
	11 y, 10 m (P)	Female	371	3
Lisboa	4 y, 0 m	Male	260	3
	3 y, 2 m	Male	226	3
London	10 y, 2 m	Male	313	3
	9 y, 11 m	Female	296	3
Marwell	1 y, 1 m	Male	ND	3
	21 y, 6 m	Female		3
	8 y, 2 m	Female		3
	19 y, 7 m	Male		3
	7 y, 1 m	Male		3
	4 y, 3 m	Female		3
Rotterdam	1 y, 4 m	Male	210*	3
	15 y, 7 m	Female	300	2
	14 y, 10 m	Male	225*	3
	10 y, 5 m	Female	250*	3
	8 y, 9 m	Female	250*	3
	1 y, 9 m	Male	215*	3
Stuttgart	10 y, 3 m	Male	260*	3
	8 y, 10 m	Male	290*	3
	8 y, 3 m	Female	260*	2
	5 y, 5 m	Female	340*	3
	4 y, 5 m	Female	330*	3
	1 y, 5 m	Male	190*	3
Wuppertal	12 y, 0 m	Female	328	4
	10 y, 8 m	Female	260	4
	5 y, 4 m	Male	237	3
12 zoos **42 okapis**	Average age = 8 years	21 Male 21 Female	34 okapis	Average BCS = 3

Body Condition Scoring: 1 being emaciated and 5 being obese

y = years, m = months

(P) = Pregnant (11 months)

* = Given weight was estimated

300 = died during this study and weighed during p.m. examination

Even though not all okapis were actually weighed, these results give an impression of the body condition of okapis in European zoos, according to their keepers and/or curators.
The average weight of the adult female okapis (older than 3 years) is: 284 kg (14 okapis) and for adult male okapis (older than 3 years) the average weight is: 253 kg (12 okapis).

Final remarks

At the end of the questionnaire, zoos were asked if to share further information with us that could be useful or to give remarks about the questionnaire itself.
Five zoos gave remarks which contained mainly additional information on the offered diet of the zoos to their okapis.
These results are summarized in a table that is given in appendix 3, table M.

Chapter 5, Discussion

5.1 Evaluation of the European okapi nutrition guidelines of 2001

When comparing the zoo diets of 1998 with those of 2006 concerning the average ingredient composition in percentages as fed, it shows that in general, the percentages for fruits and vegetables and concentrates have decreased and the percentages for browse and Lucerne hay have increased from 1998 to 2006.
When comparing the zoo diets of 1998 with those of 2006 concerning the average nutritional composition in percentages as fed, it can be observed that on the whole, CP, NDF and ADF percentages (DM-basis) have increased and NFE has (therefore) decreased.

In 2001, the European okapi nutrition guideline was established. In table 26 below, recommended ingredient values belonging to the nutrition guideline of 2001 will be compared with those values belonging to zoo diets resulting from the questionnaire of November 2006. In table 27, this comparison was also done on a nutritional basis. The final table 28 shows possible relations between the participation of several zoos with the okapi research of 1998, the satisfaction with the nutrition guideline of 2001, if the zoos apply this nutrition guideline in their own opinion and to what level the zoos actually apply this guideline on feedstuff basis and nutritional basis.

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Table 26: *Comparison recommended ingredient composition (taken from the nutrition guideline 2001) and ingredient composition offered in zoos (taken from European okapi questionnaire, November 2006)*

	Fruits &Vegetables + browse %			**Fruits &Vegetables + browse**	**Lucerne hay %**	**Lucerne hay**	**Pellets %**	**Pellets***	**Number of corresponding ingredient values**
Nutrition guidelines 2001	**0-25**				**>=50**		**>=25**		
	F&V	**Br**	**Tot.**						
Antwerp	16	10	26	+	52	0	28	0	**2/3 (66,6%)**
Basel	20	33	52	+	33	-	11	-	**0 (0%)**
Beauval	36	0	36	+	46	-	18	-	**0 (0%)**
Chester	27	19	46	+	25	-	25	0	**1/3 (33,3%)**
Frankfurt	5	16	21	0	77	0	7	-	**2/3 (66,6%)**
Koln	18	6	24	0	50	0	31	0	**3/3 (100%)**
Lisboa	10	20	30	+	46	-	22	-	**0 (0%)**
London	13	13	26	+	39	-	35	0	**1/3 (33,3%)**
Marwell	35	3	38	+	36	-	27	0	**1/3 (33,3%)**
Rotterdam	23	10	33	+	49	-	18	-	**0/3 (0%)**
Stuttgart	48	10	58	+	22	-	22	-	**0 (0%)**
Wuppertal	37	18	55	+	29	-	15	-	**0 (0%)**
Total				**2*0, 10*+**		**3*0, 9*-**		**5*0, 7*-**	

0 = value within range of nutrition guideline 2001

- = value below range of nutrition guideline 2001

+ = value above nutrition guideline 2001

* for this comparison, pellets comprise all offered concentrates

As table 26 shows, only one zoo diet contains percentages of ingredients according to the nutrition guideline of 2001 and 5 zoos do not feed any ingredients according to this guideline at all.

In the nutrition guideline of 2001, fruits and vegetables are put together with browse in the same category. This is remarkable, since fruits and vegetables and browse differ greatly in their nutritional composition (fibre content and easily digestible carbohydrates), which makes it illogical to take these feedstuffs together. Doing so can cause confusion, as can be seen in column 'F & V' in which 5 zoos over-feed the nutrition guideline for 'fruits and vegetables and browse' by fruits and vegetables alone. When taking in browse as well, this causes total levels of fruits and vegetables and browse high above the recommended range for this category according to the nutrition guideline of 2001. Therefore it was decided to divide this category in three columns (in table 26 above); one meant for fruits and vegetables, one for browse and the last column represents the total of these two feedstuffs, to make it comparable with the nutrition guideline of 2001. In this way, amounts of fruits and vegetables and browse offered per zoo per okapi are specified, to make a clear understanding of total amounts of fruits and vegetables and browse fed per zoo.

When looking at Lucerne hay, most zoo diets contain less Lucerne hay than recommended by the nutrition guideline of 2001. For pellets, it shows that the majority of zoo diets contain lower pellet percentages than recommended. This recommended percentage is quite high, since pellets (concentrates) contain a high amount of easily digestible carbohydrates compared to the natural diet, which can cause health problems like rumen acidosis and laminitis (Clauss and Kiefer, 2003).

Especially fruits and vegetables and concentrates will be eaten, since these feedstuffs are expected to be preferred by okapis in captivity. This will distort the balance between the offered amounts of feedstuff and the actual intake of certain feedstuffs. Therefore the intake diet probably contains a higher percentage of easily digestible carbohydrates compared with the offered diet which is shown in the previous table.

Table 27: *Recommended nutritional composition and nutritional composition offered in zoos compared (taken from European okapi questionnaire, November 2006)*

	CP %	CP	NDF %DM	NDF	ADF %DM	ADF	Ca %DM	Ca	P %DM	P	Fe (mg/kg DM)	Fe	Zn (mg/kg DM)	Zn	Mg %DM	Mg	Nr of corresponding nutritional values
Nutrition guidelines 2001	17-20		20-35		13-18		0,7-0,97		0,36-0,40		126 - 139		54-68		0,18-0,24		
Antwerp	17,5	0	34,9	0	22,1	+	1,1	+	0,37	0	212,2	+	64,9	0	0,23	0	**5/8 (62,5%)**
Basel	16	-	39,1	+	26,1	+	1,25	+	0,38	0	240,2	+	101,8	+	0,24	0	**2/8 (25%)**
Beauval	16,5	-	34,4	0	21,8	+	1,1	+	0,34	-	205,1	+	43,3	-	0,24	0	**2/8 (25%)**
Chester	14,6	-	35,5	+	24,5	+	1,0	+	0,37	0	263,7	+	76,9	+	0,27	+	**1/8 (12,5%)**
Frankfurt	18,3	0	41,8	+	27	+	1,24	+	0,32	-	234,6	+	47,8	-	0,26	+	**1/8 (12,5%)**
Koln	16,9	-	32,5	0	20,1	+	1,1	+	0,4	0	202,3	+	57,6	0	0,21	0	**4/8 (50%)**
Lisboa	17,7	0	34,7	0	22,2	+	1,2	+	0,36	0	199,5	+	60,0	0	0,23	0	**5/8 (62,5)**
London	18,1	0	34	0	21,3	+	1	+	0,5	+	256,1	+	90,7	+	0,28	+	**2/8 (25%)**
Marwell	14,4	-	22,3	0	14,3	0	0,66	-	0,27	-	137,9	0	26,8	-	0,2	0	**4/8 (50%)**
Rotterdam	17,1	0	37,2	+	23,8	+	1,2	+	0,38	0	246,2	+	74,6	+	0,26	+	**2/8 (25%)**
Stuttgart	13,7	-	18,4	-	12,2	-	0,78	0	0,25	-	103,6	-	20,5	-	0,17	-	**1/8 (12,5%)**
Wuppertal	17	0	32,8	0	20,5	+	0,94	0	0,3	-	167,0	+	33,4	-	0,21	0	**4/8 (50%)**
Total		**6*0 6*-**		**7*0 1*- 4*+**		**1*0 1*- 10*+**		**2*0 1*- 9*+**		**6*0 5*- 1*+**		**1*0 1*- 10*+**		**3*0 5*- 4*+**		**7*0 1*- 4*+**	

CP = Crude protein **P = Phosphor** **0 = value within range of nutrition guideline 2001**
NDF = Neutral detergent fibre **Fe = Iron** **- = value below range of nutrition guideline 2001**
ADF = Acid detergent fibre **Zn = Zinc** **+ = value above range of nutrition guideline 2001**
Ca = Calcium **Mg = Magnesium**

Four zoo diets comply with 4 or more of the recommended nutritional values from the nutrition guideline of 2001. Most of the zoo diets comply with CP, NDF, P and Mg values recommended in the nutrition guideline of 2001.

Six out of 12 zoo diets contain CP percentages according to the nutrition guideline of 2001 and the remaining 6 zoos diets contain CP percentages below the recommended CP percentage range. Most zoo diets contain NDF percentages according to the nutrition guideline of 2001, but most of these zoo diets also contain ADF percentages higher than the recommended ADF percentage range.

In the next table the results of the 2 tables above are summarized and compared with the participation of zoos with the research of 1998, the satisfaction of the zoos with the nutrition guideline of 2001 and if zoos apply this nutrition guideline in their own opinion.

Table 28: *Relation between satisfaction and application of the nutrition guideline and the total of corresponding ingredient and nutritional values of zoo diets*

	Participation Research 1998	**Satisfaction Nutrition Guideline 2001**	**Applying Nutrition Guideline**	**Number of corresponding ingredient values (3)**	**Number of corresponding nutritional values (3*)**
Antwerp	+	-	+	**3**	2
Basel	+	+	-	0	0
Beauval	-	+	-	0	1
Chester	-	+	+	1	0
Frankfurt	-	+	-	2	1
Koln	+	-	-	**3**	1
Lisboa	-	+	+	0	2
London	-	+	-	2	2
Marwell	+	+	-	1	2
Rotterdam	+	-	+	1	1
Stuttgart	+	+	-	0	0
Wuppertal	+	-	-	0	2
Total	**7+,5-**	**8 +, 4 -**	**4 +, 8 -**		

* = CP, NDF and ADF values
+ = Yes
- = No

All four zoos which stated not to be satisfied with the nutrition guideline of 2001, participated in the research of 1998. Only one of four zoos which stated to apply the nutrition guideline of 2001 almost completely applies the nutrition guideline of 2001 in its feeding practice. Two zoos completely applied the recommended ingredient composition of the 2001 nutrition guideline but did not reach the recommended nutritional composition set by this guideline.
This shows that even where the recommended ingredient values are followed, it is still possible not to reach the recommended nutritional values.

5.2 Quality of the zoo diets

The quality of zoo diets can, to a certain level, be determined by comparing the nutritional values obtained by the questionnaire of 2006 with the nutritional values of the natural diet. CP, NDF and ADF percentages represent the most important nutritional information, also because these nutritional values can be related with several health problems mentioned earlier in Chapter 2. Therefore from now on, only these three nutritional values will be used in tables for comparison. Analysis was done on samples of concentrates and Lucerne hay received from two zoos. Since browse is the only known component of the natural diet, some preferred natural browse species will be compared with the offered browse species in European zoo diets on their CP, NDF and ADF percentages (Hart et al., 1989).

Table 29: *Comparison nutritional composition of the natural diet and European captive diets*

Nutritional values	Natural Diet (Hart et al.)	Nutr. Guidel. 2001	Antwerp		Basel		Beauval		Chester		Frankfurt		Köln		Lisboa		London		Marwell		Rotterdam		Stuttgart		Wuppertal	
DM (%)	17,5	-	70,2	+	55,3	+	58,2	+	60,2	+	78,4	+	70,3	+	67,4	+	70,8	+	60,5	+	63	+	52,5	+	46,9	+
CP (%DM)	15,3 – 16,4	17-20	17,5	+	16,0	0	16,5	+	14,6	-	18,3	+	16,9	+	17,7	+	18,1	+	14,4	-	17,1	+	13,7	-	17	+
NDF (%DM)	44,7	20-35	34,9	-	39,1	-	34,4	-	35,5	-	41,8	-	32,5	-	34,7	-	34	-	22,3	-	37,2	-	18,4	-	32,8	-
ADF (%DM)	34,8	13-18	22,1	-	26,1	-	21,8	-	24,5	-	27	-	20,1	-	22,2	-	21,3	-	14,3	-	23,8	-	12,2	-	20,5	-
NFE (%DM)	**30,8****	**41,3**[2]	34,4[1]		33,2[1]		36,7[1]		36,4[1]		26,8[1]		37,9[1]		34,3[1]		35,4[1]		49[1]		32,9[1]		56,9[1]		38,5[1]	
Total rating per zoo:			**2+/2-**		**1+/2-/1*0**		**2+/2-**		**1+/3-**		**2+/2-**		**2+/2-**		**2+/2-**		**2+/2-**		**1+/3-**		**2+/2-**		**<u>1+/3-</u>**		**2+/2-**	

* = Body Weight (Average Ash percentage is taken from the 6 preferred browse species from table 33a below)
** = 100% - (average Ash% (8,6%) + CP% + NDF%) [1] = 100% - (Ash% + CP% + NDF% + CFat%)
[2] = 100% - (average ash (8,6%) + CP% + NDF% + average CFat% (4,14%)) [3] = kcal/ kg DM
0 = value within range of natural diet/ **-** = value below range of natural diet/ **+** = value above natural diet

Table 29 on the previous page shows that no zoo diet complies with any of the nutritional values from the natural diet. The CP percentage of only one zoo diet lies within the CP percentage range of the natural diet. In the nutrition guideline of 2001, the CP percentage range is higher compared with the CP range of the natural diet, but the NDF and ADF percentage ranges are lower in the nutrition guideline of 2001 compared with the NDF and ADF percentages of the natural diet.

The nutrition guideline of 2001 recommended a DM intake of 1,8% per Body Weight (BW) of an okapi. To ensure this DM intake, the offered DM should be 2 – 2,4% per BW, according to this nutrition guideline. The questionnaire results are only given on an as offered basis, which is why the offered DM in zoo diets per BW of the okapis will only be compared with the recommended offered DM of 2-2,4% per BW.

Table 30: *Offered DM% per BW, per zoo, compared to the nutrition guideline 2001*

	Offered DM% per BW (as offered)	**Applying nutrition guidelines 2001**
Nutrition guidelines 2001	2 – 2,4	
Antwerp	1,6	-
Basel	ND	ND
Beauval	2,4	0
Chester	2,3	0
Frankfurt	4,3	+
Koln	1	-
Lisboa	1,8	-
London	2,7	+
Marwell	ND	ND
Rotterdam	2,1	0
Stuttgart	1,6	-
Wuppertal	2,9	+
Total	**Average: 2,3**	**4*-, 3*0, 3*+**

BW = Body Weight
ND = No Data was given on BW of the okapis
0 = within the recommended range of nutrition guideline 2001
- = below the recommended range
+ = above the recommended range

One zoo offers only half of the minimum recommended DM% per BW, while 1 other zoo offers almost twice the recommended DM% per BW.

Table 31: *Comparison energy requirement (Kleiber rule) for okapis with offered energy in zoo diets*

	Energy (total kcal in DM)	**Applying energy maintenance requirement (Kleiber rule)**
Energy content in natural diet* **	6615 - 6773	
Recommended energy content okapi intake diet (Nutrition guideline 2001)**	8786 (m) - 9753 (f)	
Average okapi energy maintenance requirement (Kleiber rule)*	6967 - 9288	
Antwerp	7432	0
Basel	9761	+
Beauval	12618	+
Chester	11080	+
Frankfurt	16244	+
Koln	6202	-
Lisboa	16195	+
London	18218	+
Marwell	24310	+
Rotterdam	10362	+
Stuttgart	12867	+
Wuppertal	17514	+

* Averaged between male and female okapi maintenance requirements. The maintenance requirement for an adult female okapi (284 kg.) is 7268 – 9689 kcal per day/okapi (= 30,41 – 40,54 MJ per day per okapi) and for an adult male okapi (253 kg.) it is 6666 – 8886 kcal per day/okapi (= 27,89 – 37,18 MJ per day per okapi) according to Kleiber.
** 3,5 * x gr. CP + 8,5 * x gr. CFat + 3,5 * x gr. NFE = kcal per diet.
m = recommended energy intake male okapi (average weight 253 kg.)/ f = recommended energy intake female okapi (average weight 284 kg.)
*** 3,5 * x gr. CP + 3,5 * x gr. NFE = kcal in natural diet. (CFat was not taken into the calculation since it can be expected that hardly any fat is present in the natural diet)
0 = value within energy maintenance requirement/ **-** = value below energy maintenance requirement/ **+** = value above energy maintenance requirement

Overall, zoo diets offer above the average okapi energy requirements (Kleiber rule). Only one zoo offers below this energy requirement and one zoo feeds within the energy requirement range. From these results it can be expected that most captive European okapis are taking in more energy than required and might therefore experience more obesity problems. The energy content in the natural and recommended okapi diet are below the average okapi energy maintenance requirement.

To compare the nutritional values given in literature with the actual nutrient values, analysis was done on concentrate and hay samples received from two zoos (Table 32 on the next page).

Table 32: *Comparison of the value of the nutritional composition of Lucerne hay and concentrates between literature and analysis*

London	DM (%)	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	CF (%DM)
Can. Clover (Lucerne hay) (T&G, Zt)	85	9,8	18,7	43,5	28,2	34,1
Can. Clover (Analysis averaged total sample)	87,2	11,9	23,5	43,1	26,3	20,5
Can. Clover (Analysis rough sample)	86,5	10,5	21,3	47,6	32,4	30,5
Can. Clover (Analysis residue sample)	87,9	13,2	25,6	38,5	20,1	10,5
Dairy 16 pellets (T&G, Zt)	90	8,2	19	32,2	17,2	13,9
Dairy 16 pellets (Analysis)	88,2	9,4	18,8	45,5	16,9	10,4
Oats&Bran (T&G, Zt)	93,5	3,1	18,5	-	-	-
Oats&Bran (Analysis)	88	5,2	16,8	46,3	18,1	12,6
Linseed cake (T&G, Zt)	91	5,16	23,9	-	-	10,33
Linseed cake (Analysis)	87,3	9,2	33,8	46,4	24,6	13,2
Stuttgart	DM (%)	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	CF (%DM)
Horse pellets (T&G, Zt)	88	10,1	16,7	23,3	10,6	7,8
Horse pellets (Analysis)	88,7	8,8	18,5	46,1	18,6	15,4
Lucerne hay (T&G, Zt)	85	9,8	18,7	43,5	28,2	34,1
Lucerne hay (Analysis)	86,5	8,8	15,5	59,3	45,5	40,8

T&G = Zoo Animal Nutrition Tables and Guidelines (Jansen and Nijboer, 2003), Zt = Zootrition V2.6

Values for Lucerne hay were used for comparison with the analysis data from Canadian clover. Table 32 shows that the NDF value for Dairy 16 pellets differs quite from the values in literature, Also, the NDF, ADF and CF values for horse pellets and Lucerne hay samples differ quite from the values taken from literature, as well as the CP value for the linseed cake sample.

In tables 33a and b, the 6 most preferred natural browse species (Hart et al., 1989) will be compared with the offered browse species and Lucerne hay in captivity on CP, NDF and ADF percentages. These 6 preferred browse species are a result of a trial performed under semi-natural conditions in the Epulu research centre in Congo.

Table 33a: *Comparison of the value of the nutritional composition of preferred browse species in the natural diet and captive diets*

Preferred browse species Natural diet	**DM (%)**	**CP (%DM)**	**NDF (%DM)**	**ADF (%DM)**
Rinorea oblongifolia	30,8	16,1	44,2	31,8
Tremma guineensis	29,3	21,4	29,2	25,1
Macaranga monandra	37,6	17,5	31,7	26,6
Aidia micrantha	34,4	14,5	43	38,6
Ricinodendron heudelotii	23	30,3	26,7	23,2
Macaranga spinosa	39,9	15,2	29,2	23,8
Ranges preferred natural browse species	23-39,9	14,5-30,3	26,7-44,2	23,2-38,6

Table 33b: *Comparison of the value of the nutritional composition of preferred browse species in the natural diet and captive diets*

Browse species and Lucerne hay captive diet	**DM (%)**		**CP (%DM)**		**NDF (%DM)**		**ADF (%DM)**		**Number of corresponding nutritional values (4)**
Black willow (*Salix sp.*) (twigs&leaves)**	41	+	12,3	-	50,1	+	38,6	0	1
Dried ash (*Fraxinus sp.*) (twigs&leaves)*	100	?	17,1	0	ND	?	ND	?	1
Dried linden (*Tilia sp.*) (twigs&leaves)*	100	?	19,5	0	ND	?	ND	?	1
Dried raspberry (*Rubus idaeus*) (leaves)*	100	?	11,7	-	43,7	0	25,1	0	2
Beech (*Fagus sp.*) (twigs&leaves)*	40,7	+	8,7	-	74	+	58,8	+	0
Dried oak stick (*Quercus sp.*) (twigs&leaves)*	100		14	-	ND	?	ND	?	0
Silver maple (*Acer sp.*) (twigs&leaves)**	50,1	+	9,9	-	41,7	0	30,7	0	2
Lucerne hay**	85	+	9,8	-	43,5	0	28,2	0	2
Total	4*+		6*-/2*0		2*+/3*0		1*+/4*0		

* = Zootrition V2.6
** = Zoo Animal Nutrition Tables and Guidelines, (Jansen and Nijboer, 2003)
0 = value within range of natural diet
- = value below range of natural diet
+ = value above range of natural diet

The CP and ADF percentages of the preferred browse species comprising the natural diet can be seen as more or less equal compared to those percentages belonging to browse species offered in captivity. The NDF percentages of the preferred browse species comprising the natural diet are somewhat lower than the NDF percentages of the browse species comprising the captive diets.

The NDF and ADF percentages of Silver maple and dried raspberry leaves comply with the percentage range of NDF and ADF in preferred natural browse species. Besides Silver maple and dried raspberry leaves, also willow contains an ADF percentage within the ADF percentage range of the preferred natural browse species.
Beech and dried oak sticks are two other browse species offered in captivity which do not comply with any of the four mentioned nutritional values of the preferred natural browse species.

Lucerne hay is not a browse species, but is also compared because it is a large component in most zoo diets and can compensate the NDF and ADF percentages in the zoo diets since low amounts of browse are offered to okapis in captivity compared with the natural diet.

5.3 Health of the captive okapi

The health of okapis in captivity depends greatly on the composition of the offered diet. A frequently occurring health problem with okapis in captivity are hoof problems (mostly laminitis). In the first table an attempt is made to relate the hoof problems to the amounts of some offered feedstuffs, sex and average age of the okapis. In the last table an attempt will be made to relate the Body Condition Scores (BCS) to age, weight and incidence of hoof problems with okapis.

<u>Hoof problems</u>

Table 34: *Relation average age, sex, fruits & vegetables and concentrates with the appearance of hoof problems*

Zoos	Average age	Sex	Average fruits & vegetables offered per okapi per day as fed (given in grams)	Average concentrates offered per okapi per day as fed (given in grams)
<u>7 zoos</u> (12 okapis with hp, 20 okapis with nhp)	**11 y, 6m** (12 okapis with hp) **6 y, 6m** (20 okapis with nhp)	**8 Females,** **4 Males** **(**okapis with hp**)** **10 Females,** **10 Males** (okapis with nhp)	**2850 grams** (offered/okapi in zoos with hp)	**2188 grams** (offered/okapi in zoos with hp)
<u>5 zoos</u> (0 okapis with hp, 10 okapis with nhp)	**7y, 5m** (10 okapis with nhp)	**3 Females,** **7 Males** (okapis with nhp)	**1964 grams** (offered/okapi in zoos with nhp)	**1720 grams** (offered/okapi in zoos with nhp)

Hp = hoof problems Nhp = no hoof problems y = years m = months

As is shown in the table above, the 7 zoos that experience(d) hoof problems offer a diet, which among other feed categories, contains on average 2850 grams fruits & vegetables and on average 2188 grams concentrates. The other 5 zoos that do not experience(d) hoof problems offer on average 1964 grams fruits & vegetables (886 grams less) and 1720 grams concentrates (468 grams less). As in literature (Claus and Kiefer, 2003; Socha et al., 2005), these results also indicate a positive correlation between a diet containing high amounts of easily digestible carbohydrates and hoof problems with okapis.

In zoos that experience(d) hoof problems in some of their okapis, the average age of okapis with no hoof problems is 6 years and 6 months, which is on average 5 years less than the average age of okapis with hoof problems in those zoos. These results indicate a positive relationship between age and hoof problems. The overall average age of the 32 okapis (with and without hoof problems) in these zoos that experience hoof problems is 9 years.

In zoos that do not experience hoof problems in any of their okapis, the average age of their okapis is 7 years and 5 months. The average age of their okapis is 1 year and 7 months less than the overall average age of okapis in zoos that experience(d) hoof problems. This might indicate that zoos that keep older okapis, also experience more hoof problems.

According to literature, the okapi diet should contain less easy digestible carbohydrates (NFE) in order to prevent hoof problems. In the next table unmolassed beet pulp (UBP), fruits and vegetables and concentrates will be compared on their DM, CP, NDF, ADF and NFE.

Table 35: Comparison average nutritional values of unmolassed beet pulp, fruits & vegetables and concentrates

Nutritional value	UBP	Fruits& Vegetables	Concentrates
DM:	89%	11,5%	82,6%
CP:	10,3%	17,3%	15,6%
NDF:	58%	17,9%	22,5%
ADF:	24%	12,1%	13,3%
NFE:	25,1%	57,9%	53,5%

(Hyslop and Cuddeford, 1999; Jansen and Nijboer, 2003; Schmidt et al., 2005)
Percentages are given on a DM basis

This table shows that UBP contains less NFE than fruits and vegetables and concentrates. Therefore this feedstuff should be considered a suitable substitute for fruits and vegetables and concentrates.

With the results in table 34 above, it is impossible to separate the influence of concentrates and age on hoof problems. Also the population of okapis with hoof problems from zoos participating with the questionnaire (November 2006) is too small to determine the separate influences of concentrates and age on hoof problems.

Obstruction of the gastrointestinal tract

From the 12 zoos, 2 zoos indicated to experience health problems concerning obstruction of the G.I. tract in one of their okapis. It is remarkable that only these two zoos offer *Robinia pseudoacacia* as browse and the other 10 zoos don't. From literature (**http://www.neerlandstuin.nl/bomen/robinia1.html**) it can be stated that the robinia's plant parts are very hard to saw or to break. This could mean that using this species as a browse species for okapis could cause difficulties with the digestion of this hard rough material. These results might indicate a positive correlation between feeding *Robinia pseudoacacia* and the appearance of obstruction in the G.I. tract in okapis. All parts of the plant (except the flowers) and especially the bark, should be considered to be toxic.

Body condition score

When the condition of an animal needs to be determined, a BCS system is a helpful tool. Zoos scored their own okapis according to the BCS system of Disney's Animal Kingdom (2005). With these BCS's an attempt will be made to find a relation between these BCS's, average age, average weight, the appearance of hoof problems with okapis and the amount of energy offered per okapi.

Table 36: Comparison BCS with average age and weight

BCS	**2**	**3**	**4**
Nr. of okapis	3	34	5
Average age	11y, 7m	7y, 3m	11y, 6m
Average weight	274,7 kg (3 okapis)	245,9 kg (26 okapis)	260,2 kg (5 okapis)
Okapis with hoof problems	1 (33%)	9 (26,5%)	2 (40%)
Average offered energy/okapi/day (kcal)	10728	14828	14369

2 = thin 4 = fat
3 = good m = months y = years

The okapis that had a BCS of 3, are the youngest in average age compared to the okapis that were scored with a BCS of 2 and 4. The average age of the okapis that were scored with a BCS of 2 and 4 do not differ much in average age. The average weights of okapis with different BCS are also not very different from each other. Since only 4 okapis were scored with a BCS of 2 and also 4 okapis with a BCS of 4, these results are less representative when compared to the number of okapis that were scored with a BCS of 3. When looking at the number of okapis with hoof problems in relation to their BCS, no relation can be found. When looking at the average offered kilocalories (kcal) per okapi per day and their BCS, only the okapis with a BCS of 2 are offered less kcal per okapi per day compared with the okapis with a BCS of 3 and 4. No difference in offered energy and BCS 3 and 4 could be found. This shows that the expectation mentioned earlier about obesity problems in European captive okapis, could not be found and concluded from the results in the table above.

Since BCS is a quite new phenomenon in zoos, the person(s) scoring the okapis is/are not very experienced, which may cause distorted scoring results. This might be the case for the okapi BCS results for this questionnaire (November 2006). Therefore it is difficult to relate the BCS of this questionnaire to the age and weights of the okapis from zoos that participated with the questionnaire (November 2006).

Chapter 6, Conclusion

1) What is the ingredient and nutritional composition of the diet for okapis in the wild?

The diet of a wild okapi is composed almost entirely of the leaves of dicotyledenous plants of the shady forest understory (See species list, appendix 1). The soft, young leaves were more preferred than the hardened, fully expanded leaves. Okapis have not been observed eating fruits and vegetables in nature.

The observed natural diet (Hart and Hart, 1988) contained 15,3-16,4% CP, 44,7% NDF, 34,8% ADF, 30,8% NFE (calculated) on a DM basis.
From a preference trial (Hart et al., 1989), it is concluded that the most preferred foliage contained the following nutritional values; 14,5-30,3% CP, 26,7-44,2% NDF, 23,2-38,6% ADF, 31,3-50,6% NFE (calculated).

2) What is the current ingredient and nutritional composition of the diet for okapis in captivity and what are the main differences from the diet in the wild?

Main ingredient differences between the natural diet and diets fed in captivity
In European zoo diets, fruits and vegetables compositions range from 5% up to 48% on a DM basis. Okapis have not been observed eating fruits or vegetables in nature (Hart et al., 1989).
Browse compositions in zoos ranges from 0% up to 33% on a DM basis. The ingredient composition of the okapis' natural diet contains 100% browse.
Lucerne compositions range from 22% up to 77% on a DM basis and concentrates compositions range from 7% up to 35% on a DM basis. Obviously no Lucerne or concentrates are available in nature.

Main nutritional differences between the natural diet and diets fed in captivity
European zoo diets range from 47,6% up to 78,2% DM in their diets whereas the natural diet contains 17,4% DM.
In European zoo diets NDF ranges from 21,7% up to 41,4% on a DM basis. The NDF percentage in the natural diet contains 44,7% on a DM basis.
In European zoo diets ADF ranges from 14,4 % up to 27% on a DM basis. The ADF percentage in the natural diet contains 34,8% on a DM basis.
In European zoo diets, CP ranges from 14,3% up to 18,5% on a DM basis. The CP percentage in the natural diet ranges from 15,3% up to16,4% on a DM basis, which can be considered equal to each other.

3) How can the differences between the natural diet and the diet in captivity for okapis be used in order to explain occurring health problems among okapis in captivity?

Fruits & vegetables and concentrates (easily digestible carbohydrates)
The natural diet does not contain any fruits or vegetables and obviously no concentrates. In zoos, these are offered on a daily basis in relative high amounts. Okapis are expected to prefer these feedstuffs and expected to be taken in completely by the okapis. The high amounts of easily digestible carbohydrates in the captive intake diets, compared to the natural diet, are a possible explanation for the occurrence of rumen acidosis, hoof problems and glucosuria.

Browse (phenolic glycosides and tannins)
In nature, there is a great variety in browse species every day (+/- 150 browse species available in total, 30-35 different species eaten per day). Therefore the same types of phenolic glycosides and tannins do not built up in the organs of the okapi. In captivity, usually no more then 2 browse species are fed per day. The most offered browse species in captivity is willow, which is also preferred by the okapis among other browse species. The salicylic acid and tannins are expected to cause health problems to kidneys and it worsens the symptoms of rumen acidosis.
Acacia (*Robenia pseudoacacia*) offered to okapis in captivity could be a possible explanation for the obstructions of the gastrointestinal tract because of its star structure.

In order to answer the main question ("In what way do the current feeding practices in European zoos need to be altered in order to meet the nutritional requirements for okapis in captivity?") the obtained information from the three sub-questions can be summarized as follows;

- An attempt should be made in order to make the NDF and ADF percentages of the captive diets meet the NDF and ADF percentages of the natural diet, which can be obtained by increasing amounts of browse and Lucerne hay offered.
- To avoid health problems caused by the intake of high amounts of easily digestible carbohydrates, no fruits and vegetables should be offered. Also, the amount of offered concentrates should be reduced to a minimum.
- To avoid health problems caused by the intake and accumulation of a high amount of the same secondary plant compounds, more than 1 browse species should be offered each day.

Chapter 7, Recommendations

As is observed in the comparisons between the ingredient and nutritional values for the nutrition guideline of 2001 and those values for zoo diets (questionnaire 2006), shown previously in Chapter 6, it shows that even though the recommended ingredient values are followed, it is still possible not to reach the recommended nutritional values. Therefore the to be revised okapi nutrition guidelines should leave no room for interpretation within feeding practice for okapi keepers.

First of all, the ingredient requirements will be dealt with in table 37. It shows the recommendations for the to be revised okapi nutrition guidelines set during the meeting in Antwerp on December the 18th (See appendix 7) and personal recommendations calculated by the authors (See appendix 6 for calculations).

Table 37: *Ingredient recommendations for the okapi in captivity*

Ingredients	**Recommendations Antwerp (18-12-2006, appendix 7)**	**Personal recommendations (03-04-2007)**
Fruits (% DM)	0	0
Vegetables (% DM)	0	0
Browse (% DM)	=>15	=>15
Lucerne (% DM)	=>50	=> 55 (preferably ad libitum)
Concentrates (% DM)	=< 30 (10-12% concentrates and 18% unmolassed beet pulp)	=< 30 (10-12% concentrates and 18% unmolassed beet pulp)

Following, the nutritional recommendations will be dealt with in table 38 below.

Table 38: *Nutritional recommendations for the okapi in captivity*

Nutrients	**Nutritional recommendations per okapi per day**
Energy (ME, kcal/okapi/day)	6666 – 8886 (male) ^{K} 7268 – 9689 (female)^K
CFat (%DM)	4 - 4,5*
CP (%DM)	18,5*
CF (%DM)	20,8*
NDF (%DM)	30 – 45^C
ADF (%DM)	20 – 35^C
NFE (%DM)	25 – 35^C
Ca (g/kg DM)	5,5*
P (g/kg DM)	3,5*
Mg (g/kg DM)	2*
Fe (mg/kg DM)	86*
Zn (mg/kg DM)	42*

* Values from Tables & Guidelines and Zootrition V2.6 are averaged
^{K} = Kleiber rule used
^{C} = Calculated (See appendix 6)

Fruits and vegetables

In the nutrition guideline of 2001, fruits and vegetables were put together with browse in the same category. This is remarkable, since fruits and vegetables and browse differ greatly in their nutritional composition. To avoid any confusion and to take away any room for interpretation, the recommended percentages of fruits and vegetables and browse should be divided and not put together in the same category.

Because okapis do not require fruits and vegetables in their diet and because these feedstuffs do not contribute a great deal to the nutritional value of the diet and contain high amounts of easily digestible carbohydrates, **amounts fed are reduced to 0 percent of the total diet**.

Browse

Since zoos can not offer a 100% browse diet to okapis, an obtainable percentage should be considered in the advice. On average 1,67 kg browse per day per okapi is offered in European zoos. In order to increase the average amounts of browse offered, and still keep the amount obtainable for zoos, it was decided that the average offered browse in zoos should increase with 10% → **1,84 kg. fresh browse → 14,4% ≈ 15% browse in the DM diet should be offered**.

To avoid the accumulation of the same types of (toxic) phenols, it is advised to feed **at least two different browse species every day** with the types of browse species being varied periodically (preferably every two months). With the current state of knowledge, the use of willow for okapi browse is not discouraged as long as it is not the main browse species. The structure of Acacia (*Robinia pseudoacacia*) and its possible negative effects on obstructions of the gastrointestinal tract should be further studied to determine whether this is a suitable browse species for okapis.

Lucerne hay

Lucerne hay provides nutrients as well as crude fibre (CF) which is essential for the digestive system to function properly. **For the intake of sufficient CF, Lucerne hay should make up for at least 53,8% ≈ 55% (DM) of the total diet**. Preferably, Lucerne hay should be offered **ad libitum** to compensate for amounts of browse which probably will be offered less than is recommended (=> 15%) in this advice (practical reasons).

Concentrates

Concentrates can provide the nutrients lacking in Lucerne hay and browse. Since concentrates contain a considerable amount of easily digestible carbohydrates, which can cause health problems, a maximum percentage of concentrates in the diet should be given in stead of a minimum percentage. It should also be taken into account that okapis are expected to consume all of their offered concentrates and beet pulp and therefore should not be offered more than 1,72 kg fresh concentrates and beet pulp **(32% ≈ 30% of the total DM diet)**.

For the introduced ingredient requirements for concentrates, there is a division between concentrates and unmolassed beet pulp. Unmolassed beet pulp is considered a high-fiber energy concentrate with a high NDF and ADF percentage**.**

Concentrates and unmolassed beet pulp should be fed in a ratio respectively 1:1,5, which translates into respectively 10-12% concentrates and 18% unmolassed beet pulp.

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