Elephant nutrition in Dutch zoos

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An inventory of the diets of the African elephant (*Loxodonta africana*) and the Asian elephant (*Elephas maximus*) in Dutch zoos

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Preface

This report was written in the scope of the final thesis project of the study Animal Management at Van Hall Larenstein in Leeuwarden, The Netherlands. Both of us choose the major Wildlife Management, with a module on animal nutrition.

Elephants are a difficult species to keep in zoos when it comes to all aspects of husbandry, and especially nutrition. Over the past few years, elephants have therefore been the centre of attention and a lot of focus has been put on correct elephant husbandry and nutrition. In light of this fact, several reports have been written, with the BIAZA 2010 [Walter, 2010] report on elephant husbandry being the most recent, that want to help contribute to improving elephant keeping. This project, an initiative of dr. J. Nijboer of Rotterdam Zoo and the NVD Nutritional Group, is therefore the start of a European-wide inquiry into the elephant diets to investigate if these comply to the nutritional requirements as described in literature.

We chose this study as our thesis project because we both would like to contribute to the improvement of elephant health and because of our growing interest in zoo nutrition.

We would like to thank everybody that helped us during this study, especially our supervisors T.R. Huisman and C. Oomkes from Van Hall Larenstein for their guidance, support, and commentating on the manuscript. We would also like to thank the following zoos for responding to our online survey:

- Natura Artis Magistra Amsterdam
- Burger's Zoo Arnhem
- Diergaarde Blijdorp Rotterdam
- Dierenpark Amersfoort Amersfoort
- Dierenpark Emmen Emmen
- Dierenrijk Europa Mierlo
- Ouwehands Dierenpark Rhenen
- Safaripark Beekse Bergen Hilvarenbeek

We hope this report will mark the start towards an inquiry into the health and nutrition of European zoo elephants.

Ingrid van Baarlen
Mercedes Gerritsen
Leeuwarden, Februari 2012

Summary

There is no clear overview of the current dietary practices and problems with regard to elephants within Dutch and Belgian zoos, so to be able to assess whether zoos comply with current requirements. The goal of this study was to gain insight in the present feeding practices of the African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants held in Dutch and Belgian zoos and to compare these to the current dietary ex-situ requirements for elephants.

Elephant are hindgut fermenters with a low digestive efficiency. Their natural diets vary enormously and are of low quality. The low digestive efficiency and low feed quality result in a high forage and feeding time of 15-18 hours a day.

Their diet in captivity, however, is relatively high in quality with a high energy and sugar content compared to the natural diet. Products like fruit, concentrates and bread lead to the high energy and sugar content. Obesity can be a result of this and is therefore a major problem among captive elephants. Other nutrition related health problems include foot problems, vitamin E deficiency, colic and hypocalcaemia.

To gain insight into the current feeding practices, 11 online survey questionnaires were sent out to Dutch and Belgian zoos holding elephants. The surveys contain questions about the animals, their diets, their body condition and their health. The results from the surveys' dietary questions were analysed by calculating the nutritional value (energy, dry matter and nutrients) of all the ingredient used in the diets. These results were then used to calculate the nutritional value of the diet per animal per day on a dry matter basis.

Of the 11 zoos that received the survey, 8 zoos replied. All 8 of these zoos were Dutch and this resulted in a 100% response rate from the Netherlands and 0% from Belgium.

The results show that a wide range of ingredients used in elephant diets, though there are six most commonly used, namely: grass hay, apple, concentrates, carrots, bread, and willow branches (in that order). All these ingredients were supplied in widely differing amounts in the various zoos, with differences of up to 59kg (grass hay).

There were 12 different diets in total: in some cases males and females are housed separately, and two zoos alternate between grass hay and fresh grass at different times of the year.

The results show that the roughage contained the highest proportion of most nutrients, with the exception of vitamin E and biotin.

The calculation of the average amount of energy offered by the zoos shows that none of the diets complied with the average MMR per animal. All diets are either too rich (7) or deficient (5) in the amount of energy. However, the calculation of the MMR did not take the age, sex or life stage of the elephants into consideration.

The calculated total nutritional composition shows major fluctuations between zoos in the total amount of ingredients, dry matter and energy, with one zoo (zoo 8) feeding significantly less than other zoos. The nutrient composition of the diets is similar, however , with the exception of the vitamin E and biotin levels, which do show major differences.

The conclusion that can be drawn from the results is that most diets do not differ extensively from the requirements, but that there are large exceptions. Zoo 8 showed a few major

deficiencies when compared to the requirements. Three other concerns include the calcium, phosphorus and vitamin E content. All three of these nutrients could have a serious effect on the health of the elephants when fed in incorrect amounts.

Zoos should monitor the health and weight of their elephants on a regular basis using either a weigh-bridge or Body Condition Scoring method. Also, zoos should keep good records of the ingredient amounts, changes in feeding behaviour of the animals and weight changes. Finally. roughage should be analysed on a regular basis so concentrates and supplements can be fed accordingly.

To be able to gain valuable and usable results for a diet study, it is necessary to let zoos know the importance of good record keeping and how data should be supplied. Also, if zoos are open to the idea, personal visits could be a possibility if time allows.

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1. Introduction

Numerous studies have been conducted into the diet of wild African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants. Two examples are Rode et al. (2006) and Santra et al. (2008).

In the wild, elephants are considered to be generalist feeders, consuming a large number and variety of plant species varying regionally and seasonally [Sukumar & Ramesh, 1995; Ullrey et al., 1997; Clubb & Mason, 2003], with Asian elephants utilizing up to 75 different species of plant [Shoshani & Eisenberg, 1982]. Several studies conclude that grasses are the predominant ingredient in the diet of wild elephants (both African and Asian elephants), with over 80% of the time spent feeding on this [Buss, 1961; Wing & Buss, 1970; Sukumar & Ramesh, 1995].

Animals make very complex choices when it comes to their food ingredients [Dierenfeld, 1997] and there is still a limited understanding of the factors that affect food choices [Baer et al. 2010]. It is, however, not necessary and also rarely possible to replicate these food choices and the ingredients when feeding captive animals [Dierenfeld, 1997; Baer et al., 2010], mostly because plants found in the wild differ in nutrient composition from the produce that is domestically grown [Baer et al., 2010]. It is, however, necessary that the diets fed to wild animals in captivity should meet the nutritional needs of the animals and should take the various digestive physiology and natural feeding behaviour into account [Baer et al., 2010]. Therefore it is important to focus on the nutrient content of food ingredients, making sure these are provided in the appropriate quantities and quality [Dierenfeld, 1997; Baer et al., 2010]. This will help in avoiding nutrition-related diseases, for many of the diseases observed in captive animals are a result of dietary nutrient deficiencies [Baer et al., 2010].

Several of these nutrition-related diseases and problems for elephants have been described in the past, for example vitamin E deficiency [Dierenfeld & Dolensek, 1988], colic [Walter, 2010], and foot problems [Sadler, 2001].

The most commonly found nutrition-related problem in elephants is obesity. Obesity can cause foot lesions [Fowler, 2001], and joint problems can worsen due to the excess weight [Hatt & Clauss, 2006].

Elephants in most zoos have been reported to be obese, or have surpassed the body mass of their wild conspecifics significantly [Ange et al., 2001]. Hatt & Clauss (2006) attribute this to the fact that there is a tendency to focus on mineral and vitamin levels in a diet, and overlook the energy levels in the food. It is clear that there is a strong correlation between the energy intake and the body condition, for an animal's body condition offers an assessable indication of the nutritional status of an individual animal [Hilderbrand et al., 1998] and the impact of the dietary management [Fernando et al., 2009].

Seeing as these health problems, especially obesity, can have severe negative effects on the animals' health, it is advisable to compose a diet that meets estimated nutrient requirements [Baer et al., 2010]. If, as Baer et al. (2010) says, it is not possible to replicate the food choices made in the wild, ensuring that nutrients of the appropriate quantity and quality are provided might be the next best thing to consider.

The nutrient requirement recommendations currently used for elephants in captivity are, however, not based on the natural diet of their wild conspecifics. Dierenfeld (2006) gives recommendations for nutritional requirements for elephants in a review. These requirements are based on recommendations for the domestic horse formulated by the National Research Council (1989 Standards) [Roehrs et al., 1989; Dierenfeld, 1994; Ange et al., 2001]. However, further research is necessary to determine the actual elephant requirements for elephants have a lower digestive efficiency than horses [Clauss et al., 2003].

While various aspects of elephant feeding, including the health problems and dietary requirements, have been explored in the past, a comprehensive dietary inventory of captive elephants in European zoos has not been made recently. The most recent welfare review containing a dietary component is a report commissioned by BIAZA in 2010, however this report only covers British and Irish zoos [Walter, 2010].

There is no clear overview of the current dietary practices and problems within Dutch zoos with regard to elephants. This study compares the current diets provided to the zoo elephants in 11 Dutch zoos to requirements found in husbandry guidelines of Dierenfeld (1994) and BIAZA (2010) and in-situ findings regarding nutritional composition of diets. These in-situ finding are described in chapter 3.2.3. This is done to be able to assess whether the zoo diets are similar to these requirements, and if any health problems that exist in zoos at the moment can possibly be traced back to suboptimal nutrition.

1.1 Objective

The main goal of this study is to gain insight into the present feeding practices of the African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in Dutch zoos, in particular with regard to the ingredient, energy and nutrient intake.

1.2 Research questions

Main question:

How much does the current nutritional composition for African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in Dutch zoos comply with recent nutritional guidelines for elephants?

This main question can be divided into two sub questions. To be able to answer these two sub questions, these have been further divided into a number of questions:

1. *What are the nutritional requirements for both species?*
    - 1.1 What is the nutritional composition of the in-situ diet of the African elephant and the Asian elephant?
    - 1.2 What is the nutritional requirement described in the literature for an ex-situ diet of the African elephant and the Asian elephant?

2. *What is the current nutritional composition of the diets in Dutch zoos?*

1.3 Definitions

The definitions of the used terms in this report are as follows:

Elephant

During this project the term ‘elephant’ has been used when both the African elephant (*Loxodonta africana*) and the Asian elephant (*Elephas maximus*) are meant. If any information or reference applies to just one of the two species, this has been explicitly mentioned by using the species name or this will be clearly indicated.
Recent studies are speculating that there are two species of African elephant, namely the African savannah elephant (*Loxodonta africana*) and the African forest elephant (*Loxodonta cyclotis*) [Roca et. al, 2001]. This study does not make any differentiation between these two species in the survey and survey results, and has combined both under the name of African elephant (*Loxodonta africana*). These species have, however, been defined as two species in the literature review, and have been explicitly mentioned in the text.

In-situ situation

The term in-situ means the wild situation of the elephant, so anything that has to do with their natural habitat and nutritional requirements.

Ex-situ situation

The term ex-situ means the captive situation of the elephant, so anything that has to do with their living situation and diet in a zoo.

Nutritional composition/nutritional requirement

Within this report the nutritional composition/nutritional requirement of a diet or ration includes the ingredients and their amounts in grams, daily amount of energy and the amount of nutrients (kg/DM) within that diet or ration.

1.4 Research population

The research population of this study consists of the ex-situ population of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants held in Dutch zoos that are a member of the European Association for Zoos and Aquaria (EAZA). The total number of African elephants held in zoos at the moment is 8 (2.6.0) and of Asian elephants is 45 (15.30.0) across a total number of 11 (2 with African elephants and 9 with Asian elephants) zoos. This means that 11 surveys will be sent out [EAZA African elephant annual report, 2010; EAZA Asian elephant studbook, 2011].

The number of expected responses lies between the 25-50%, based on a number of similar dietary studies that sent out surveys to zoos (Nutritional requirements of the European mink by K. Bergman and J. Elzinga in 2003 with a response of 29%, Evaluation of the EAZA colored leg band service by I. van Baarlen in 2010 with a response of 31%).

2. Methodology

This chapter deals with the methods used while conducting the study which is presented in this report, beginning with the method of data collection and continuing with an explanation as to how the data was analysed and processed.

This report consists of two parts, namely a literature study and the results from the survey. The purpose of the literature study was to gather information about biology and nutrition relating to the African (*Loxodonta africana*) and the Asian (*Elephas maximus*) elephants. The survey results provide an inventory of the daily elephant diet at the responding zoos, including the nutritional composition of these diets, and a calculation of the energy these diets provide versus the actual energy requirements.

The 'Method of data collection' section below primarily explains how the literature review was conducted and provides information about the survey. The 'Analysis and processing of the data' paragraph then concentrates on the survey results and describes how the nutritional composition of the current ex-situ diets was calculated.

2.1 Method of data collection

2.1.1 Literature review

A literature review was conducted to gather information on both elephant species, including their digestive system, habitat, foraging behaviour, in-situ diet composition, estimated ex-situ diet recommendations, and the nutritional composition of the diet ingredients that the zoos indicated they use. The focus was on the nutrition of the elephants both in-situ and ex-situ.

General information about the elephant

The literature review begins with general information about both elephant species with regard to the taxonomy, the biology and the physiology of the digestive tract. 'Animal biology' describes the biological characteristics of both species and the differences between them. Following this, a description of the in-situ situation, namely their habitat, their foraging behaviour and the nutritional composition of the wild diets. Lastly, a description of the ex-situ diets, health problems found in captivity, and critical nutrients.

Nutritional composition of the current ex-situ diet ingredients

As part of the survey, each respondent provided information about the ingredients they use in their elephant diets. Of all these ingredients, the nutritional composition was collected using several sources from the literature. The respondents were requested to send a current analysis of browse, concentrates and supplements from which a more accurate calculation of the nutritional composition could be determined. If these were not provided, or not available (in the case of browse), a literature source was used to obtain a composition. An overview of these literature sources can be found in appendix VII. These compositions were used to calculate the total nutritional composition of the elephant diet of each respondent. In addition to the dry matter (DM) content, the following nutrients were chosen to be used in the nutritional analysis, with a more detailed description of this choice described in chapter 3.3.2:

- Protein
- Fat
- Crude fibre (CF)
- Non-fibrous carbohydrate (NFC)
- Neutral detergent fibre (NDF)
- Ash
- Acid detergent fibre (ADF)
- Calcium (Ca)
- Phosphor (P)
- Magnesium (Mg)
- Vitamin E (Vit. E)
- Biotin

A complete explanation of how the data was analysed and processed is later described in paragraph 1.2.

Estimated ex-situ nutritional requirements and in-situ diet composition

In order to make a comparison between the current ex-situ diets and the actual requirements, the estimated ex-situ nutritional requirements for both species were gathered from the literature. Two requirements were used for the comparison: one set down by Dierenfeld in a 1994 publication, and one by BIAZA in a 2010 publication with a few added requirements from a BIAZA report from 2006.

The in-situ diet composition was compiled to be able to make a more complete comparison. Several studies on the diet composition for the wild conspecifics of both species of elephant were used to determine the range in which several nutrients are found in the wild diet, and this was used for the comparison. These studies and the final ranges are described in paragraph 3.2.3.

The comparison of the current ex-situ diets with the estimated ex-situ requirements and the in-situ composition can be found in the discussion in chapter 5.

Acquisition of the literature

Several methods were used to obtain information from various sources for the literature review. These are listed in full in appendix I.

The search words were divided into 3 categories. The first degree search words categorised the species of elephants. The second degree words categorised the housing condition of the elephants. Both these categories could be used either separately or in combination to conduct a broad and general search. For a more detailed and specific search, these search words were used in combination with the words in the third and fourth columns.

Other books and articles were borrowed from the college library and from the supervisors. The literature review was collected between September 2011 and February 2012.

2.1.2 Survey

The surveys for the zoos were made using the online survey generator SurveyGizmo (www.surveygizmo.com)[2.2]. Initially, a choice was made for the SurveyMonkey survey generator (www.surveymonkey.com)[2.3], because this is most commonly used within EAZA.
However, after examining SurveyGizmo, it became clear that this service offers certain features and question types which SurveyMonkey does not offer. The table below displays the features that made SurveyGizmo the optimal choice for generating the survey.

Table 2.1 SurveyGizmo features compared with SurveyMonkey.

Features	Explanation
Cheaper monthly subscription fee	€14,26/month* instead of €25/month
Page and question logistic	The option of making certain questions or even whole pages of questions visible or invisible when a particular answer is given to a certain question.
Use of graphics within questions	Pictures used as examples to illustrate how to fill out certain questions.
Use of different fonts and effects	To highlight certain key words in questions by making these bolder or underlining these.
Option to add links	This makes the use of web addresses and email addresses possible.
Question types	For example 'table of text boxes', a table in which all the answers can be filled in by the respondent, which made it possible to combine questions that would otherwise be separate.

* calculated from a monthly fee of US$19 using the exchange rate of 4 October 2011 (wisselkoersen.nl)[2.4]

A total of 11 surveys were sent to the Dutch and Belgian zoos holding elephants. It consisted of 8 parts containing questions on the following subjects:

- Contact information (of the zoo)
- General information (on the animals)
- Body condition score of the elephants
- Diet inventory
- Source of the diet
- Roughage analysis
- Health problems of the elephants
- Additional comments

All 11 zoos received an email with the link to the online survey, a letter of recommendation written by Joeke Nijboer from Diergaarde Blijdorp in Rotterdam (appendix II), and an explanation as to how to use the Body Condition Scoring (BCS) method[2.1] (appendix III). An example of the survey can be found in appendix IV.

Of these zoos, 7 received an email with a Word version of the survey including data on their specific diets. This data was collected during two earlier studies by students from Van Hall Larenstein [Hubers, 2010; Ravenswaaij & Rusman, 2011]. The study by Ravenswaaij & Rusman (2011) was used for Ouwehands Dierenpark, while the study by Hubers (2010) was used for all the other zoos that received a Word version. The table below lists the zoos that received the survey, and which of these zoos received a Word version of this survey. The data on the Ouwehand Dierenpark diet was later completed with data supplied by the zoo itself in an Excel document listing the feeding information per animal per day.

Table 2.2 Zoos that received a survey

Country	Zoo	City	Zoos that received a Word version of the survey
The Netherlands	Natura Artis Magistra	Amsterdam	✓
	Burger's Zoo	Arnhem	✓
	Diergaarde Blijdorp	Rotterdam	✓
	Dierenpark Amersfoort	Amersfoort	✓
	Dierenpark Emmen	Emmen	✓
	Dierenrijk Europa	Mierlo	
	Ouwehands Dierenpark	Rhenen	✓
	Safaripark Beekse Bergen	Hilvarenbeek	✓
Belgium	Zoo Antwerp & Planckendael	Antwerp	
	Bellewaerde Park	Ieper	
	Paradiso	Cambron	

2.2 Processing and analysis of the data

The analysis and processing of the data regarding the diet inventory and the calculations involved to acquire the nutritional composition are described step by step (A through E) in this paragraph. To clarify the process, a simplified diet is used as an example. The calculations were performed by using Microsoft Excel 2010.

A. Feeding information of the participating zoos

The survey results generated a list of ingredients with the daily amounts in which they are given. The amounts were submitted per group. Thus, in order to be able to determine an average amount per animal, these amounts per ingredient were divided by the number of animals per group, making comparisons between zoos possible.

Calves were excluded in determining the average amounts per animal. This was done by omitting the youngest animals in a group to the amount corresponding to the number of lactating females. The reason for excluding the calves was that their metabolic requirements differ from adult maintenance requirements [Stevenson & Walter, 2006]. In addition, because they still need to drink milk from the mother, they will not consume proportionally the same amount of the food.

Several zoos feed an alternative diet at varying times of the year. These diets are listed separately. Zoos with more than one group- usually the male is housed separately- have two separate listings.

A list of all the diet ingredients used by the respondent zoos, including the average amount per animal per ingredient, is supplied in chapter 4.2 of the results. To provide optimal clarity, ingredients were categorised per type. All zoos were given a number, and in some cases a letter code corresponding to alternate diets/groups, in order to render the results anonymous.

Example:

This example uses two zoos: zoo 1 houses four female elephants together, while zoo 2 houses one male and 2 female elephants. The table below shows the ingredients and the daily amounts that are being fed per group.

Table 2.3 Example of a simplified zoo elephant diet with amounts given per group

Ingredients (kg)	Zoo 1 4 females	Zoo 2 1 male	Zoo 2 2 females
Grass hay	100	35	60
Apple	6	2	4
Elephant pellets	12	4	7

The average daily amount per animal per zoo is calculated by dividing the amounts by the number of animals in that zoo, resulting in the following amounts:

Table. 2.4 Example of a simplified zoo elephant diet with amounts given per animal

Ingredients (kg)	Zoo 1	Zoo 2m	Zoo 2f
Grass hay	25	35	30
Apple	1.5	2	2
Elephant pellets	3	4	3.5

m = male, f = female

B. Nutritional composition of all ingredients

After having received all the surveys and after having made the inventory of all the ingredients that are used in the elephant diets, the nutritional composition of all these ingredients was calculated. The aspects that had to be taken into consideration and the calculations that were needed in order to obtain the nutritional composition, have been categorized below. This resulted in a table that includes all the ingredients and their nutritional composition, which can be found in appendix V.

Amounts and units

All the nutrient amounts of the ingredients are listed per 1 kilogram (1000grams) DM. The dry matter and energy amounts are given per 1 kilogram product. Any amounts that were not given per kilogram in the literature were converted.

All nutrients have been listed in grams (g), with the exception of vitamin E which was expressed in milligrams (mg), and biotin which was expressed in micrograms (µg). The energy was expressed in Mega Joule metabolisable energy (ME) requirement for maintenance (MJ ME/day).

When any nutrients were encountered in units differing from those described above, these were converted using a conversion website[2.5] when possible.

Dry matter

All nutrients are listed per kilogram DM, which means that any nutrients taken from sources describing the value per kilogram product had to be converted. The calculation for this is shown below in box 1.

If the moisture amount was provided, the dry matter could be determined by first calculating the moisture amount in grams per 1 kilogram product and then by subtracting that from 1000 grams.

When the dry matter of a supplement or concentrate was not provided in the analysis in the literature, the assumption was made that the dry matter content was 90% of the whole product, 900 grams per kilogram product [Huisman, personal contact].

Box 1. Calculation for amount of nutrient whole product to dry matter.

(nutrient (g/kg product) * 1000) / DM (g/kg product) = nutrient per kg DM

Example:
Ash in apple is 3 g/kg product. What is the amount per kg DM?
If an apple contains 876g moisture per 1 kg apple --> the DM content is 124g
So the ash content is (3 * 1000) / 124 = 24.19g/kg DM

Energy

Energy can be expressed as gross energy (GE), digestible energy (DE), and metabolisable energy (ME). In many cases the energy was not provided in ME MJ, so this had to be calculated using the formulae in box 2[2.6,[Huisman]]. When the type of energy was unknown, the amount of energy given in the literature source was used without converting it.

For the ingredients of which the energy content was unknown, the GE was calculated when possible using the first formula and then converted to ME by the second. When the GE or DE was provided, then the ME was calculated by the second or third formula. All nutrients in the formulae are in grams per kilogram dry matter.

When using these formulae, the final amount of ME (in MJ/kg) is listed in kg/DM and must be converted to kg/product. The fourth formula shows how this is achieved.

Box 2. Formulae to calculate ME

GE (in MJ/kg DM) = ((24,14 x crude protein) + (36,57 x fat) + (20,92 x crude fibre) + ((16,99 x (sugars + starch)) – (0,63 x sugars*)) / 1000
ME (in MJ/kg DM) = 0,65 x GE (in MJ/kg DM)
ME (in MJ/kg DM) = 0,90 x DE (in MJ/kg DM)
ME (in MJ/kg product) = ME (in MJ/kg DM) * DM / 1000

* The sugar is only subtracted when the product contains more than 80 g sugar/kg DM[2.6,[Huisman]]

Non-fibrous carbohydrate

When a source did not list the value of NFC, it was calculated using other nutrients from the analysis as shown in box 3. All nutrients in the formula are in g/ kg DM.

Box 3. Calculation of NFC

NFC = 1000 – (crude protein + neutral detergent fibre + fat + ash)[(2.7)]

Vitamin E

When the amount of vitamin E was provided in International Units (IU), it was converted to milligrams with help of the website www.etoolsage.com[2.8], using ‘vit. E natural d-alpha tocopheryl’.

Example:

After having done the calculations above, the nutritional composition of the ingredients of the two zoo diets are displayed in table 2.4. The nutritional values of the ingredients have been taken from the table in the appendix V.

Table 2.5 Simplified example of a nutritional composition as used in this study

Ingredients	DM (g/kg product)	Energy (MJ ME/kg)	Protein (g/kg DM)	CF (g/kg DM)	Ca (g/kg DM)	Vit. E (mg/kg DM)	Zoo
Roughage							
Grass hay	826	6.42	130.00	309.00	5.00	18	[1,2]
Fruit							
Apple	124	1.92	24.19	177.42	0.31	44.35	[1,2]
Concentrates/supplements							
Elephant pellets	900	10.10	184.44	111.11	16.67	555.56	[1,2]

The table shows the ingredients in the left column, divided into the different ingredient categories (roughage, browse, vegetables, other products, and concentrates and supplements). The dry matter, energy and nutrients are displayed at the top of the table. The right hand column lists the zoos that use that type of ingredient.

C. Total nutrient value of the elephant diets of the participating zoo

The calculation of the daily nutritional value of the diet of each zoo is described below. The average daily amount of each ingredient per animal (step A) and the nutritional composition of each ingredient (step B) are needed for these calculations.

The average daily amount per animal from the table arrived at via step A is shown in the second column under ‘amount’.

The DM/kg product of each ingredient in the diet was multiplied by the amount of product (in kilograms) to establish the total amount of dry matter per ingredient.

Similarly, the energy (ME MJ/kg) of each ingredient was multiplied by the amount of each ingredient in the diet to ascertain the total amount of energy per ingredient.

The nutrients were multiplied by the total amount of dry matter (in kilograms) to get the total amount of each nutrient per ingredient on a dry matter basis.

The results per column were then totalled to show the total amounts of dry matter, energy and nutrients in the daily diet per animal. The tables that show these results can be found in appendix VI.

Note that a few zoos use browse items (willow and oak) in their diet. Because elephants only eat the bark from the oak and willow branches, the average daily amounts used for calculations involving these browse products differs from that used for other dietary products. It is assumed is that the bark accounts for approximately ¼ of the total amount of the willow branches and $^1/_3$ of the total amount of the oak branches [no source]. Therefore, the average

daily amounts of the browse ingredients from the survey results (or step A), do not coincide with the amounts that are displayed in the appendix VI.

Example:
The daily nutritional composition per animal for each zoo was calculated and is shown in the tables below. The results of zoo 1 are displayed in table 2.6 and those for zoo 2 in table 2.7. The results were calculated using the data from steps A and B.

Table 2.6 Simplified example (of example zoo 1) of a nutritional composition of an average daily diet as used in this study

Ingredients	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	CF (g/DM)	Ca (g/DM)	Vit. E (mg/DM)
Roughage							
Grass hay	25,000	20,650	160.50	2,684.50	6,380.85	103.25	371.70
Fruit							
Apple	1,500	186	2.88	4.50	33.00	0.06	8.25
Concentrates/supplements							
Elephant pellets	3,000	2,700	30.30	497.99	300.00	45.01	1,500.01
Total	29,500	23,536	193.68	3,186.99	6713.85	148.32	1,879.96

Table 2.7 Simplified example (of example zoo 2) of a nutritional composition of an average daily diet as used in this study

Ingredients	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	CF (g/DM)	Ca (g/DM)	Vit. E (mg/DM)
Roughage							
Grass hay	35,000	28,910	244.70	3,758.30	8,933.19	144.55	520.38
Fruit							
Apple	2,000	248	3.84	6.00	44.00	0.08	11.00
Concentrates/supplements							
Elephant pellets	4,000	3,600	40.40	663.98	400.00	60.01	2,000.02
Total	41,000	32,758	288.94	4428.28	9,377.19	204.64	2,531.40

As in the previous table, this table shows the ingredients per category, together with the total average daily amounts of ingredients, dry matter, energy and nutrients that are fed per elephant.

D. Nutritional composition of the elephant diets of the participating zoo

The requirements used for the comparisons are not given in totals, but in amounts per kilogram DM and energy density (per kg DM). Thus, to make comparison possible, the totals calculated in the previous step need to be converted.

In addition to the total amount of ingredients, the total amount of dry matter and the total amount of energy, the energy density and the DM/kg product were calculated. The DM in g/kg product was calculated by dividing the total amount of DM in grams with the total amount of ingredients in kilograms. The energy density (MJ ME/DM) was calculated by dividing the total energy/day (MJ/ME) with the total amount of DM (in kg). It is important to

note that when the energy of an ingredient was unknown, the DM of that ingredient was excluded from the total amount of DM that was used to calculate the energy density.

Finally, to calculate the nutrient content per kilogram DM, the total amount of each nutrient was divided by the total amount of DM (in kilograms).

To make a comparison between all the zoos possible, the mean and stand deviation (SD)were calculated.

Example:

The table below shows a simplified example of the table used to display the results that were generated during this step of the process.

Table 2.8 Simplified example of a nutritional composition of an average daily diet as used in this study

	Zoo 1	Zoo 2	Mean ± SD
Total average offered per animal per day			
Total amount of ingredients (g)	29,500	41,000	35,250 ± 5,750
Total amount of DM (g)	23,536	32,758	28,147 ± 4,611
DM (g/kg product)	797.83	798.98	798.41 ± 0.58
Total energy/day (MJ ME)	193.68	288.94	241.31 ± 47.63
Energy density (MJ ME/DM)	8.23	8.82	8.53 ± 0.30
Nutritional composition (per kg DM)			
Crude fibre (g)	285.26	286.26	285.76 ± 0.50
Calcium (g)	6.30	6.25	6.28 ± 0.025
Vitamin E (mg)	79.88	77.28	78.58± 1.30

E. Energy offered and energy requirement

The body condition scores (BCS) and body weight (BW) of the elephants as reported in the survey, and the total energy offered to the elephants (calculated in step C) were used together as an indicator for the diet quality. A table displaying the data from the survey on age, sex, lactation, BW, BCS, and date of last weighing/estimation, together with the total energy offered, the maintenance metabolic rate (MMR), and the relative difference between these two (expressed as a percentage) is found in appendix VIII.

The Kleiber formula (1961) was used to calculate the requirement for MMR per individual animal using the BW in kilograms. The same formula was used by Dierenfeld (1994) to establish the energy requirement. Box 4 shows the formula.

Box 4. Formula to calculate the maintenance metabolic rate.

$$\text{MMR (ME MJ)} = \frac{\text{BW}^{0,75} * 140 \text{ Kcal} * 4.182}{1000}$$

The Kleiber formula uses Kcal to calculate the MMR. To convert the Kcal to MJ, extra calculations were added to the formula [Huisman, personal contact]: a multiplication by 4.182 to convert Kcal to kJ, and a division by 1000 to convert the kJ to MJ.

The energy offered per day was calculated during step C. The relative difference between the offered and required energy was calculated by dividing the offered amount of energy by the MMR and multiplying it with 100.

To make it possible to compare the results of the zoos with one another, the average MMR was calculated per zoo, after which the relative difference was calculated again. When a zoo indicated that it had two groups of elephants or fed more than one diet, these were calculated separately.

Example:
The table below lists results of the energy calculations of the two example zoos. The energy offered per animal was already calculated in step C. To calculate the MMR per animal for this example, an average body weight of 3,500kg was used for the elephants in zoo 1, and an average body weight of 4,000kg for those in zoo 2 .

Table 2.8 Simplified example of a table used to display the energy calculations per zoo

Zoo	Energy offered per animal (ME MJ)	Mean MMR per animal (ME MJ)	Relative difference (%)
1	193.68	266.42	72.70
2	288.94	294.48	98.12

When the relative difference is 100%, this means that the amount of energy offered is the same as the amount of energy required. This is the optimal situation. The closer the relative difference is to 100%, the more the offered amount matches the requirement. From this example it appears that zoo 2 offers the same average amount of energy as the average energy required, but that zoo 1 does not offer enough energy to its elephants.

3. Literature review

This chapter contains the literature review of the elephant species. It begins with general information, their wild and captive situation with a focus on food composition, and ends with a description of health problems in captivity. In this chapter the norm for the diet in captivity is described as well as a nutritional recommendation based on their natural diet. Finally, the choice of the nutrients for the analysis of the diets is discussed.

3.1 General information

The following paragraph contains information about the Asian and African elephants, including their wild and captive population numbers, their taxonomy, their status, and their biology. The anatomy and physiology of their digestive tract is also described. This information serves as background in order to understand more about these species prior to focusing on their nutritional needs.

3.1.1 Population numbers

Wild population

According to an IUCN report from 2007, the population of the African elephant (*Loxodonta africana*) in 2006 was estimated to be over 470,000 animals (definite number) in the whole of Africa.

Recent numbers for the population of the Asian Elephant (*Elephas maximus*) are estimated to be between the 40,000 and 50,000 [Blake & Hedges, 2004], but this is a crude estimation and the population trends appear to show a decrease.

Captive population

There are a total number of 341 (82.259.0) Asian elephants held in 96 EAZA (European Association of Zoos and Aquaria) institutions. Of these, 45 (15.30.0) that can be found in 9 Dutch and Belgian zoos.

In contrast to the Asian elephants, there are fewer African elephants in captivity. There are 183 (42.141) African elephants kept in 43 EAZA zoos, with 8 of these (2.6.0) being in 2 Dutch zoos [EAZA African elephant annual report, 2010; EAZA Asian elephant studbook, 2011]. This can be partially explained by the fact that Asian elephants have been utilized by man for 4000 years, while no evidence exits that indicates African elephants were used by man before 300 B.C [Olson et al., 1994].

3.1.2 Taxonomy

Elephants belong to the order of the Proboscidea. Within this order they belong to the family of the Elephantidae and subfamily Elephantinae. The genus of the African elephant is *Loxodonta,* while the genus of the Asian Elephant is called *Elephas,* see table 3.1.

Table 3.1 Taxonomy of the Asian and African elephant.

Scientific classification		
Order	Proboscidea	
Family	Elephantidae	
Subfamily	Elephantinae	
Genus	*Loxodonta*	*Elephas*
Species	African elephant	Asian elephant
	Loxodonta africana	*Elephas maximus*
	Blumenbach, 1797	Linnaeus, 1758

Yang, 1996; Macdonald (ed.), 2001; Rogaev 2006; source 3.1 & 3.2

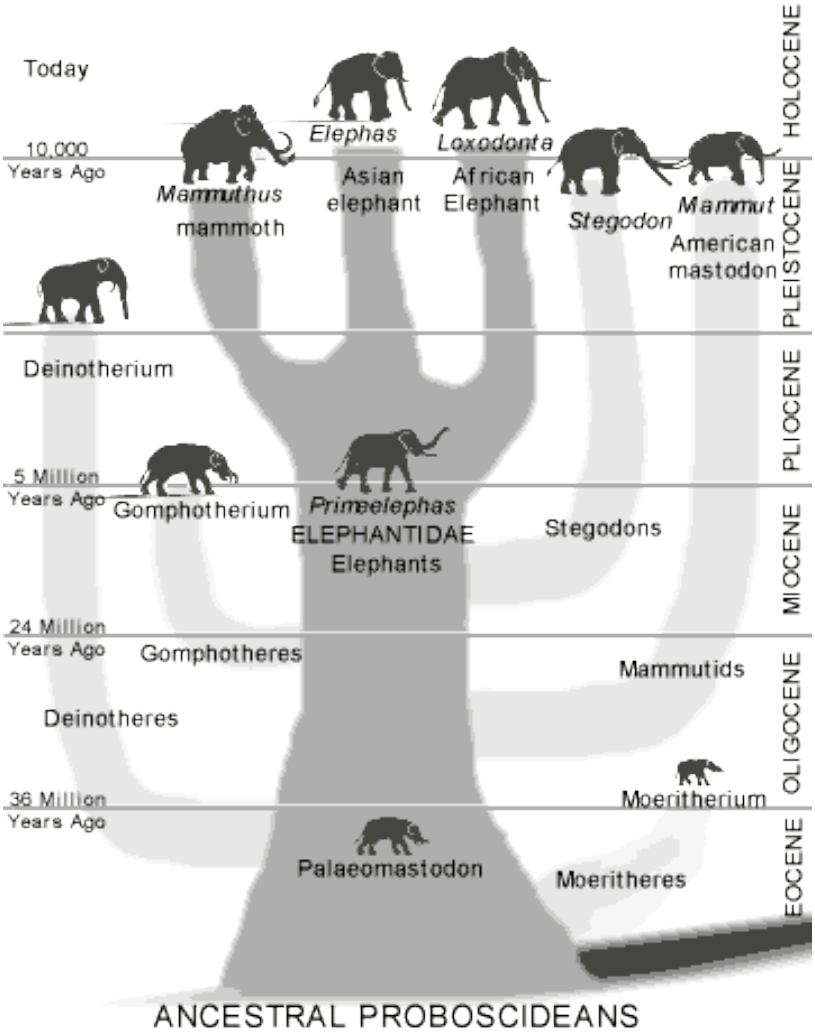


Figure 3.1 Ancestral proboscideans [Spinage, 1994]

According to fossil records, the split between *Elephas* and *Loxodonta* occurred in the Pliocene Epoch around 3.5 - 5 million years ago, while genetic evidence suggests this split was 2.6 million years ago. Interesting is the fact that the now extinct *Mammathus* and extant *Elephas* lineages also separated during the Pliocene Epoch, after the split between *Elephas* and *Loxodonta* as shown in picture 3.1. Fossil records show that both *Elephas* and *Loxodonta* coexisted in Africa until 100,000 years ago, when Elephas disappeared entirely from the continent [Wilson et al., 2011].

African elephant

In 2001, the existance of two African species, *Loxodonta africana (*African Savannah elephant) and *Loxodonta cyclotis (African Forest elephant)* was supported in part by genetic evidence. Specifically, this was based on the large genetic distance, multiple genetically fixed nucleotide site differences, morphological and habitat distinctions, and the extremely limited hybridization of gene flow between forest and savannah elephants [Roca et al., 2001]. The genetic distance between these African species is more than half as great as the difference between the genus *Elephas* and *Loxodonta*. It is still a matter of debate as to whether these genera are different species or races [Wilson et al., 2011]. A third species, the West African Elephant, has also been postulated, however more extensive research is required to support this [IUCN SSC African Elephant Specialist Group 2003].

This assessment was conducted for the single species as currently described, without making any differentiation between different species of African elephants, but encompassing all African species.

Asian elephant

Asian elephants are classified in three subspecies: *maximus* in Sri Lanka, *indicus* on the mainland and *sumatranus* in Sumatra. The Asian elephants in Borneo are thought to be a distinct subspecies as well, classified as *Elephas maximus borneensis*. DNA analysis [Fernando et al., 2003] indicates this on the basis of genetic variance and evolutionary history. [Wilson & Mittlemeier, 2011; Sukumar, 2006].

This assessment encompasses the *Elephas maximus* as a whole, without making any differentiation between its subspecies.

3.1.3 Status

According to the IUCN Red List of threatened species, the status of the African and Asian elephant are both “Endangered’’, as assessed in 2008.

3.1.4 Animal biology

What distinguishes elephants the most is the trunk, or proboscis, which is their nose and upper lip. The trunk is an extremely sensitive organ, and is used by the elephants for breathing, olfaction, touch, manipulation, and sound production. It allows the animal to eat from the ground but also to feed from trees and shrubs [Macdonald (ed.), 2001]. This muscular part of the body plays an important role in the search of food [Ullrey et al., 1997]. Another important morphological aspect of elephants are the ivory tusks, which are enlarged second incisors. These are used for foraging, digging, and defense. The tusks also continue growing throughout life, and may reach a weight of 60 kilograms by the age of 60 [Macdonald (ed.), 2001]. Unique to the family of the Elephantidae is the presence of subcutaneous musth gland and the pharyngeal pouch. The purpose of the musth gland is primarily for social communication, especially among males during their sexually active musth state. The pharyngeal pouch is used in infrasonic communication and to store water. The large size of the extant Elephantidae is probably an adaptation to highly variable environments. These large animals survive on lower quality diets better than smaller animals because of the relationship between metabolic rate and body size [Wilson & Mittelmeier, 2011].

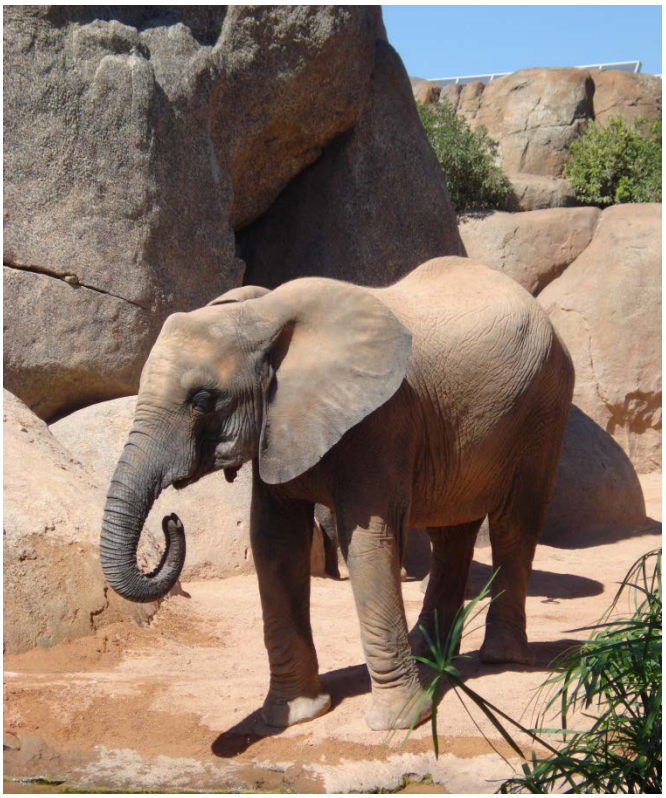


Figure 3.2 Picture of an African Elephant [3.3]

Figure 3.3 Picture of an Asian Elephant [3.4]

The most important morphological differences between the African elephant and the Asian elephant are listed in Table 3.2. The African elephants are bigger than their Asian counterparts, and they also have bigger ears. The back slopes less and the highest point of the

African elephant's body lies at its shoulders rather than at the head as in the case of the Asian elephant (see figure 3.2 and 3.3). Unlike African elephant females, Asian females do not have tusks[3.7]. The upper incisors of the elephant, when present, have developed and became tusks and unlike the horse, they have no canines or lower incisors. In contrast to most mammals, the grinding teeth of the elephant move forward from the back of the jaw, and do not succeed each other vertically [Clauss et al., 2007].There are other differing morphological characteristics per species that cannot be detected by sight. The African elephant has, for example, 21 pair of ribs in contrast to the Asian elephant which has 20. The trunk of the African elephant has two lips instead of one which the Asian elephant has [Macdonald (ed.), 2001]. In addition, the hind foot of the Asian elephant has 4 nails rather than 3[3.7].

Other differences between the species based on their biology, such as their longevity, breeding gestation and number of offspring, are shown in Table 3.2 as well.

Table 3.2 Differences between both species

	African Elephant	**Asian Elephant**
	3.5	3.6
Weight*	4,000 – 7,000 kilograms	2,000 – 5,500 kilograms
Height at shoulder*	3-4 meters	2-3,5 meters
Skin*	More wrinkled	Smoother
Number of ribs°	21	20
Highest point*	Top of shoulder	Top of head
Size of ears*	Larger, exceed height of neck	Smaller, do not exceed height of neck
Tusks*	Both sexes have tusks, larger in males	Usually carried by males, absent or vestigial in females
Trunk*	More rings (annulated, less rigid) Two lips	Less annulations, more rigid One lip
Number of nails*	Forefeet: 4 or 5 Hind feet: 3,4 or 5	Forefeet: 5 Hind feet: 4 or 5
Longevity	60-70 years, more than 80 years in captivity°	70 years in de wild†, 75-80 years in captivity°
Gestation period†	22 months (average)	18-22 months
Breeding season†	Births more frequently during rainy seasons, may occur throughout the year	May occur throughout the year
Number of offspring	2 (maximum), 1 (average)	1 (average)

* [Shoshani, 2006]
† Source 3.7
° [Macdonald (ed.), 2001]

3.1.5 Anatomy and physiology of the digestive tract

Both Asian and African elephants are intermediate feeders with a preference for browse. An intermediate feeder is an animal that has a mixed diet of grass and browse and that responds to seasonal fluctuations of forage quality by changing its diet composition [Clauss et al., 2007; Kos et al., 2011]. Elephants have a hindgut fermenting digestive system also characteristic of horses and rhinoceroses [Feldhamer et al., 2007]. The cecum in elephants appears to function largely as a simple extension of the proximal colon, for this reason elephants are also called 'colon fermenters' [Hume, 1997].

Elephants spend at least three-quarters of the any 24 hour period searching for and consuming food [Dierenfeld, 1994; Macdonald (ed.), 2001; Wilson & Mittelmeier, 2011]. Due to the fact that their digestive system is built for rapid passage (11-46 hours) and has a low digestive efficiency, elephants must eat large volumes of food in a short time. This is beneficial when the forage is of poor quality. [Ullrey et al., 1997; Feldhamer et al., 2007]

The elephants' digestion starts when the trunk brings the food into the animals' mouth. In the mouth there is a large grinding tooth, forming a transverse ridge, in wear on each side of the upper and lower jaw, especially for reducing siliceous foods, such as grass, or highly lignified foods, such as branches, to a more digestible size [Ullrey et al., 1997; Clauss et al., 2007]. While the food is being chewed, it is mixed with saliva from the parotid salivary glands (*glandula parotis*). Elephants' saliva does not have alpha-amylase and thus does not play an important role in the digestion of the elephant. It may, however, serve as a lubricant for coarse ingesta [Dumonceaux, 2006]

Digestion continues in the stomach by means of enzymatic activity. Proteins are digested and food then moves rapidly to the small intestine, allowing new food enter the stomach [Feldhamer et al., 2007]. In the small intestine sugars, starch, amino acids and lipids are first broken down and then absorbed [Ellis & Hill, 2005].

The food then passes into the large intestine, which consists of 4 parts: the cecum, the great colon, the small colon and the rectum. This is the major site of microbial fermentation and absorption of nutrients [Ellis & Hill, 2005]. The colon is for this matter of considerable proportions as you can see in figures 3.4 and 3.5 below. Two-thirds to three-quarters of the wet digesta were found in the cecum and colon. The average wet weight of the digestive tract contents (digesta) found in 10 wild African elephants in the Kruger National Park of South Africa was 415 kilograms, whereas three adults in Kenya had an average digesta weight of 487 kilograms. [Macdonald (ed.), 2001; Ullrey et al., 1997]

The cecum and the colon together form the 'hindgut' and are inhabited by anaerobic bacteria and protozoa. It is here that microbial fermentation takes place. The anaerobic bacteria and protozoa are comparable to those found in the rumen and reticulum of the ruminant. These microorganisms digest plant fibre, principally cellulose and hemicellulose, that otherwise could not be utilised because elephants have no fibre-digesting enzymes. The product of this process together with other partly digested compounds and lactic acid, results in the production of fatty acids that can be absorbed and used for energy. Anaerobic bacteria and protozoa have also been found in the small intestine, although concentrations of protozoa are lowest in the beginning of the small intestine and increase towards the end. [Macdonald (ed.), 2001; Ullrey et al., 1997]

Differences between both species

The intestinal tract of Asian elephants differs in its physiology from that of the African. In the following figures (fig. 3.4 and 3.5) the gastrointestinal tract of both species is illustrated. Below these figures, a table with body mass and measurements of the digestive tract of both species is displayed.

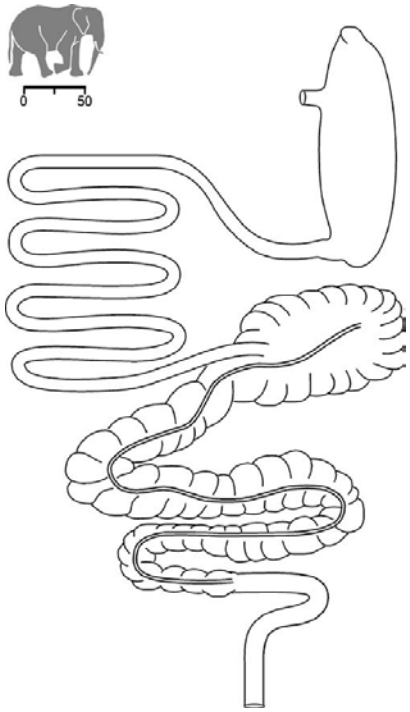


Figure 3.5 Gastrointestinal tract of an African elephant (*Loxodonta africana*). The scale bar represents 50 cm [Clauss et al., 2007]

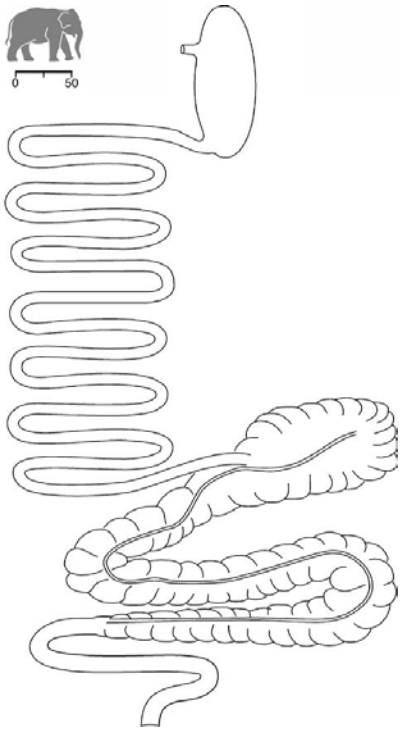


Figure 3.6 Gastrointestinal tract of an Asian elephant (*Elephas maximus*). The scale bar represents 50 cm [Clauss et al., 2007]

Table 3.3 Comparison between body mass and length measurements of the digestive tract of an African and an Asian elephant [Clauss et al., 2007].

	L.africana	***E.maximus***
BM (kg)	3,140	4,228
Length (m)		
Stomach	1.8	1.4
Small intestine	9.2	20.2
Cecum	1.0	1.0
Colon	9.4	11.8
Total intestine	**19.6**	**33.0**

BM = body mass

The first difference between the digestive tracts of these species can be found in the molar structure in the mouth; African elephants have fewer enamel ridges that their Asian counterparts. This shows a better adaptation for grass forage in the *Elephas maximus* as they ingest a higher proportion of grass than African elephants.

Asian elephants have a digestive tract of 33.0 meters long while the African elephant's digestive tract is shorter, specifically 19.6 meters (see table 3.3). Although the cecum is of similar size in both species (see table 3.3), the small intestine, and to a lesser extent the large intestine, are longer in the Asian elephant (20.2 meters versus 9.2 meters). This difference in length could account for the Asians elephants' higher digestive efficiency and longer ingesta mean retention time. A longer retention time and a higher digestibility are both possible adaptations of herbivores consuming grass, as grass produces fermentative energy at a slower rate than browse. [Clauss et al., 2007]

Besides the adaptations in dental morphology and digestive physiology, two more observations might support the adaptation of both elephant species to different diets. First, the size of salivary glands which is usually smaller in grazers as compared with those in browsers. The total weight of the glands in an Asian elephant was 4 kilograms, while the average weight of the glands from six African elephants was 10.8 kilograms heavier.
Second, the grazers in ruminants may have a larger masseter insertion surfaces due to their higher masticatory forces to grind grass. Similarly, Asian elephants have a larger masseter insertion surface than the African elephants. [Clauss et al., 2007]

3.2 Wild situation

This paragraph provides information on the in-situ situation of both the African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephant.

It begins with a chapter containing the habitat description, including information about the different biomes that are found within the range of both species as well as a general overview of the types of plants that are found within these biomes and ranges.

The chapter continues with a description of the behaviour of the elephants, specifically focussing on the feeding behaviour.

The chapter ends with a paragraph about the in-situ diets, highlighting some of the studies that have been conducted into the diets of both species. These diets can differ extensively, as will become clear from that chapter.

3.2.1 Habitat description

African elephant (Loxodonta africana)

The African elephant (*Loxodonta africana*) can be found wherever there is enough water and food, with their distribution ranging from the South African Cape to the Sahel, with habitats being diverse. Historically, the African savannah elephant (*Loxodonta africana*) inhabited all types of sub-Saharan habitats, including deserts, mountainous tropical forest, semi-arid savannah, bushland, and dry woodlands, except for the driest regions. Their current distribution includes most habitats on the continent, with the greatest densities in dry wood- and shrublands, and with some found even in desert regions such as Namib and Mali's Sahel.

In the latter, the animals are highly threatened by climate change and human activity. Their range overlaps with that of the African forest elephant on the forest and savannah fringes. There are speculations that both species use the same habitat in Central Africa. However, the current range where the elephants live correlates with human activity in a negative way by restricting any further distribution of the animals. Total density varies widely, based on past and current human pressure. [Wilson & Mittelmeier (ed.), 2011]

African forest elephants (*Loxodonta cyclotis*) inhabit the tropical rainforests of the Central African Congo Basin (like the Ituri forest in the Congo[3.8]), but due to hunting pressure their current distribution is becoming fragmented, even in regions where the forest is still intact. Their preference goes out to areas with secondary growth. The highest number of elephants live in the forests of Central Africa where savannah and tropical forest border each other, leading to the conclusion that the preferred habitat is a forest/grassland combination. A hotspot for the forest elephant are the mineral bais ('swampy forest clearings that are typically visited for accessing mineral resources' [Wilson & Mittelmeier (ed.), 2011]) in the forest, being a critical component of an individual's range and a primary limiting resource in forest ecosystems. Today the distribution is determined by human density and hunting, and large areas of protected forest contain no elephants anymore due to overharvesting. [Wilson & Mittelmeier (ed.), 2011]
Figure 3.6 shows the range of the African elephant as assessed by the IUCN SSC African Elephant Specialist Group in 2008.

It is very clear that the African elephant inhabits different kinds of habitat types (biomes). This means that the vegetation type found in the habitat varies extensively. As will be explained in chapter 3.2.3, elephants utilize a great variety of plants and plant materials [Buss, 1961; Wing & Buss, 1970; Sukumar & Ramesh, 1995], and therefore the different biomes will be discussed below.

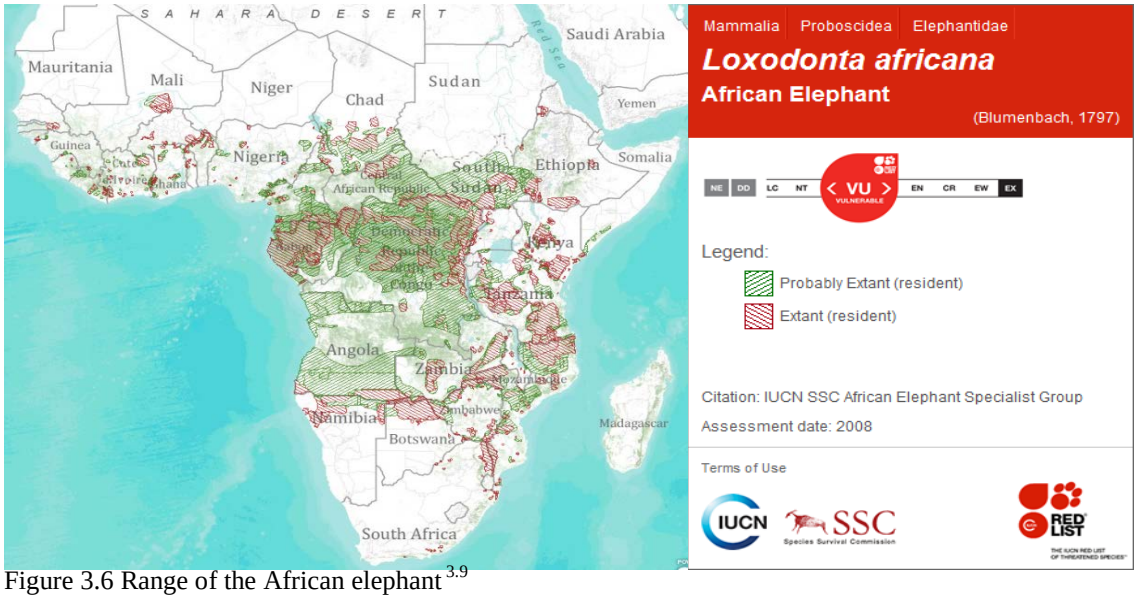


Figure 3.6 Range of the African elephant[3.9]

The figure shows very clearly that the African elephant is only found in Central Africa, with just a few exceptions in South-Africa and a population in Mali. This means that they mostly

live in savannah and tropical forest regions, which is very clear from the description above and the next part of the chapter about the general habitat.

General habitat

As described above, the three biomes where African elephants are most commonly found are desert, savannah and tropical forest. Figure 3.7 indicates that the different ranges of these three biomes are clearly delineated. In general, savannahs are found at the transition between rainforests and deserts, which can be clearly seen on the map.

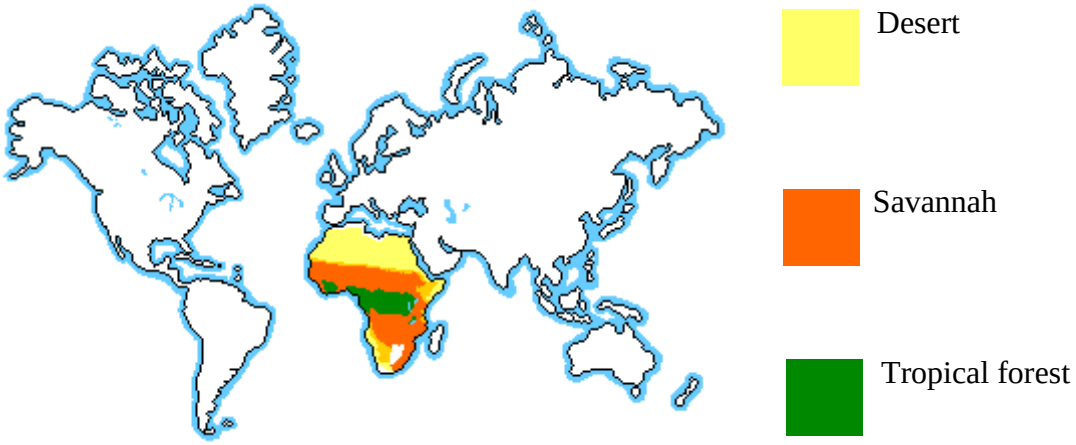


Figure 3.7 Biomes of Africa [3.10]

To provide a more complete picture of the climate in which the animals exist, the following table lists general information about these three biomes, such as temperature, rainfall, and vegetation.

Table 3.4 General information about the three biome types found in the range of the African Elephant.

	Desert of Namib[3.11]	**Ituri Forest**[3.8]	**African savanna**[3.13]
Mean annual temperature	Coast: 10° - 16°C Inland: 30° - 38°C	31°C	Dry season: 10° - 20°C Rain season: 20° - 30°C
Mean annual rainfall	Coast: 13mm Inland: 51mm	1,900mm	800 to 1500mm
Vegetation	Grasses are relatively scarce, whereas browse (bushes and shrubs) are relatively abundant. Other	Climax vegetation: Three dominant species of *Caesalpinioideae ssp., Three species of hardwired legumes (Gilbertiodendron deweverei, Cynometra alexandrii, Brachystegia laurentii), Albizia sp., Celtis sp., Ficus sp.*	Trees: *Acacia* sp., *Combretum* sp., Thick-trunked baobabs (*Adansonia digitata*), Sturdy palms (*Borassus*), *Euphoria* sp., Wide diversity of spiny shrubs, *Brachystegia sp., Anogeissus sp., Strychnos sp.*

vegetation types include leaf- and stem-succulents and trees (*Acacia* sp.)[3.12]	Vegetation in other successional stages: Umbrella trees (*Musanga cecropoides*), hardwood trees, various liana and shrub species	Grasses: *Andropogon* sp., *Hyparrhenia* sp., *Themeda* sp., Elephant grass (*Pennisetum purpureum*)

Asian elephant (Elephas maximus)

Asian elephants inhabit a number of different kinds of habitats including grassland, tropical evergreen forests and dry thorn forests. This species used to inhabit a large range in tropical Asia: from Iraq, India, and Sri Lanka to Malaysia, Indonesia, and Southern China. Their western range extended to the Tigris-Euphrates River and their eastern range extended to the Yangtze River. Today, however, the elephants have been wiped out of over 85% of this range by human expansion and their current distribution is primarily a result of human distribution and density, instead of selection by the elephants themselves. It resulted in fragmented populations mostly limited to mountainous and forested regions. The remaining elephant populations are mostly isolated in protected areas that are not suitable for agriculture and are typically forested or open woodland. About 60% of the animals are thought to live in India, divided into three populations: a southern, north-central, and north-eastern population, with other populations in Myanmar, Thailand, and some of the larger islands of the Malay Archipelago. The elephants also populate some parts of Sri Lanka, where they seem to have a preference for grassland savannah instead of dense forest. Animals can be found from sea level to over 3000 meters, with regular movement to heights above 3000 meters in the summer months in the Eastern Himalaya in north-east India. [Wilson & Mittelmeier (ed.), 2011] Figure 3.8 shows the range of the Asian elephant as assessed by the IUCN in 2008.

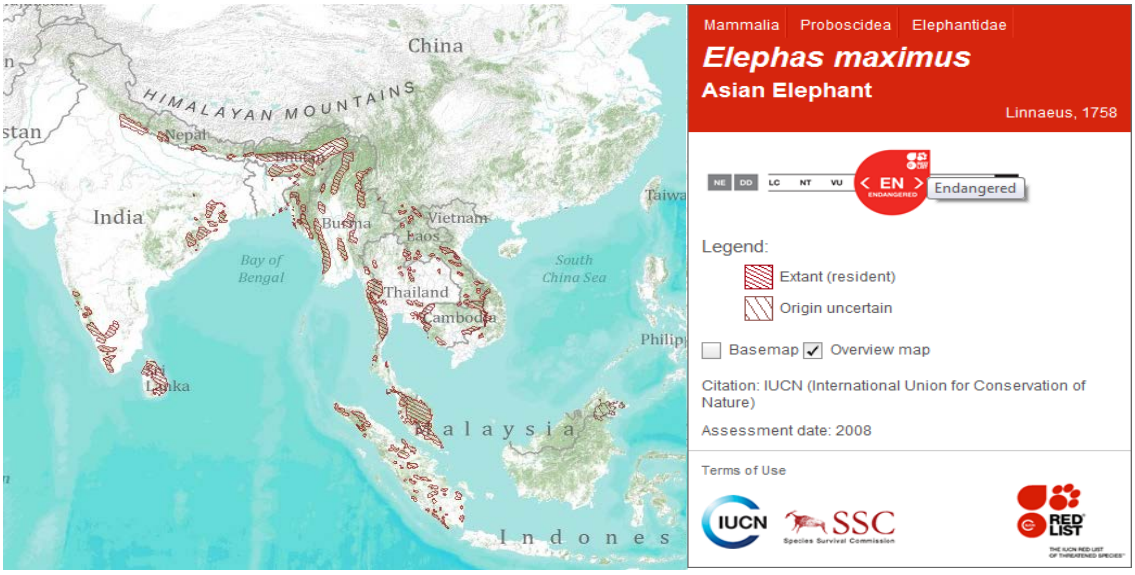


Figure 3.8 Range of the Asian elephant[3.14]

The figure above shows the range and populations of the Asian elephant. The map shows several larger and smaller dispersed populations in the southern countries of Asia. As will become clear in the next part of the chapter about the general habitat, these regions are mostly tropical forest.

General habitat

As mentioned above, the Asian elephant mostly lives in tropical rainforests throughout southern Asian countries as can be seen on the map of figure 3.9. The figure below shows the extent of the tropical forests that can be found within the range of the Asian elephant.

Figure 3.9 Range of the tropical forests of southern Asia [3.15]

The following table will give general information about the tropical forests where the Asian elephant can be found.

Table 3.5 General information about tropical forests in Asia[3.16]

	Tropical rainforests of Asia
Mean annual temperature	20º - 29ºC
Mean annual rainfall	1,800 to 2,500 mm
Vegetation	All major groups of terrestrial organisms are represented, such as: angiosperms, palms (*Arecaceae sp.*), *Dipterocarpaceae sp.*(*Dipterocarpus tuberculatus, Pentacme suavis, Shoreabtusa*), *Bromeliaceae sp.* (epiphytes), teak (*Tectona grandis*), *Xylia xylocarpa*, ferns, mosses, liverworts, lichens, algae, fungi

3.2.2 Foraging behaviour

African elephant

Elephants are mostly generalist feeders, but differences within varying habitats do exist. Because of their low digestive efficiency, size, and nutritional requirements, elephants spend the majority of any 24 hour period feeding (60-75% of the time).

The time elephants spend foraging during the day is about equal to that spent during the night. There are generally 3 peaks in activity: mornings, late afternoons, and around midnight. These peaks are probably related to ambient temperature, and are furthermore likely to be influenced by differences in ecological conditions, such as the distance between food and water, which influences movement and feeding patterns.

African elephants dig for water when surface water is not available. Because they are water dependent, elephants may consume over 100 litres of water on a daily basis.
[Wilson & Mittelmeier (ed.), 2011]

The African Savannah elephant spends more time feeding during the wet season than the dry season. They do not spend a lot of time sleeping: only 3-4 hours daily. This time is divided into 2-3 hours of sleep during the night and 1-2 hours during the midday heat. This pattern can vary however. It depends on the temperature and the quality of the diet.

This species usually only drinks once a day. The time of day the animal drinks differs per population, which seems to be correlated to the threat connected to heat stress or human activity.
[Wilson & Mittelmeier (ed.), 2011]

Observational data on the African Forest elephant is very difficult to collect in the forest, so most of the information on foraging behaviour and activity patterns is collected by means of dung analysis and radio tracking. Any information about activity and behaviour collected from direct observations is mostly collected in bais (‘swampy forest clearings that are typically visited for accessing mineral resources’ [Wilson & Mittelmeier (ed.), 2011]). The activity patterns of this species seem related to hunting pressure, and bais are mostly used at night when a population is under pressure.

The species appears to have a circadian rhythm similar to the African Savannah elephant, spending most of any 24 hour period feeding or searching for food. Most of the movement patterns are based around the mineral deposits in bais. Individuals seem to return to these deposits at least once a week.

Sleeping patterns appear to be the same as those of the African Savannah elephant. The drinking patterns, on the other hand, are quite different. Water is abundant in their habitat so activity patterns are not focused around water resources and the animals are likely to drink at least once a day.
[Wilson & Mittelmeier (ed.), 2011]

Asian elephant

There is not a great deal known about the foraging behaviour of this species. Only a few radio tracking studies have been conducted. Because of their habitat, 24-hour observations are very hard to do. It seems, however, that their circadian rhythm is very similar to that of their African conspecifics, with large amounts of time spent foraging and feeding and only a few hours a day spent sleeping. Drinking occurs at least once a day. [Wilson & Mittelmeier (ed.), 2011]

Like the African elephant, the Asian elephant digs for water when surface water is not available. Elephants are dependent on water and may drink over 100 litres of water on a daily basis. [Wilson & Mittelmeier (ed.), 2011]

3.2.3 In-situ diet composition

Both elephant species are considered generalist feeders, or mixed feeders [Sukumar, 1989; Codron et al., 2006]. They feed through browsing and grazing, consuming a large number and variety of plant species depending on the region and season [Sukumar & Ramesh, 1995; Ullrey et al., 1997; Clubb & Mason, 2003], and the types of plant categories vary widely from one region to another [Sukumar, 1989]. Several of these studies are highlighted below. A general feeding pattern cannot easily be generated, because a pattern seen in one area may not be the same in a different area. [Sukumar, 1989] A number of dietary studies are highlighted below in which it becomes clear that there is indeed no general feeding pattern and that this can be attributed to the habitat and the time of the year.

African elephant in-situ diet composition

In 1961 Buss published a study into the food habits and behaviour of the African elephant by looking at the stomach content of 71 elephant that lived in the Murchison Falls National Park region of Uganda, a savannah habitat. The elephant stomachs were collected between 22 December 1958 and 7 May 1959 to determine the food habits of the Murchison elephant population during and soon after the dry season. According to Buss, the dry season in his study period began early November 1958 and ended late May 1959. The following table is based on the table Buss generated with the results collected from the stomach content [Buss, 1961].

Table 3.6 Stomach contents of the 71 African elephants examined during a dry season in Uganda between 22 December 1959 and 7 May 1959 [Buss, 1961].

Item	Total kilograms found in the stomach contents n = 71	Percentage of total mass found in the stomach contents	Percentage of 71 elephants in which items occurred
Mature grass [1]	3793.3	78.74	99
Young grass [1]	478.5	9.93	56
***Combretum binderanum* (combretum)**	266.3	5.53	35
***Vitex doniana* (black-plum)**	59	1.22	9
***Afromomum* sp. (wild ginger or masasa)**	tr.	-	8
***Stereospermum kunthianum* (mulemangundu)**	17.2	0.36	7
***Sansevieria-Aloe* (sansevieria-aloe)**	83.5	1.73	6
***Kigelia aethiopica* (sausage tree)**	15.9	0.33	4
***Trichilia roka* (makaku)**	3.6	0.07	3
***Piliostigma thonningii* (camel's foot leaf tree or mugali)**	tr.	-	3
Harrisonia abyssinica	72.2	1.50	1
***Portulacaeae* (purslane)**	0.45	<0.01	1
***Cissus quadrangularis* (ivy)**	0.45	<0.01	1
***Balanites aegyptiaca* (desert date)**	tr.	-	1
***Terminalia celuntina* (terminalia)**	tr.	-	1
***Khaya grandifoliola* (African mahogany)**	tr.	-	1
***Entandrophragma* sp. (Budongo**	tr.	-	1

mahogany or muyovu)			
***Ficus* sp. (fig tree)**	tr.	-	1
***Hoslundia opposita* (nkibibi)**	tr.	-	1
***Tinnea aethiopica* (kanyahira)**	tr.	-	1
Sticks (6.35, 7.62, 10.8 cm long)	tr.	-	1
Stones (35, 28, 25, 20 mm in diam.)	tr.	-	1
Unidentified woody materials	27.2	0.56	30
Total	**4817.60**	-	-

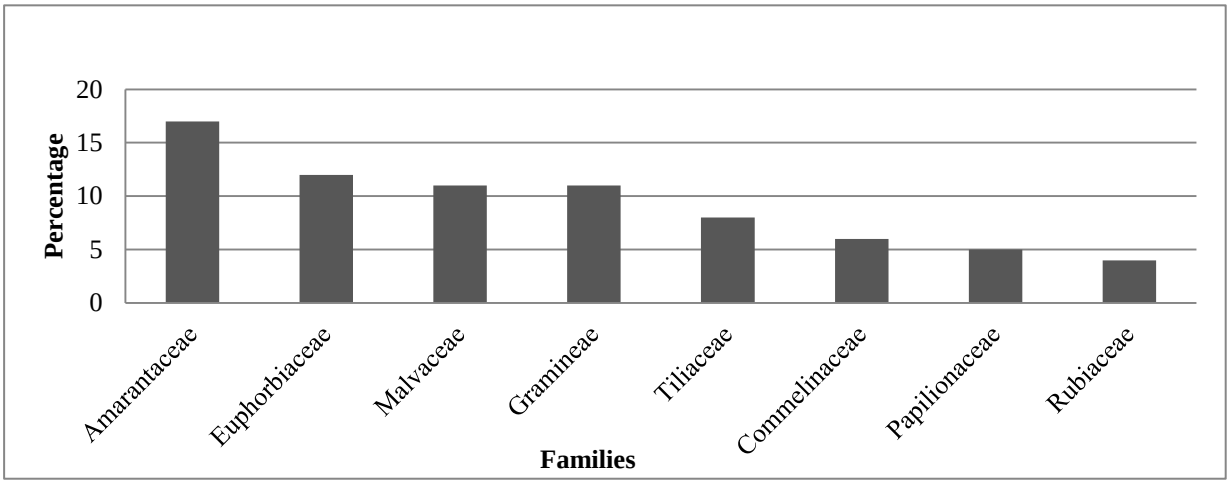
[1] Includes *Hyparrhenia dissoluta, H. filipendula, Pennesetum purpureum, Panicum maximum,* and probably *Heteropogon contortus, Brachiaria brizantha,* and *Sporobolus* sp.
tr. = traces

The results of this study show that grasses were the most important food source of the Murchison elephant population during the dry season of 1958 - 1959, comprising 88% of the total food materials mass in the stomachs of the 71 elephants examined. Browse only provided a low percentage of the diet, with leaves, twigs, and fruit only making up about 10% of their food. Herbaceous plants are only of minor importance. The stomach contents of the 71 elephants only contained about 2% of these types of plants.

A different study was published in 1964 and was conducted by Dougall and Sheldrick. They observed a 10-year old elephant on 16 May 1963 from 6:55AM to 6:30PM in Tsavo National Park in Kenya. His feeding habits were monitored during these 11 hours and 35 minutes, and samples of the plants that the animal had been seen eating were obtained for identification and analysis.

The elephant consumed 28 botanical Families and browsed from a total of 64 different species. Of these species, 59 were analysed. The analysis of these 59 species can be found in appendix X.

Of all the species consumed, 74% came from eight Families. These Families are listed in the figure below, along with the percentage of the total number of times he browsed from these Families. This figure is based on a similar figure given in the article by Dougall and Sheldrick (1964).



Graph 3.1 The eight Families of plants that were consumed most often by the elephant and the percentage of the time these Families were browsed [Dougall & Sheldrick, 1964].

Seven of the eight Families of plants in the graph above are flowering plants, including herbs, subshrubs, shrubs, trees, and some succulents. The only grass Family is the Gramineae, which was browsed about 11% of the time.

Table 3.7 Ranges of the nutrients found in the 59 plant species that were analysed [Dougall & Sheldrick, 1964].

Nutrient	Amount (% of DM)	Mean value
Crude protein	6.14 – 22.63	12.56
Ether extract	0.57 – 5.89	2.43
Crude fibre	20.80 – 49.41	32.26
Calcium	0.37 – 3.61	1.50
Phosphorus	0.08 – 0.58	0.19
Sodium	0.010 – 1.668	0.095
Potassium	0.41 – 7.36	2.09

The table above (table 3.7) shows the ranges of nutritional value of the plants analysed by Dougall & Sheldrick, which can also be found in the appendix X. These ranges depict the lowest and highest nutrient level found in the 59 plants.

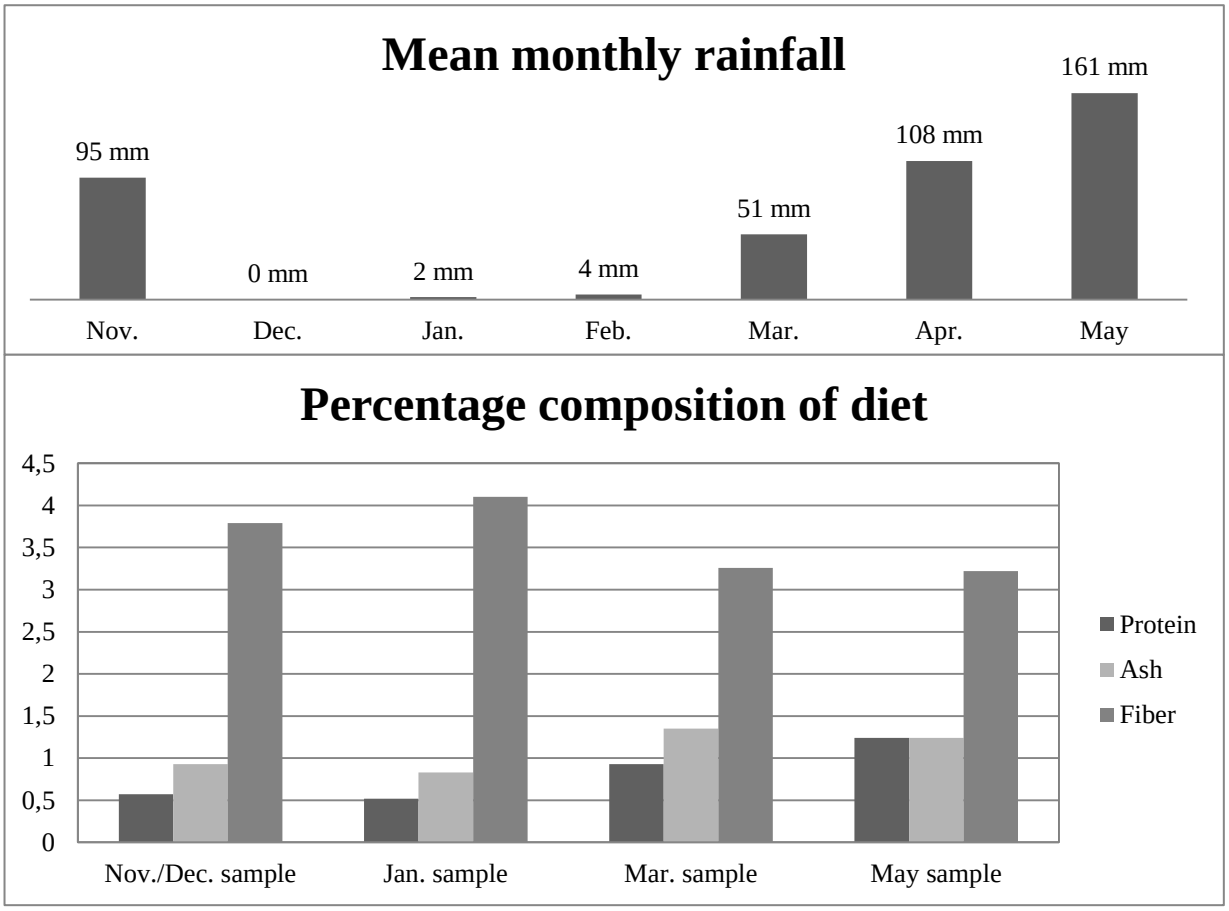
McCullagh (1969) looked at the stomach content of 148 elephants, cropped at different times of the year between mid-November 1966 and mid-May 1967 in Murchison Falls National Park in Uganda. These 148 elephants were divided into 4 groups, evenly spaced over this six month period, consisting of both sexes and all ages. The stomach content was chemically analysed. The results are displayed below in table 3.8, 3.9 and 3.10, and figure 3.11 and display an adaptation of the results given in the article by McCullagh (1969).

Table 3.8 The chemical composition of the dry matter of elephant stomach contents collected in different months of the year (g/kg) [McCullagh, 1969].

Dietary constituent	Nov./Dec.	January	March	May	All months
Protein	57 ± 10	52 ± 11	93 ± 18	124 ± 34	84 ± 33
Lipid	15 ± 9	12 ± 8	18 ± 12	15 ± 10	15 ± 10
Carbohydrate	465 ± 35	429 ± 33	429 ± 21	413 ± 64	435 ± 43
Fibre	379 ± 14	410 ± 60	326 ± 35	322 ± 55	357 ± 55
Ash	93 ± 16	83 ± 23	135 ± 29	124 ± 38	110 ± 34
MJ ME/kg	6.49	5.93	6.69	6.96	6.60

The right-hand column shows the mean for all the samples, while the other columns show the means for the four collection periods. Each collection period lasted about a calendar month, with the exception of Nov./Dec., which extended from 19 November to 12 December. This is of importance and this can be seen in the varying results from one period to another. These differences are of significance, which can be seen from the standard deviation and the large number animals used in the study. The differences between January and March are particularly striking.

The nutrient content in plants was influenced by the amount of rainfall. For example, there was a strong correlation between the level of rainfall and the protein content of the diet. The food items had a low protein/high fibre content under drought conditions, while the protein content in the food items rose with the amount of rainfall which resulted in new growth. To be able to show this and further correlations between nutrients and rainfall, graph 3.2 displays



the amounts of protein, ash, and fibre, along with the mean monthly rainfall in the Park over the study period. The rainfall in November was high during the first two weeks of that month, whereas the stomach samples were collected mostly during the drought of December. This explains the low protein levels in the Nov./Dec. period.

Graph 3.2 Diagrammatic representation of changes in the composition of the elephant's diet and changes in the mean monthly rainfall (rainfall data calculated from the records of three station in Murchinson Falls N. Park, supplied by the Uganda Meteorological Dept.) [McCullagh, 1969].

The January sample was collected during the drought, which can account for the low protein and high fibre content in the diet. This matched the dry, brown and burnt condition of the vegetation around that time. The stomach samples of the first group were mostly collected in December because of the high rainfall during the first two weeks of November, and were also collected during dry conditions. The growth of new grasses was the result of the heavy rainfall after the dry season and McCullagh concluded that the increase in protein in the diet from March to May was the result of the elephants feeding on these grasses.

There were differences discovered in the ash content between the wet season diet and the dry season diet. To be able to make a more detailed comparison between the two seasons, 15

random samples were taken from the January group and 15 from the March group. The results are displayed below.

Table 3.9 The mineral composition of the dry matter of elephant stomach contents collected at different times of the year in 1967 in Murchinson Falls N. Park [McCullagh, 1969].

	Dry season (Jan. sample)	**Wet season (March sample)**
Calcium g/kg	3.80 ± 0.70	1.30 ± 0.60
Phosphorus g/kg	1.80 ± 0.30	2.10 ± 0.10
Sodium g/kg	1.50 ± 0.30	1.60 ± 0.20
Potassium g/kg	3.70 ± 1.10	6.20 ± 0.30

As can be seen in the table, the phosphorus and sodium content in the diet was relatively consistent in both seasons. A significant ($p<0.01$) difference, however, could be found in the calcium and potassium concentrations between the January and the March group. The complicating factor in this study was the fact that the January samples were taken from animals living north of the Nile and the March samples were taken from animals living south of the Nile. The habitats are not identical; the northern habitat has more woodland areas. To evaluate whether the animals north of the river consumed more woody vegetation, or if the differences could be attributed to seasonal differences, McCullagh took 4 grass samples and 4 woody samples from the January group and the March group that were predominantly found in the diets of the elephants. The results are shown in the table below.

Table 3.10 The mineral composition of the dry matter of elephant stomach contents from the January group and the March group containing different food materials [McCullagh, 1969].

	January sample		**March sample**	
Mineral	Grass	Woody	Grass	Woody
Calcium g/kg	2.90	4.70	1.60	2.90
Potassium g/kg	3.20	1.90	8.10	9.50

The comparisons show a rise in potassium levels and a drop in calcium levels from January to March. This is consistent with the results found in table 3.10 above. McCullagh therefore concluded that the differences between the two months could be traced back to seasonal vegetation changes and not to differing amounts of grass in the diet.

In a more recent study conducted by Rode et al. in 2006, the food items consumed by an elephant population in Kibale National Park in Uganda were analyzed by quantifying the food items consumed along fresh feeding trails. These trails were only less than 3 days old, randomly chosen, and followed for a minimum of 5 kilometers. A trail is formed by repeated travel across a surface whereby the environment is modified [Blake & Inkamba-Nkulu, 2004]. The number of plants consumed was recorded (plant species and parts eaten, like young/mature leaves, fruits, stems, lianas, bark or roots). Also recorded were the number of

each food item that was consumed of items of similar size, except for fruits. Elephants are known to eat fallen fruit, so Rode et al. recorded fruit as eaten if the trails passed fruiting trees with ripe fruit that had fallen to the ground. Broken off and discarded stems were not considered to have been consumed.

These feeding trails provide a reasonable estimate of the diets consumed by the Kibale elephant population, because these animals consume mostly browse. Signs of feeding, rather than direct observation, are used to determine diets and commonly used to determine diet quality.

The findings of their study are displayed in table 3.11. A table with all the analysed species and their Acid Detergent Fibre (ADF) and sodium (Na) content can be found in appendix X.

Table 3.11 Nutrient concentrations (dry matter basis) of Kibale elephant diets estimated from feeding trails [Rode et al., 2006].

	Kibale diets
Copper (mg/kg)	10.50 ± 1.10
Manganese (mg/kg)	148.20 ± 71.50
Zinc (mg/kg)	27.90 ± 5.20
Iron (mg/kg)	133.30 ± 20.90
Sodium (mg/kg)	130.40 ± 10.7
Magnesium (%)	0.30 ± 0.10
Potassium (%)	1.60 ± 0.20
Calcium (%)	0.90 ± 0.18
Phosphorus (%)	0.24 ± 0.06
Crude protein (%)	22.20 ± 2.20
Acid Detergent Fibre (%)	32.40 ± 3.00
Energy (MJ ME/kg)	12.55 ± 0.52

The analysis found that there were significant differences in nutrient levels between the different types of food items (fruit, bark, stem, or leaves). Fruit, for instance, had a higher energy concentration than bark, leaves and stems. Calcium concentrations turned out to be 3.5 times higher in bark than in leaves and stems. Leaves had a significantly higher concentration of crude protein than bark and fruit.

Asian elephant in-situ diet composition

A study by Jin et al. (2006) conducted in 2000 in Shangyong, Xishuangbanna, China, involved the identification and analysis of food items consumed by elephants in that area. The researchers followed fresh elephant trails during different periods in 2000: January 5 – 8, May 4 – 6, and August 27 – 28, and walked more than 3 kilometres each time. They recorded all the plants that had been eaten by the animals, identified the type of foraging (grazing or browsing), and the life form.

Jin et al. also collected dung samples throughout the study: every month from September 1998 to December 1999, and every two months in 2000. In total they collected 22 samples, taken from more than 10 different places each time, with the nearest distance between each site being more than 30 metres. Analysis of the dung was performed under the microscope by counting and identifying the appearance of the plant species.

In total, the researchers recorded the utilization of 106 species by field observation and 83 by dung identification. Appendix X provides a list of these species and their proportions within the diet. Of the latter 83 species, a nutrient analysis was conducted of the 29 most commonly consumed plants, a table of which can be found in appendix X. Table 3.12 below lists the number of species consumed and the proportion (in %) in which they are found in the diet of the elephants.

Table 3.12 The number of species (n) and proportion in diet (%) of different kinds of plants consumed by Asian elephants [Jin et al., 2006].

Life form								**Life history***						**Foraging type**			
Herb		**Vine**		**Shrub**		**Tree**		**ES**		**LS**		**Unid.**		**Graze**		**Browse**	
(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
14	18	19	24	10	12	37	46	42	59	32	37	9	4	6	9	77	91
(26)		(24)		(12)		(41)		(55)		(41)		(9)		(7)		(99)	

* ES: Early successional plants, LS: Late successional plants, Unid.: Unidentified

The data is based on dung analysis and the numbers in parentheses are the numbers of species identified by field observation

The number of species (n) displayed in the table illustrates the number of species identified in the dung analysis. The number in brackets represents the number of species in that category that were identified from direct field observations.

The elephants consumed a variety of plants in a variety of plant categories as the table above shows (herbs, vines, shrubs and trees). A slight preference went out to early successional (ES) plants, accounting for 59% of the diet. Direct observations gave slightly different numbers, which can be found in parentheses. The higher proportion of ES plants can be attributed to the fact that Asian elephants often visit parts of the forest (secondary forest habitats or forest gaps) where ES plants are more abundant. The table also shows that browse species contribute much more to the diet than graze species.

Santra et al. (2008) made an assessment of the nutritional status of plants consumed by elephants in South-West Bengal in India. The full nutrient analysis of 17 of the species consumed by the elephants can be found in appendix X. The table below shows the ranges of different chemicals and minerals found during the analysis. These results have been taken from the tables included in appendix X.

Table 3.13 Chemical and mineral composition of 17 elephant food items analysed by Santra et al. (2008)

Chemical composition	**DM basis**	**DM, NDF, ADF and Lignin**		**Minerals**	**g/kg dry matter**
Crude protein	3.18 - 21.25%	Dry matter (DM)	85.5 – 93.3%	Sodium (Na)	0.78 – 2.57
Ether extract	1.10 - 3.64%	NDF	57 - 74%	Potassium (K)	18.76 – 154.83
Crude fibre	20 - 54%	ADF	24.8 - 40%	Calcium (Ca)	0.40 – 32.50
Ash	3.25 - 8.73%	Lignin	4 - 9.1%	Zinc (Zn)	0.01 – 3.36
				Manganese (Mn)	0.02 – 0.77
				Copper (Cu)	0.03 – 1.42
				Iron (Fe)	0.16 – 3.18

NDF = neutral detergent fibre, ADF = acid detergent fibre

The researchers recorded 52 plant species in the South West Bengal forest, of which the elephants only selectively utilized 22 of these species. This low number of wild plant species utilized by migratory elephants can be explained by their dependency on cultivated crops, which are more palatable and have a higher nutritive value. This dependency on crops has evolved because of the shrinking and degradation of elephant habitat due to mining activities, forcing them to move out of traditional living habitats and to raid crops to meet nutritional requirements.
Evidence showed that the species utilized were eaten either fully or partially by breaking branches, debarking, uprooting, etc. The elephants had a clear preference, namely *Diospyros melanoxylon* (34.4%) and *Pterocarpus marsupium* (24.9%). The high utilization of the latter can probably be explained by the high protein content of the leaves (21.2%). It has been found that ungulates can select food with a desired nutritive value by using knowledge about the nutritional content [Field, 1976]. This might also explain, for example, the moderate utilization of the species *B. latifolia* (10.6%), which the elephants debarked, because this has a high calcium content (22.72 g/kg).

This study concluded that the elephants were probably influenced by the high nutritive values of the plant species, as investigated by Field (1976). He found that ungulates have a nutritional wisdom that they can apply to find food items with the desired nutritive value. This strategy resulted in the preference of crops over natural vegetation.

Another example of a nutrient study was conducted in a different part of southern Asia (Bardi National Park, Nepal) by Prajapati in the hot-dry season of May 2008. It involved the analysis of the food items most frequently fed on by the elephant. Prajapati found that the animals fed on three tree species during the hot-dry season in that area, namely *Mallotus phillippinensis* (61.54%), *Desmodium oojeinense* (30.77%), and *Dalbergia sissoo* (7.69%). The following table contains the data collected from the nutrient analysis done by Prajapati (2008).

Table 3.14 Mean value of nutrient content (%) in the plant parts of different food tree species [Prajapati, 2008].

	M. phillippinensis		***D. oojeinense***		***D. sissoo***	
Nutrients	Bark (n = 22)	Leaves (n = 15)	Bark (n = 7)	Leaves (n = 2)	Bark (n = 3)	Leaves (n = 2)
DM	12.32	6.84	13.11	12.06	13.04	13.78
N	0.26	0.59	0.48	0.75	0.38	1.05
CP	1.60	3.69	2.97	4.69	2.38	6.57
EE	2.29	3.73	0.74	2.70	1.73	3.30
CF	36.26	18.51	14.49	13.50	35.93	67.60
Ash	10.36	8.41	15.54	6.60	8.60	8.00
Ca	0.70	0.31	1.14	0.19	0.78	0.35
P	0.60	0.21	0.45	0.30	0.55	0.53
NFE	49.49	65.66	66.25	72.51	51.36	14.54
OM	89.64	91.59	84.46	93.40	91.40	92.00
TC	85.75	84.16	80.74	86.01	87.29	82.14
Na	3.05	2.08	3.09	3.75	3.37	3.00

DM = dry matter, N = nitrogen, CP = crude protein, EE = ether extract, CF = crude fibre, Ca = calcium, P = phosphorus, NFE = nitrogen free extract, OM = organic matter, TC = total carbohydrate, Na = sodium.

As the table shows, the bark of *M. phillippinensis* contained a high level of nutrients and minerals. Compared to the other two species, *M. phillippinensis* bark had a higher dry matter,

crude fibre, calcium, phosphorus and sodium content than the other two species. This, and the fact that grasses have a poor nutritive value in the dry season in Bardia National Park, explains why this species is more preferred by the elephants in this season than other plant species.

Summary

Numerous studies, including the ones described above, were conducted in the past to investigate the native diets of both the African and the Asian elephant. A number of researchers collected plants for nutrient analysis, others sampled stomach contents.

This study requires a knowledge of the nutritional composition of these native diets in order to be able to compare these to the diets currently fed in the zoos. The tables below (Table 3.15 and 3.16) show ranges found for a number of the nutrients that have been looked at in this study. These ranges were collected by utilising the minimum and maximum values described in Ullrey et al. (1997) and Dierenfeld (2006) - taken from several studies into the native diets of the elephants - and from the studies described above. The first table lists the percentages that were used to calculate the levels shown in the second table. All values are expressed on dry matter basis.

Table 3.15 Nutrient ranges for the native diets of the Asian and African elephant expressed in percentages.

	In-situ nutritional composition Asian elephant	**In-situ nutritional composition African elephant**
Energy animal/day (MJ ME)	-	-
Energy density/kg DM	-	-
Dry matter	1.5 – 1.9% of body weight [Sukumar, 1989] 2,000 – 5,500kg body weight [Shoshani, 2006]	1 – 1.5% of body weight [Ullrey et al., 1997] 4,000 – 7,000kg body weight [Shoshani, 2006]
Protein	2 – 26% [Sukumar, 1989]	3 – 30% [Williamson, 1975; Bax & Sheldrick, 1963]
Fat	0.74 – 3.73% [Prajapati, 2008]	0.57 – 5.89% [Dougall & Sheldrick, 1964]
Crude fibre	13.5 – 67.6% [Prajapati, 2008]	13 – 62% [Dougall & Sheldrick, 1964; Eltringham, 1982; Malpas, 1977]
NFC	-	-
NDF	57 - 74% [Santra et al., 2008]	62% (average) [Meissner et al., 1990]
ADF	24.8 - 40% [Santra et al., 2008]	48% (average) [Meissner et al., 1990]
Ash	3.25 – 15.54% [Santra et al., 2008; Prajapati, 2008]	110g/kg DM (average) [McCullagh, 1969]
Ca	0.19 – 5.72% [Sukumar, 1989]	0.13 – 8.92% [McCullagh, 1969; Chiaki, 1996]

P	0.21 – 0.60% [Prajapati, 2008]	0.08 – 0.66% [Dougall & Sheldrick, 1964; Williamson, 1975]
Mg	0.06 – 0.21% [Sukumar, 1989]	0.3% (average) [Rode et al., 2006]
Vitamin E	-	-
Biotin	-	-

Table 3.16 Nutrient ranges for the native diets of the Asian and African elephant derived from the values in table 3.15.

Nutrients	In-situ nutritional composition Asian elephant (*Elephas maximus*)	In-situ nutritional composition African elephant (*Loxodonta africana*)
Energy animal/day (MJ ME)	-	-
Energy density/kg DM	-	-
Total amount of DM (kg)	30.0 – 104.5	40.0 – 105.0
Dry matter (g/kg product)	-	-
Protein (g)	30 - 300	20 - 260
Fat (g)	7.4 – 37.3	5.7 – 58.9
Crude fibre (g)	135 - 676	130 - 620
NFC (g)	-	-
NDF (g)	570 – 740	620
ADF (g)	248 - 400	480
Ash (g)	32.5 – 155.4	110
Ca (g)	1.9 – 57.2	1.3 – 89.2
P (g)	2.1 - 6	0.8 – 6.6
Mg (g)	0.6 – 2.1	3
Vitamin E (mg)	-	-
Biotin (µg)	-	-

3.3 Captive situation in zoos

For both African and Asian Elephants, this paragraph provides information with relation to their diet in captivity and current nutritionally related health problems within their captive situation. The focus lies on nutrition and health problems, meaning that other aspects of captivity, such as husbandry, will not be included in this thesis report.

A description of most of the ingredients composing the diet will follow, as well as the possible methods of food presentation.

Furthermore, nutritional norms for the feeding of elephants in zoos will be described and presented in the form of a table.

This paragraph finishes with an overview and description of health problems in captivity. When possible, the choice of the nutrients included in the analysis of the diets will be explained by linking them to various health problems.

3.3.1 Diet in captivity

This paragraph continues with information about the captive situation of both African and Asian Elephants with respect to their diet and current nutritional related health problems. The focus lies on nutrition and health problems, meaning that other aspects of captivity, such as husbandry, will not be included in this thesis report.

A description of most ingredients composing the diet will follow as well as the possible methods of food presentation.

Furthermore, nutritional norms for the feeding of elephants in zoos will be described listed in table form.

This paragraph finishes with an overview and description of health problems elephants experience in captivity. The reasons for choosing to analyse certain nutrients in the context of the diets will also be explained by linking these nutrients to health problems, when possible.

Diet in captivity

In this paragraph, the diet of elephants in captivity will be described: the most common composition of a diet in captivity and the ingredients used, plus the method of food presentation in zoos. Finally, nutritional norms from various sources for diets in captivity will be worked out in detail.

Knowledge of various animal species and their digestive systems, natural feeding behaviours, food sources and diet-related diseases is essential when aiming to be successful at feeding wild animals in captivity [Baer et al., 2010].

An understanding of the nutrition of elephants is essential in view of the occurrence of welfare issues and diseases, and low reproduction rates [Hatt & Clauss, 2006].

In captivity elephants are typically fed cultivated hays, concentrates, produce, and browse [Dumonceaux, 2006]. These food items together usually form the elephant diet and will be explained in more detail below.

Roughage

Hays are harvested and dried forages are largely made from legumes and/or grasses [Baer et al., 2010]. An elephant diet in captivity consists mainly of grass hay. This is ideal for animals that eat plants high in fibre [Hatt & Clauss, 2006]. Examples of grass hays are timothy,

orchard grass, Bermuda grass, fescue, bluegrass, etc. An example of a legume is alfalfa (called lucerne in Europe). Providing a mixture of legume and grass-hay is beneficial because it provides sufficient protein and calcium levels, largely derived from legume [Baer et al., 2010]. Roughage should make up 70 - 85% of the total dry matter intake. The main concerns are the possible deficiencies in minerals, vitamins and proteins and the hygienic quality. Nutrient deficiencies in hay can only be identified through laboratory analysis, and thus this should be done for every batch of hay [Hatt & Clauss, 2006]. The nutritional composition of roughage can vary widely and depends mainly on the stage of maturity when cut and on soil fertility [Ullrey et al., 1997], but also on climatic region, growing conditions, drying, curing and storage of forage [Baer et al., 2010].
If there are nutrient deficiencies, these can be compensated by providing supplements, such as pelleted compound feeds. These feeds or mineral supplements should be provided accordingly. Roughage that is offered *ad libitum* should contain a high level of fibre, such as late-cut hays, oat/hay/straw, or branches. Roughages that contain a low level of fibre and a high level of protein such as legume hays, early-cut hays and fresh grass should be avoided. This type of roughage can also contribute to a bigger body mass [Hatt & Clauss, 2006]. Nevertheless, mixed legume-grass hay may be beneficial due to the proper content of calcium and protein. Legume provides enough calcium and protein and grass hay may have lower levels of calcium and protein [Baer et al., 2010]. Breeding bulls, lactating and pregnant females and growing young need a higher level of protein than found in most types of grass hays, though this should be tested by laboratory analysis of the grass hay [Ullrey et al., 1997].

Roughage provides sufficient abrasion and can prevent molar problems, meaning that non-roughage food should be restricted in the diet. Moreover, other food items just add energy to the diet. This energy can also easily be added to the diet by offering more roughage. [Hatt & Clauss, 2006]

Browse

Browse consists of various kinds of vegetation such as twigs, branches, plants, buds, leaves, flowers. In zoos there is great variation in the quality, nutrient composition and type. Some species of browse may be toxic, so good identification, selection and use of browse is important [Baer et al., 2010]. Browse is essential in a diet due to its high level of dietary fibre. It also serves to increase elephants' foraging behaviour and the time spend on this. Branches and twigs from browse also require more manipulation with the trunk than hay. [Stevenson & Walter, 2006; Hatt & Clauss, 2006]

In addition, when insufficient proportions are provided, molar problems seem to occur more frequently. Most zoos have a limited amount of browse, and other animals have a higher priority to receive browse than elephants. It is suggested to feed the elephants the leftovers of the branches that are not eaten by animals if there is no risk in disease transmission [Hatt & Clauss, 2006].

Fruit and vegetables

Fruit and vegetables are not harmful to include as a part of the elephants'diet when looking at their nutrient and dry matter content [Hatt & Clauss, 2006]. Nevertheless, giving produce

items that have been cultivated for humans to captive animals can be a problem due to the higher sugar and lower fibre content than the produce animals eat in the wild. These sugars can cause an excess in energy, obesity, heart disease, diabetes, cancer and hypertension. [Hensrud, 2002]. Produce may still be practical for training and medical purposes [Walter, 2010].

Concentrates and supplements

There is a large variety of manufactured feeds that can be provided to herbivores in captivity, with the pellet being the most common form. Pellets are made from compressed ground ingredients [Baer et al., 2010]. These concentrates mostly contain a high level of proteins, vitamins and minerals, and possibly some fat [Walter, 2010]. The levels of nutrients still depend on the nutritional composition of the concentrate. It is important to first consider which nutrients need to be added when choosing to supplement the diet. Concentrates such as pellets should make up 10-30% of the total dry matter and should be used to supplement the roughage. When this range is exceeded, minerals and energy may not be given in the correct amounts. Pelleted compound feeds are not really obligatory. They add fibre and energy, but these nutrients can also be provided by increasing the hay ration. When sufficient amounts of hay cannot be given, pellets high in fibre can be a substitute. Legume hay, such as lucerne or clover, and freshly cut grass can be added to the grass-hay ration when higher levels of proteins are needed [Hatt & Clauss, 2006]. The vitamin and mineral levels recommended for horses should be appropriate for elephants as well [Ullrey et al., 1997].

Diets based on hay often lack in vitamin E due to the loss of up to 90% of this vitamin during the processing of hay. Therefore, the interest in vitamin E for elephants increased, and thus there is a demand for supplements especially made for elephants [Walter, 2010] .

Other products

As with horses, bran, oats, corn, and other grains were traditionally used in feeding programs for elephants, and some zoos continue this practice. With the appropriate use of nutritionally complete pelleted feeds and adequate amounts of fibre from good quality hays, the benefits of bran may be overstated. Excessive use of bran for the horse has been associated with nutritional secondary hyperparathyroidism, due to bran's high phosphorus content and a marked inverse Ca:P ratio. The use of whole grains, once necessitated by the unavailability of nutritionally complete pelleted feeds, is also no longer required. On occasion, bran has been used as a carrier for liquid medications, and different carriers may be required for medications in other forms. Because elephants are reluctant to consume unfamiliar foods, it is appropriate to periodically offer possible medicant carriers such as bran, fruit and vegetables so they will be consumed when needed. However, it should not be necessary to offer such items continuously. [Walter, 2010]

Possibly methods of food presentation

It is important to consider that elephants in the wild spend about 18 hours a day in foraging [Walter, 2010]. Elephants should be fed frequently during the day, including the night, to fulfil foraging time needs. As browse is high in fibre and low in energy, offering it is appropriate because it requires processing and thus takes time. By distributing the browse

around the enclosure, elephants are stimulated to walk more [Walter, 2010, Hatt & Clauss, 2006]. There are various methods to present browse, hay and other food.
Elephants need to be stimulated to perform their natural behaviours such as foraging behaviour. Thus it is important that their enclosure is enriched. Food can be used in methods of enrichment, for example: a food-ball, frozen food in ice blocks, moveable hay boxes, swing out feeders, scatter feeding, elephant feeding devices, etc. These different methods of presenting the food should be unpredictable [Walter, 2010].

Nutritional norms

There are different guidelines found in the literature that can be used as nutritional norms for captive elephants. Dierenfeld 1994 and BIAZA 2006 & 2010 have been used as nutritional norms for the captive feeding of elephants.

The nutrition requirements of the domestic horse should represent a nutritional model for captive elephants because of the similarities in their digestive tracts. This data is available for different physiological stages and derives from the National Research Council (NRC) from 1989. These minimum requirements for horses are compared by Dierenfeld with in-situ diet compositions from the studies of Sukumar (1989), Dougall and Sheldrick (1964) and McCullagh (1969) on African and Asian elephants [Dierenfeld, 1994].

BIAZA 2010 provides a nutritional norm for elephants which is generally based on nutritional requirements for horses, taken from Ullrey et al. (1997). Some data that was missing from the BIAZA 2010 report, was taken from the report of BIAZA from 2006.
Due to the lower digestive efficiency of elephants as compared to that of horses, the horse equations for energy cannot be used to estimate energy for elephants [BIAZA, 2010; Hatt & Clauss, 2006].

When the norms for particular nutrients are specified for both species of elephant individually, these norms will be mentioned separately. Both guidelines for nutrients mentioned in the literature are listed in table 3.16. These norms were then converted into the units used for analysing the diets later in this study, and are shown in the final table, table 3.18.

Assuming that the body weight ranges between 2,000 and 5,500 kilograms for Asian elephants and between 4,000 and 7,000 kilograms for African elephants as mentioned in table 3.17, the ranges for energy intake per animal per day and dry matter intake can be calculated.

Table 3.17 First concept with nutritional requirements for captive elephants

Nutrients	Dierenfeld, 1994	BIAZA, 2006 & 2010
Body weight (mass)	Asian: 2,000- 5,500kg African: 4,000- 7,000kg**	Asian: 2,000- 5,500kg African: 4,000- 7,000kg**
Energy per animal/day	$Mass^{0.75}$ * 140Kcal	-
Energy density (per kg DM)	2.0 Mcal DE	-
Total amount of DM (g)	1.3% of body weight	1.5% of body weight
Protein	10 – 12% per kg DM	8 – 10% per kg DM
Fat	1.2-1.8%	1.2-1.8% per kg DM
Crude fibre	-	13-62% per kg DM
NFC	-	-
NDF	-	62% per kg DM*
ADF	-	Hay with over 30%, mean= 48% per kg DM*
Ash	-	-
Ca	1.5% per kg DM	0.3% per kg DM
P	0.2% per kg DM	0.2% per kg DM
Mg	0.1% per kg DM	0.1% per kg DM
Vitamin E	130 - 167 IU per kg DM	100mg per kg DM
Biotin	-	-

* BIAZA, 2006.

**Shoshani, 2006

Table 3.18 Nutritional requirements for captive elephants.

Nutrients	Husbandry guidelines nutrition Dierenfeld (1994) (per kg DM)	Husbandry guidelines nutrition BIAZA (2006 & 2010) (per kg DM)
Energy animal/day (MJ ME)	Asian: 175.30 - 374.35 African: 294.82 – 448.57	
Energy density (MJ per kg DM)	7.53	
Total amount of DM (kg)	Asian: 26.0 – 71.5 African: 52.0 – 91.0	Asian: 30.0 – 82.5 African: 60.0 – 105.0
Dry matter (g per kg product)	-	-
Protein (g)	100 - 120	80 - 100
Fat (g)	12 - 18	12 - 18
Crude fibre (g)	-	130 - 620
NFC (g)	-	-
NDF (g)	-	620*
ADF (g)	-	>300*
Ash (g)	-	-
Ca (g)	15	3
P (g)	2	2
Mg (g)	1	1
Vitamin E (mg)	100	100
Biotin (µg)	-	-

***** Derived from the BIAZA report of 2006.

3.3.2 Nutritional health problems in captivity and their critical nutrients

Many diseases that affect captive wildlife are usually the result of malnutrition: nutrient deficiencies, an inability to metabolize or synthesize nutrients, or excess in nutrient intake [Baer et al., 2010]. Providing good quality food and nutrients in the appropriate quantities is critical in order to avoid nutrition-related diseases and/or ailments [Baer et al., 2010].
A number of these diseases and ailments found in captive elephants are described below.

Obesity

Obesity is a known problem for zoo animals. Many captive elephants are obese or have a body mass that is considerably higher than conspecifics in the wild [Hatt & Clauss 2006]. Captive Asian elephants show an average difference of 27% and captive African elephants 21% in body mass as compared to published average values (Asian elephant: 2720 kilograms and African elephant: 2800 kilograms) [Ange et al., 2001].

Hatt & Clauss (2006) attribute this to the fact that the formulation of a diet focuses more on the mineral and vitamin components and less on the supply of energy, which is the most important and most obvious reason for feeding. Obesity is also attributed to the consumption of overly digestible diets, feed that is readily available and requires minimal physical activity [Dierenfeld, 2006].

Obesity can cause several behavioural and physiological problems [Walter, 2010]. Elephants have a tendency to develop foot lesions [Fowler, 2001], hyperthermia [Dierenfeld, 2006] or joint and ligament problems in legs and feet [Kurt, 1995; Hatt & Clauss, 2006]. Obesity can also potentially exacerbate or compound arthritis in elephants [Walter, 2010].
Being (considerably) overweight can also have a negative impact on reproduction, causing poor reproductive output and performance [Taylor & Poole, 1998] in males and females. Obesity can also contribute to longer labour, dystocia, stillbirths [Taylor & Poole, 1998], as well as the deaths of both calf and cow [Olson, 2004].

The goal of elephant husbandry should be to maintain a moderate body mass for each animal. Values for wild conspecifics can be used as a guide. If any animals are overweight, their diets should be reduced accordingly. Furthermore, elephants should be weighed and measured on a regular basis using a calibrated weigh-bridge. If a weigh-bridge is not available, Wemmer et al. (2006) developed a visual method, the Body Condition Score, to be able to assess the body condition of both captive and free ranging Asian elephants. It employs a numerical scale index ranging from 0 – 11, which corresponds to morphometric variables for different parts of the body, namely the prominence of bony characters to assess body fat stores and muscle mass. This method is recommended by the Asian Elephant Specialist Group. [Wemmer, 2006; Fernando et al., 2009]

Foot problems

There are a number of causes of foot problems that can be related to nutrition. Malnutrition [Fowler, 2001] and overweight [West, 2001] are mentioned as two of these causes. It seems that African elephants have fewer foot problems than Asian elephants. The reason for this difference is unknown [Fowler, 2006].

Conditions that are thought to have a possible link to malnutrition are: toenail cracks [Benz, 2005; Fowler, 2006], slow nail and pad growth [Buckley, 2001], brittle nails [Buckley, 2001], excessively thin pads and soft nails [Buckley, 2001], and laminitis caused by overfeeding [Benz, 2005], though for all conditions the precise link to nutrition is not mentioned by any of the above named sources.

Figure 3.10 Cracked toenail of an Asian elephant[3.17]

Biotin, one of the water-soluble B vitamins, also known as vitamin H or B complex vitamins[3.19], is thought to improve foot health in elephants when supplementation of this vitamin is offered [Sadler, 2001]. Like all B vitamins, it helps the body metabolise fatty acids, metabolise carbohydrates into glucose (both for energy), and metabolise fatty amino acids into protein[1] . B complex vitamins are also needed for healthy skin, hair, eyes, and liver, also aiding in the proper function of the nervous system. Therefore biotin is often recommended to help strengthen nails and hair[1].
For this reason it is said that biotin can improve elephant foot and nail health and a number of zoos use biotin supplementation. However, there is no definitive study to confirm this fact [Sadler, 2001; Benz, 2005; Dierenfeld, 2006]. During a study by Geyer & Schulze (1994), biotin supplementation in horses showed an improvement in hoof horn condition after 8 to 15 months, while the horn condition of the control group showed constant results. Results even showed a deterioration in the condition after reduced biotin supplementation in the study group. The final recommendation states therefore that biotin should be continuously supplemented in horses with severe hoof horn alterations [Geyer & Schulze, 1994].

Because improvements in foot health contributed to biotin supplementation go hand in hand with improvements in (foot) husbandry, further research into the direct effects of biotin supplementation is needed. It has, nevertheless, been proven to be beneficial to equine foot health [Sadler, 2001].

It is also not known if captive elephants have a deficiency in this vitamin, as levels of biotin have not yet been measured in wild conspecifics [Clubb & Mason, 2003]. It is known that bacteria present in the large intestine can produce biotin under optimal circumstances. However, in the case of intestinal problems that cause a bacterial imbalance, the body is not able to synthesise this alternative source of biotin and has to rely on food as a source.[3.20]

Vitamin E deficiency

Vitamin E deficiency is a known problem amongst zoo animals, including elephants [Dierenfeld & Dolensek, 1988; Dierenfeld, 1989; Papas et al., 1991]. Vitamin E functions as a biological antioxidant and protects tissues, in particular membranes, against products of metabolism and/or lipid oxidation [Dierenfeld, 1989] . It also stimulates wound healing [Walter, 2010].

A lack of this vitamin can have several and varied adverse effects and symptoms, namely: cardiac or skeletal muscle degeneration [Lui et al., 1982, 1983, 1984], reproductive

failures [Trinder et al., 1969], vascular and immune system deficiencies [Lipinski & Machlin, 1981; Stuart, 1982], serous atrophy of fat [Dierenfeld, 1994], and nervous system disorders [Muller et al., 1983; Nelson, 1980]. In worst cases it can cause death [Dierenfeld & Dolensek, 1988; Papas et al., 1991]. A form of muscular dystrophy called capture myopathy, mostly caused by stress or labour, shows similar pathologies to a deficiency in vitamin E [Boever, 1986]. Several ungulate species, including an Asian elephant in the New York Zoological Park prior to 1983, showed pathologic signs of having a vitamin E deficiency [Dierenfeld & Dolensek, 1988]. These cases showed cardiac and skeletal myopathies, as well as neuronal degeneration.

A reason for the vitamin E deficiency in elephants can be related to the fact that these animals seem inefficient in absorbing some forms of this vitamin which are normally used in feeding programs. The reasons appear to be unknown. [Papas et al., 1991].

Although all the above sources about vitamin E deficiency are relatively old, the results of this study show that it could potentially still be a ongoing issue for zoos. This subject will be thoroughly discussed in later chapters.

Colic

Colic is another term for any abdominal pain, which can be a chronic disorder or an acute onset of pain and is frequently seen in captive elephants [Hatt & Clauss, 2006]. It can lead to a number of problems including constipation, infectious causes, bloat, spasmodic colic, mesenteric tears, and impaction [Walter, 2010]. Colic in elephants can occur after abrupt changes in the diet, ingestion of mouldy hay [Hatt & Clauss, 2006], and ingestion of large amounts of earth, sand, or stones, although the latter is less common [Walter, 2010].

There are a number of ways to prevent colic in elephants. First of all, hay should be the basis of the diet, and fibre intake should be sufficient to ensure that the gut functions normally. Movement and activity should be promoted by the keepers, while the swift intake of concentrates or pelleted feed should be controlled and monitored. Changes in the amount or type of roughage should be introduced gradually, and sufficient fresh water should be available to the elephants at all times. Bran is suggested to prevent colic by offering it together with concentrates or pelleted food to provide high fibre material. [Walter, 2010]

Hypocalcaemia

Hypocalcaemia is a calcium deficiency caused by the insufficient intake of calcium or loss of calcium from the blood circulation[3.18]. It can also arise as a result of low levels of vitamin D, which is necessary for calcium absorption[3.21]. In elephants, a low level of vitamin D can be caused by being housed indoors for prolonged periods of time, with no access to sunlight [Toit, 2006].

Hypocalcaemia is known to be a possible cause dystocia in animals, including elephants in captivity. It has been said to account for some cases of initial failure during the second stage of labour, which resulted in dystocia [Hermes et al., 2008]. Kolk et al. (2008) and Sonsbeek et al. (2011) conducted studies into calcium metabolism and hypocalcaemia in elephants as a result of anecdotal reports of dystocia in captive elephants. Both reported that the exact cause of the dystocia was unknown, but that it may have been related to hypocalcaemia. Moreover, the latter reported that two Asian elephants suffering from

dystocia responded with renewed contractions of the uterus upon intravenous administration of calcium. Dystocia related to hypocalcaemia can be prevented by supplementing the diet with calcium and vitamin D during the pregnancy [Hermes et al., 2008]. The study by Kolk et al. (2008) into the subclinical hypocalcaemia in captive Asian elephants concluded that captive Asian elephants might be hypocalcaemic and that elephants should be fed calcium-rich diets at all times due to the fact that they absorb dietary calcium mainly from the intestine.

4. Results

Of the 11 surveys that were sent out, 8 zoos responded (72%). The table below shows the respondents of the survey. All of these 8 zoos were Dutch, meaning that the response rate from the Netherlands was 100% and from Belgium 0%. Information about the elephant diets of one of the zoos (Ouwehands Dierenpark) was collected from a diet overview from the zoo itself, and supplemented with data from the report by Ravenswaaij & Rusman (2011) when amounts were not known.

Table 4.1 Respondents of the survey.

Country	Zoo	City
The Netherlands	Natura Artis Magistra	Amsterdam
	Burger's Zoo	Arnhem
	Diergaarde Blijdorp	Rotterdam
	Dierenpark Amersfoort	Amersfoort
	Dierenpark Emmen	Emmen
	Dierenrijk Europa	Mierlo
	Ouwehands Dierenpark	Rhenen
	Safaripark Beekse Bergen	Hilvarenbeek

This chapter discusses the results obtained from the survey and the report on Ouwehands Dierenpark. It begins by listing the general information about each zoo necessary to interpret the results and includes a list of all the ingredients and amounts fed daily at each zoo. The chapter then continues with calculations of the energy offered to and the energy requirements for each elephant in each zoo. The chapter includes a listing of the average amount of nutrients offered per animal per zoo. It then highlights any deviations between the amounts offered versus the husbandry guidelines established by Dierenfeld (1994) and BIAZA (2006, 2010) and versus the nutrient composition of the in-situ diets.

4.1 Elephant group composition in participating zoos

The following table shows the elephant group composition of all the respondent zoos, with the species, number of males/females/calves, number of groups and any specifics that are of importance.

Table 4.2 Elephant group composition of the responding zoos.

Zoo	Species	Males	Females	Calves	Nr. of groups	Specifics
Artis Natura Magistra	Asian	-	3	1	1	One female is lactating Calf is female
Burger's Zoo	Asian	-	2	-	1	
Diergaarde Blijdorp	Asian	1	4	2	1	Two females are lactating Calves are female
Dierenpark Amersfoort	Asian	1	5	1	2	One female is lactating Calf is female Male is housed separately
Dierenpark Emmen	Asian	3	6	4	1	Four females are lactating Calves are male
Dierenrijk Europa	Asian	3	-	-	1	
Ouwehands Dierenpark	African	1	4	-	2	Male is housed separately

Safaripark Beekse Bergen	African	1	4	-	1

4.2 *Feeding information of the participating zoos*

Table 4.3 below shows all ingredients and the amounts fed in the Dutch zoos, providing a complete overview of elephant diet ingredients at the various zoos. All the amounts are given in grams and represent the average amount one animal receives daily. The legend for table 4.3 regarding the corresponding numbers and zoos can be found in appendix IX.

Table 4.3 All the ingredients of elephant diets at Dutch zoos, with the amounts given per animal per day in grams.

Ingredients	**1gh**	**1fg**	**2**	**3**	**4f**	**4m**	**5gh**	**5fg**	**6**	**7f**	**7m**	**8**
Roughage												
Fresh grass	-	150,000	-	-	-	-	-	111,111	-	-	-	-
Grass hay	30,000	-	22,500	30,000	56,275	75,000	24,444	-	50,000	31,300	62,500	16,000
Silage	-	-	-	-	5,100	-	-	-	-	-	-	-
Straw (barley)	3,333	3,333	-	-	-	-	-	-	-	-	-	-
Browse												
Oak (*Q. robur*)	-	-	-	-	-	-	44,444	44,444	-	-	-	-
Willow bark (*S. alba*)	38,333	38,333	-	4,000	-	-	-	-	667	520	520	6,000
Vegetables												
Beet	-	-	6,000	-	-	-	-	-	-	-	-	-
Beetroot	-	-	-	-	-	-	7,222	7,222	-	-	-	-
Carrot	6,667	6,667	19,000	4,000	1,375	-	6,111	6,111	6,667	3,700	3,700	-
Cucumber	-	-	-	-	-	-	6,667	6,667	-	900	900	-
Endives	2,667	2,667	-	1,600	-	-	-	-	-	1,000	-	-
Lettuce	-	-	-	-	-	-	-	-	-	-	1,000	-
Onion	-	-	-	-	1,975	-	-	-	-	600	600	-
Sweet pepper (green)	-	-	-	-	-	-	5,556	5,556	-	-	-	-
Fruit												
Apple	1,667	1,667	6,000	3,000	850	500	5,556	5,556	1,667	3,400	3,400	1,000
Other												
Bread (brown)	267	267	3,500	-	525	1,000	1,389	1,389	333	800	800	200
Peanuts	-	-	-	-	-	-	-	-	-	10	10	-
Walnuts	-	-	-	-	-	-	-	-	-	10	10	-
Concentrates/supplements												
Grain (barley)	-	-	-	-	-	-	889	889	-	-	-	-
Bran	-	-	-	-	-	-	-	-	3,333	-	-	1,000
Horse biscuit	933	933	-	-	-	-	-	-	-	-	-	-
KFF elephant pellets	3,000	3,000	-	-	1,625	4,500	-	-	3,000	-	-	400
Kiezenbrink e.t.b.	-	-	-	-	-	-	-	-	167	-	-	-
Linseed	-	-	-	-	-	-	-	-	-	143	143	-
Totalin Stricker	-	-	-	-	-	-	-	-	-	-	-	36
T. elephant pellets	-	-	-	4,000	-	-	-	-	-	-	-	-
T. horse pellets	-	-	-	400	-	-	-	-	-	-	-	-
Tropische grazerbrok	-	-	-		-	-	-	-	-	2,900	6,600	-

fg = fresh grass diet, gh = grass hay diet, f = female group, m = male group, KKF = Kasper Fauna Food, e.t.b. = elephant training biscuit, T. = Treurniet

There are 4 zoos (numbers 1, 4, 5 and 7) that feed two different diets. Numbers 1 and 5 feed fresh grass during a limited period of the year. The first zoo substitutes grass hay for fresh grass in the summer months and the second zoo feeds fresh grass during 7 months of the year. For both zoos, the amount of fresh grass fed is adjusted so the total amount of dry matter is approximately the same as when the animals are fed grass hay. Zoos 4 and 7 house two separate groups; males and females are kept separately. The differences (grass hay vs. fresh grass, males vs. females) between these diets are specified in table 4.3 above.

The table shows that there are a few ingredients that most, if not all, zoos use in their elephant diet. The following table lists the five most frequently fed ingredients throughout the Dutch zoos.

Table 4.4 The six most frequently fed ingredients throughout the Dutch zoos.

Ingredients	Frequency (nr. of zoos)	Range (in kg)
Grass hay	8	16 – 75
Apple	8	0.5 – 6
Concentrates	7	0.143 – 6.6
Carrot	7	1.4 – 19
Bread (brown)	7	0.2 – 3.5
Willow branches	5	0.5 – 38

Even though most, or all, zoos feed the ingredients from table 4.4, there are big differences between the average amounts given per animal. When looking at apple for instance, one zoo (number 4) only feeds 500 or 850 grams of apple per day, while zoo number 2 feeds an average of 6 kilograms of apple per elephant per day. For all five of the ingredients, there are relatively big differences in the average amounts fed per animal.

Other ingredients are specific to only one or two zoos, like most of the concentrates/supplements. There are also differences between different groups in the same zoo, where the male and female diets differ in amount of ingredients or even types of ingredients.

Another clear difference between the zoos is the number of different types of ingredients. Zoo 7, for instance feeds twelve types of ingredients, while zoo 2 feeds five types of ingredients and zoo 4 feeds four different ingredients to their male elephant.

The table below shows to what extent (in percentages) the different nutrients are provided by the various ingredient types that are used in the elephant diets in the Dutch zoos, and shows the importance of some of the major food types.

Table 4.5 The distribution of the different nutrients throughout the various ingredient types in the elephant diets in Dutch zoos, displayed in percentages.

Nutrients	Roughage	Browse	Produce	Other	Concentrates/ supplements
Protein	87.7	1.2	1.0	1.2	8.9
Fat	82.0	2.9	2.0	1.5	11.7
Crude fibre	93.1	1.5	1.4	0.4	3.6
NFC	76.4	-	12.3	-	11.3
NDF	96.9	1.1	0.3	-	1.7
ADF	98.1	-	0.5	-	1.5
Ash	86.7	2.4	1.4	0.5	8.9
Ca	69.6	7.0	0.8	0.2	22.5
P	77.8	1.8	1.6	1.7	17.2
Mg	79.0	0.9	1.8	0.4	17.9
Vitamin E	56.6	-	1.7	0.1	41.6
Biotin	-	-	1.4	0.5	98.0

It is clear from the table that most of the nutrients are found in the roughage given in the zoos, with the exception of biotin which is found almost exclusively in the concentrates and supplements provided. This corresponds with the two tables above, which show that roughage, and mainly grass hay, is the prime ingredient in the diets.

Calcium and vitamin E are also provided by two zoos through the feeding of concentrates and nutrients, with almost half of the vitamin E being supplied in this manner.

4.3 Energy offered and energy requirement

In this paragraph, the energy offered and energy requirement for each group of elephants in every zoo will be described. The relevant data of every individual elephant per group per zoo, along with the corresponding energy intakes per group, and the maintenance metabolic rate per individual, is shown in appendix VIII. The mean energy intake per day per individual animal and the mean maintenance metabolic rate per individual animal, or energy requirement, is shown in table 4. The relative difference between both these amounts is also shown in the table below.

Table 4. Relative difference between mean energy offered per animal and mean maintenance metabolic rate per animal for each zoo.

Zoo	Mean EO per animal (ME MJ)	Mean MMR per animal (ME MJ)	Rel. difference (%)
1gh	368.2	242.2	152.0
1fg	390.1	242.2	161.1
2	223.2	252.0	88.6
3	263.9	227.0	116.3
4f	409.3	266.2	153.8
4m	538.0	363.7	147.9
5gh	185.9	239.5	77.6
5fg	187.8	239.5	78.4
6	411.0	256.7	160.1
7f	254.1	300.1	84.7
7m	476.7	321.7	148.2
8	140.2	285.2	49.2

EO = energy offered, MMR = maintenance metabolic rate, Rel. diff. = relative difference.

Four of the 12 diets do not offer sufficient energy in comparison to the energy requirement. These diets range between 11.4% and 50.8% below the requirement. The energy offered by the other diets exceeds the energy requirement by a range of 16.3% to 61.1%. The energy offered to the elephants in zoo 8 is far below the energy requirement; they receive less than half of their maintenance metabolic rate. In contrast, the energy offered to the elephants in zoo 1, those with the fresh grass diet, is far above the requirement: more than 1.5 times higher.
The mean energy offered to elephants from zoo 1 with grass hay is 22.0 ME MJ lower than the diet with fresh grass (1fg). Both diets surpass the mean energy requirement per animal. Also, the energy offered between 5gh and 5fg only differs by 2.0 ME MJ, while the energy offered is below the energy requirement of both diets. Furthermore, the energy offered to the males in zoos 4 and 7 is higher than that of the females: in zoo 4 128.7 ME MJ, and in zoo 7 222.6 ME MJ.

4.4 Nutrient composition of the elephant diets of the participating zoos

The nutrient compositions of all the ingredients have been analysed and calculated. The table with these results can be found in appendix V. Using the results from this table, the results in the following table were calculated for each zoo (see chapter 2.2 for details on the calculations), and then used to calculate a mean and standard deviation for all the zoos, which can also be found in table 4.6.

All the nutrients are on dry matter basis and the units are displayed per nutrient. The amounts in the tables are an average per animal.

Table 4.6 Nutritional composition of the current elephant diets at all Dutch zoos

	1gh	1fg	2	3	4f	4m	5fg	5gh	6	7f	7m	8	Mean ±. SD
Total average offered per animal per day													
Total amount of ingredients (kg)	54.1°	178.1°	57	44°	67.7	81	134.4°	47.8°	65.3°	40.9°	74.4°	20.1°	72.1 ± 43.6
Total amount of DM (kg)	37	37.5	24.5	30	51.2	66.7	27	28.4	48.4	30.3	58.4	15.5	37.9 ± 15.2
Dry matter (g/kg product)	683.1	210.8	429.0	681.9	755.9	823.4	200.6	594.3	741.2	740.6	785.9	768.9	618 ± 218.9
Total energy/day (MJ ME)	368.2	390.1	223.2	263.9	409.3	538.0	187.8	185.9	411.0	254.1	476.7	140.2	320.7 ± 128.0
Energy density (MJ ME/DM)	10.19×	10.63×	9.12	8.80	8.00	8.07	8.94*	8.29*	8.51†	8.40	8.16	9.05	8.8 ± 0.8
Nutritional composition (per kg DM)													
Protein (g)	109.9	158.8	121.7	128.9	133.2	133.2	174.9	125.1	134.4	134.6	135.1	127.5	134.8 ± 17
Fat (g)	27.0	34.5	28.7	29.6	29.2	29.4	43.8	35.7	31.3	32.0	31.1	29.0	31.8 ± 4.5
Crude fibre (g)	253.3	207.6	269.4	268.3	298.3	294.7	243.5	292.4	302.3	281.8	287.3	294.5	274.4 ± 28
NFC (g)	102.1	138.3	154.5	127.2	97.2	102.9	131.2	93.4	108.3	90.2	85.9	90.0	110.1 ± 22.3
NDF (g)	527.6	421.7	521.3	584.2	618.7	641.3	365.1	486.2	591.3	578.7	595.6	600.6	544.3 ± 83.7
ADF (g)	274.7	198.1	305.8	334.5	359.2	371.6	195.2	281.6	342.7	334.4	345.1	336.9	306.7 ± 58.8
Ash (g)	85.9	101.3	73.5	116.9	84.7	85.6	90.4	74.8	83.3	72.2	73.4	81.5	85.3 ± 13
Ca (g)	7.77	8.54	4.23	16.7	5.28	5.66	6.36	5.50	5.34	5.33	5.31	5.78	6.82 ± 3.34
P (g)	2.68	3.76	2.79	4.03	2.90	2.99	3.92	2.80	3.51	3.11	3.07	3.40	3.25 ± 0.47
Mg (g)	1.74	2.35	1.65	2.75	1.78	1.95	1.98	1.38	2.15	2.25	2.22	2.05	2.02 ± 0.36
Vitamin E (mg)	54.1	165.7	21.7	86.8	33.3	50.5	130.0	14.6	48.4	38.4	37.0	30.9	59.3 ± 45.9
Biotin (µg)	412.5	406.2	35.7	1,135.4	160.6	338.3	10.4	9.89	331.5	2.75	1.43	145.6	249.2 ± 323.6

* Calculated by excluding the DM of oak leaves from the total amount of DM because of the missing energy value for oak leaves.

† Calculated by excluding the DM of Kiezebrink elephant training biscuit from the total amount of DM because of the missing energy value of the biscuits.

° The total amount differs from the total amount offered to compensate for the fact that only the bark is eaten from the willow and oak branches.

× Calculated by excluding the DM of Horse biscuit from the total amount of DM because of the missing energy value of the biscuits.

The standard deviations show that there are some huge differences amongst the zoos. The most noticeable differences are found in the first part of the table, where the total amount of ingredients and the total amount of dry matter differ immensely between the eight zoos. This in turn results in a big difference between the zoos when looking at the dry matter per kilogram product. Also the total energy per day varies between the zoos, with 140.18 MJ offered at zoo 8 and 537.95MJ offered to the male at zoo 4.

The bottom part of the table shows that the biotin levels have a higher standard deviation compared to the mean, meaning that the levels of biotin in the diets differ immensely between the zoos. When looking at these levels, it can be seen that the lowest amount of biotin per kilogram dry matter is found in the diet of the male at zoo 7 (1.43µg), while the highest level is found in the diet of zoo 3 (1,135.37µg).

When looking at the crucial nutrients calcium and vitamin E, the results show that there seem to be some differences. Most zoos offer around the 6 grams of calcium per day, while zoo 3 offers more than twice that amount. Vitamin E levels vary amongst all zoos, with the lowest level offered at zoo 2 (21.69mg per day) and the highest level offered at zoo 1 in the fresh grass diet (165.68mg per day).

5. Discussion

Several points of discussion arose during this study. This chapter will discuss these points and provide a comparison between the current elephant diets in Dutch zoos, the ex-situ requirements and the in-situ nutritional composition.

5.1 Survey

Of the 11 surveys that were sent out, 8 zoos responded. The overall response rate of the questionnaire was 72.7%, with a 100% response rate from the Dutch zoos. This is an outstanding response rate, which can be attributed to the NVD Nutrition Group. Having one organisation within a country seems to positively influence the zoos' motivation.

Because diet data from zoo 7 was not supplied via the online survey, no additional information regarding age, weight, and health of this zoos' elephants was available for this zoo. The fact that weight data was missing meant that the average MMR per animal could not be calculated. The other missing information would have provided useful input, but does not influence the results.

The responses to questions about the diet composition were not answered as intended, for some zoos did not explicitly provide amounts in kilograms/grams. Instead, answers such as 'ad libitum', 'when available', 'sometimes', and 'for variation' were given instead of accurate measures of ingredients (in SI units). The respondent, however, may not have the time and/or motivation to record or weigh the amounts properly, and is more likely to give estimated amounts. Thus, some diet ingredients that were named but for which no explicit amount was given could not be used in the diet results because of the subjectivity of the answers. This resulted in nutrient levels that do not reflect the actual reality.

The respondents were asked to send (if available) an analysis of their hay, labels of the concentrates and supplements provided, and current photos of their elephants to be used for the body condition score. Only two zoos responded to this request; one sent photos of the labels, and two zoos sent photos of the elephants.

The survey was designed such that the respondents would supply the diet ingredients and amounts per group and not per individual. All results thus reflect an average of all animals in a zoo in terms of life stage, age, lactation, sex, and weight and these aspects could therefore not be used in calculating results such as energy and nutrient requirements. However, it is possible to conclude a higher energy requirement for lactating animals for instance.

5.2 Comparing diet composition with requirements/recommendations

This paragraph compares the estimated requirements for ex-situ elephant diets and the in-situ diet composition with the current elephant diets in Dutch zoos.

5.2.1 Energy

The average total energy provided by the diet was calculated for the whole group, meaning individual differences in energy intake between animals was not taken into account. Also the

total amount of energy calculated may be lower in some diets than the actual amount offered to the elephants due to inaccurate ingredient quantities, as explained above.
To calculate the maintenance metabolic rate for each elephant, the Kleiber formula was used, which originally calculates the basal metabolic rate for captive animals. This formula used the weight of the animal as given in the survey results. When applying the formula, an overweight elephant would require more energy than an elephant in good condition, which would not be correct if the animal is overweight and should actually be losing weight. This formula does not take this into account. It also does not specify differences in energy requirements based on factors such as sex, age and whether the animal is lactating.

Another point to consider was that the actual weights of elephants retrieved from the surveys were sometimes estimated. These estimated weights were not necessarily accurate, in part because zoos and keepers might not be objective when estimating the weight. Experience in scoring of the body condition on elephants is also lacking. In addition, while sometimes the elephants had actually been weighed, the weights provided were not always current, with measurements ranging from 2 to 20 months old. Weight may change over time.

The fact that the weights used in applying the Kleiber formula were not always accurate or up-to-date meant that the MMR scores were perhaps not always correct and therefore these may give an incorrect picture of the real-life situation.

The data on the body condition scores that were given through the survey may be out of date or incorrect because of no objectivity when scoring the body condition of the elephants. This means that the BCS of the elephants could not be used when discussing the results on the diets.

The following table lists the ranges, mean, and SD of the energy offered to African elephants, as well as the energy requirements cited by Dierenfeld (1994) for this species. Zoo 7 provides two separate diets: one for one male, and one for four females. In contrast, zoo 8 offers one diet to one male and four females together.

Table 5.1 Comparison of the energy offered in 3 diets used in 2 zoos for 10 African elephants with the requirements

	Ranges	**Mean ± SD**	**Dierenfeld (1994)**
Total energy per animal per day(MJ ME)	140.2 – 476.7	290.3 ± 171.2	294.8 – 448.6
Energy density (MJ ME/DM)	8.16 – 9.05	8.5 ± 0.5	7.53
Total energy per animal per day (MJ ME)*	254.1 – 476.7	365.4 ± 157.4	294.8 – 448.6
Energy density (MJ ME/DM)*	8.16 – 8.40	8.3 ± 0.2	7.53

SD = standard deviation
* Excluding the diet of zoo 8 with 5 elephants

The range of total energy per day overlaps the range given by Dierenfeld. It is remarkable that the mean for total energy per day per animal is below the minimum requirement for African elephants. The results of zoo 8 may be incorrect due to an underestimation (16kg per animal per day as an ad litibum estimation[Huisman]) of the amount of grass hay given through the survey results and therefore influence the numbers in the above table.

When this zoo is disregarded, the ranges for the total daily energy per animal per day and the energy density per kilogram DM is much smaller and the mean of 365.4 MJ ME

meets the requirement. However, when both diets from zoo 7 for the male and females are considered separately, the energy offered to the females (254.1 MJ ME) is lower than the required range and that given to the male (476.7 MJ ME) is higher. The lower amount of energy offered to the females can be as result of the provision of less willow bark and produce than in similar diets. The male from zoo 7 gets twice as much grass hay and concentrate than the average female receives.

When looking at the energy density, the range is above the requirement given. This is a result of the large amount of the concentrate 'tropische grazerbrok' in both diets, which has a high energy density of 9.33MJ ME/DM.

Table 5.2 below displays the ranges, means, and SD of the energy offered to Asian elephants and lists the energy requirements cited by Dierenfeld (1994) for this species. Zoos 1 to 6 house a total of 28 (8,20,0) Asian elephants. Zoos 1, 4 and 5 offer 2 diets, with zoo 1 and 5 alternating between a diet with grass hay or fresh grass and zoo 4 housing the females and male separate.

Table 5.2 Comparison of the daily amount of energy offered in 9 diets used in 6 zoos for 20 Asian elephants with the requirements.

	Ranges	**Mean ± SD**	**Dierenfeld (1994)**
Total energy per day per animal (MJ ME)	185.9 – 538.0	330.8 ± 121.4	175.3 – 374.4
Energy density (MJ ME/DM)	8.00 – 10.63	9.0 ± 0.9	7.53

SD = standard deviation

The Asian elephants in Dutch zoos are offered a wide range of the total energy per day. The lowest amount still lies within the range given by Dierenfeld while the highest, being 538.0 MJ ME, surpasses this range. This amount was calculated for the male of zoo 4 and surpasses with the MMR calculated for its weight by about 50%. His weight was 5,300 kilograms, which still lies within the weight range for this species (2,000 to 5,500kg) [Shoshani, 2006]. The greater amount of grass hay offered per day could be contributed to the fact that this animal is a male with a higher dry matter requirement due to a higher body weight.

The average daily energy supply lies within the range given by Dierenfeld. The SD is quite wide, with 4 of the 6 zoo diets (zoos 1,3,4 and 6) far above the range for the total amount of energy required. The fact that zoos 1 and 4 each house one lactating female, and zoo 3 houses two, should explain the higher amount of energy offered due to a higher requirement during the lactation period [Ullrey et al., 1997]. However, the energy amount offered to zoo 1 in both diets should be higher because of the missing energy value of the horse biscuit, which should account for approximately 10 MJ extra. The high energy level in the diet of zoo 6 could be explained by the fact that all 3 animals are males and thus require more energy than females because of their higher body weight. Their daily diet includes 3,3 kg bran per animal (5.05% of the total amount) with a high energy content and accounts for an extra 40,5 MJ ME per animal per day (9.9% of the total energy amount).

Zoos 2 and 5 provide diets with a low energy level to the elephants. These levels still lie within the range given by Dierenfeld, but in zoo 2 the diet is 11.4% lower and in zoo 5 the

diets are 22.4% and 21.6% lower than the average MMR calculated. The energy amount provided by browse was excluded from the calculations for zoo 2 because no proper measurement of the browse provided was given. In the survey, the subjective term ad libitum was used to indicate the amounts of oak, birch, beech and willow. If the energy provided by browse had been included, it could possibly generate a much higher energy level calculation.

Though zoo 5 houses 3 males and 4 lactating females and thus requires more energy than all other zoo elephant groups, the mean energy offered per animal is approximately 52 ME MJ lower than the mean MMR per animal. Useable measurement of oak branches was included in the calculations, however other types of browse were mentioned (willow and birch branches, spruce-fit and beech) without an explicit amount. The same was true of bamboo which was said to be fed 'when available'. These missing values may account for a lower total, while the actual total per day may be much higher.

The highest levels for energy density (10.63 and 10.19 MJ ME per kg DM) are provided by zoo 1. This diet consists of a rather high amount of elephant pellets, which in turns leads higher energy density in both diets. Concentrates in all diets lead to a higher energy density. Furthermore, in the diet at zoo 2, bread is responsible for a high energy density.

5.2.2 Dry matter

Table 5.3 below, shows the ranges, means and SD of the total amount of DM content in the diets of the African elephants and displays the ex-situ requirements for DM cited by Dierenfeld (1994) and BIAZA (2006 & 2010). Zoo 7 provides two diets for one male and four females.

Table 5.3 Comparison of the daily amount of energy offered in 2 diets used in 1 zoos for 5 African elephants with the requirements.

	Ranges	**Mean ± SD**	**Dierenfeld (1994)**	**Husbandry guidelines nutrition BIAZA (2006 & 2010)**
Total amount of DM (kg/animal/day)	30.3 – 58.4	44.4 ± 19.9	52.0 – 91.0	60.0 – 105.0

The diet at zoo 8 has a DM level of 15.5 kilograms per animal per day. This diet was disregarded, as explained previously, because of the higher amount of roughage and thus dry matter than reported in the survey. The total DM amounts to 58.4 kilograms for the male in zoo 7, and this lies within the Dierenfeld range (1994). The total amount of DM in the diet of the females from zoo 7 equals 30.3 kilograms, and does not lie in either of the ranges given. The energy offered to these females is lower than recommended as discussed before, and this could be the result of lower amounts of ingredients with a high DM, such as roughage and concentrates. The low mean of 44.4 kilograms dry matter is due to the high energy density level in the diets. The high energy density in the diets means that there is less dry matter necessary to comply to the energy requirements, explaining the low DM mean in the diets.

The next table displays the ranges, means and SD of the total amount of DM in the diets of the Asian elephants and displays the ex-situ requirements for DM cited by Dierenfeld (1994) and BIAZA (2006 & 2010). Zoos 1 to 6 house a total of 28 (8,20,0) Asian elephants.

Table 5.4 Comparison of the dry matter offered to 20 Asian elephants in 9 diets at 6 Dutch zoos with the requirements.

	Ranges	Mean ± SD	Dierenfeld (1994)	Husbandry guidelines nutrition BIAZA (2006 & 2010)
Total amount of DM (kg/animal/day)	24.5 – 66.7	39.0 ± 14.0	26.0 – 71.5	30.0 – 82.5

It becomes apparent that the requirement for the total amount of DM in a diet provided to Asian elephants is much lower than that for the African elephants due to the fact that these animals are smaller and thus have a lower body weight and requirement. The mean of total DM lies within both ranges given and the SD is smaller than that for the African elephants. The highest amount of DM is 66.7 kilograms and met all requirements, while this diet had one of the lowest levels of energy density. The lowest amount (24.5 kg DM), that of the diet of zoo 2, is the only one that does not meet any of the requirements. This is a consequence of not including the browse in the diet due to the lack of specific amounts, as explained above. The total amount of dry matter in the diet provided by zoo 2 is thus underestimated.

5.2.3 Nutrients

The following table shows the ranges, means and SD of all nutrients provided by all the zoo diets, and also displays the ex-situ requirements for DM cited by Dierenfeld (1994) and BIAZA (2006 & 2010).

Table 5.5 Comparison of the nutrient profile both elephant species at Dutch zoos to the ex-situ requirements (per kg DM).

	Ranges	Mean ± SD	Husbandry guidelines nutrition Dierenfeld (1994)	Husbandry guidelines nutrition BIAZA (2006 & 2010)
Protein (g)	109.9 – 174.9	138.8 ± 17	100 - 120	80 - 100
Fat (g)	27.0 – 43.8	31.8 ± 4.5	12 - 18	12 - 18
Crude fibre (g)	207.6 - 302.3	274.4 ± 28	-	130 - 620
NFC (g)	85.9 – 138.3	110.1 ± 22.3	-	-
NDF (g)	365.1 – 641.3	544.3 ± 83.7	-	620*
ADF (g)	195.2 – 371.6	306.7 ± 58.8	-	>300*
Ash (g)	72.2 – 116.9	85.3 ± 13	-	-
Ca (g)	4.23 – 16.7	6.82 ± 3.34	15	3
P (g)	2.68 – 4.03	3.25 ± 0.47	2	2
Mg (g)	1.38 – 2.75	2.02 ± 0.36	1	1
Vitamin E (mg)	14.6 – 165.7	59.3 ± 45.9	100	100
Biotin (µg)	1.43 – 1,135.4	249.2 ± 323.6	-	-

Protein

The mean for protein is higher than both requirements given. When looking at the ranges, the highest level for protein is 174.9g/kg DM in zoo 5, with the fresh grass diet. This may be the consequence of the higher protein level in fresh grass compared to that of grass hay and may therefore explain the high protein level in the fresh grass diet of zoo 1. If the nutrient profile for fresh grass used for this study is based on grass grown on heavy fertilized soil, this could explain the high protein content.

Bread and some concentrates and supplements contribute to a higher protein level in other diets having a high protein level. Lactating and growing animals have a higher protein requirement, 120 -150 and 100 – 130 grams per kilogram DM [Dierenfeld, 1994]. This should explain the high mean in protein level in all diets. A protein level higher than the requirements given by Dierenfeld (1994) and BIAZA (2006 & 2010) would most likely not have any adverse effects. In horses, excess protein is broken down into nitrogen and is excreted as urea, and carbohydrates are metabolized into glucose and used as energy [Bishop, 2003]. Because the elephant digestive tract is similar to that of the horse, it can be assumed that this explanation can also apply for the elephant.

Fat

All diets contain a higher level of fat than the requirements, with the lowest level calculated being 27.0g. The high content of fat in the diets of zoo 5 may be caused by the high fat level in oak leaves branches and the high amount of this product in the diet. Though the absolute levels show that all diets contain an excess of fat, the fat content of the current diets is not that high when considering the proportion of fat in the whole diet.

Fibre (CF, NDF and ADF)

All crude fibres levels in the diets is within the range cited by BIAZA. The mean of these levels is 274.4 grams, and falls between the minimum and maximum requirement.

The mean NDF level in the diets is lower than the requirement of 620 grams per kilogram DM. Only one of the diets had a higher NDF level than required. This could be a consequence of the missing NDF values for many concentrates and supplements, some vegetables, other products and some roughage ingredients. NDF values for 15 from the 28 ingredients (44.9% of the diet on DM basis) were missing.

In general, as the NDF percentage increases, the dry matter intake decreases. The NDF value derives from the total cell wall (cellulose, lignin and hemicellulose). Lignin, for example, influences the digestibility of the plant wall material, decreasing the digestibility as it increases. A high NDF percentage therefore means that the dry matter intake will decrease. [5.1] Missing certain NDF values can mean that the intake of dry matter cannot be determined with any certainty and that it could be higher or lower than the results show, meaning that the NDF is probably higher than calculated, meaning that the dry matter intake is lower.

According to BIAZA, the ADF-level should be less than 300 grams per kilogram DM. Five zoos have a ADF-level much higher than recommended. Sixteen of the 28 ingredients lacked an ADF value, and no ADF values for browse were found, meaning that the ADF value is probably higher than calculated during this study.

Calcium

The calcium recommendation used by BIAZA for captive elephant diets are based on horse recommendations and may be inadequate due to the fact that natural elephant forage contains 2 to 3 times more calcium than the equine recommendations. A male requires 8-9 grams of calcium per day for tusk growth, and a lactating cow requires up to 60 grams of calcium daily. The various recommendations given are for maintenance and do not take into account the elephants that are, for example, lactating or growing. [Dierenfeld, 1994] Calcium ranges

provided at Dutch zoos are adequate and fall between both levels (3 - 15) required by Dierenfeld and BIAZA. The calcium is largely provided by roughage, concentrates and supplements. The calcium levels of Totalin and horse biscuit were missing, but this did not influence the total amount of calcium of zoos 1 and 8 because of the small amounts of these ingredients in the diets (Totalin 36 grams and horse biscuit 933 grams).

Phosphorus

The lowest amount of phosphorus was in the grass hay diet of zoo 1. A diet with fresh grass does meet the requirements for phosphorous, but the grass hay diet of this zoo does meet the requirement for phosphorous because grass hay contains less phosphorous than fresh grass.

Zoo 3 has the highest level. This is due to the high phosphorus content (13.33 gram per kg DM) of a concentrate used in the diet. Four kilograms of this concentrate in the diet amounts to a total of 47.9 grams phosphorous.

Magnesium

The lowest level of magnesium is 1.38 grams and is higher than the requirement of 1 gram per kg/DM. This level is actually higher because the magnesium value of the oak leaves was missing. The highest level of magnesium was found in the diet of zoo 3 and may be the result of the high levels of this nutrient in large amount of elephant pellets given, and also in the horse pellets included.

Vitamin E

The average vitamin E content of 59.3 mg per kilogram DM is lower than the recommended value of 100 mg per kilogram DM. In reality this mean may be higher because of the missing values for the vitamin E in the browse being fed in five of the eight Dutch zoos. The actual level of vitamin E in the diets would probably be much higher when taking this into consideration. The highest level of this nutrient was found in the fresh grass diet in zoo 1 because of the high vitamin E level in fresh grass [Brown, 1953]. A deficiency in vitamin E can result in cardiac or skeletal muscle degeneration [Lui et al., 1982, 1983, 1984], reproductive failures [Trinder et al., 1969], vascular and immune system deficiencies [Lipinski & Machlin, 1981; Stuart, 1982], serious atrophy of fat [Dierenfeld, 1994], and nervous system disorders [Muller et al., 1983; Nelson, 1980].

5.2.4 Comparison with in-situ nutritional composition

Information about the in-situ diet composition can be valuable for establishing requirements. However, it is very difficult to determine a fixed diet or feeding pattern for either the African or the Asian elephant. Patterns are not easily recognized, for these vary not only between species, but also between populations in different countries or even between areas within the same country. The diet composition and nutrient composition of diets also vary from one season to the next and from one region to another [Sukumar, 1989;Sukumar & Ramesh, 1995; Ullrey et al., 1997; Clubb & Mason, 2003]. Therefore it was quite difficult to establish the actual in-situ diet composition and nutrient levels of the in-situ nutritional composition may be higher than maximum requirements for ex-situ and have a wider range. As a result, a

comparison between the current diets and the in-situ nutritional composition is difficult to make. The second issue that arose with regard to the in-situ diet composition was the fact that vitamin analyses of the food items are non-existent, or at least these could not be found during the literature study. This makes a comparison with the vitamin levels in the current ex-situ diets not possible.

It is important to note certain differences between the energy, dry matter and nutritional composition of the current diets and the in-situ diet.

Overall, the energy density of all the current diets is much higher than the ex-situ requirement. However, a study by Codron et al. (2007) show that in the wild, diet quality decreases with increasing body size, and that smaller species require a higher energy concentration in their food to maintain higher metabolic rate. This means that elephants in the wild do not need high quality food and high amount of energy. So the high energy density (higher than ex-situ requirements) in the current diets contradicts the needs of elephants in the wild, because their in-situ diets are of relatively low quality and contain relatively less energy than the current ex-situ diets offer.

Furthermore, the total dry matter of the diets is much lower than the requirement. In the wild, elephants consume low quality food and thus need to consume more to meet the required dry matter intake. The elephants' natural diet is characterized by a very high fibre/cell-wall content with a crude fibre content of 30-50% DM and a NDF content of 50-70%. As mentioned previously, a high NDF content in the diet means a low DM intake. An average adult elephant consumes about 1 - 1.5% of their weight in DM. [Hatt & Clauss, 2006] The low quality, and thus high NDF, of the natural diet results in the elephant needing to consume more food to receive the required amount of dry matter. The low total amount of DM fed per animal per day of the zoo diets could indicate a lack of roughage.

5.3 Reflection on the research objective and main research question of this study

The research objective was to gain insight into the feeding practices of the elephants in Dutch and Belgian zoos. Unfortunately, none of the Belgian zoos responded to the survey request, meaning that no data could be gathered about the elephant diets in those zoos. Moreover, the diets of Dutch and Belgian zoos could thus not be compared with one another. Thus, even though there was a very good response from the Dutch zoos, the research objective was not met due to the fact that the Belgian zoos did not answer the survey.
Nevertheless, all the Dutch zoos responded, and this may be as result of the effectiveness of the NVD Nutrition group, as explained previously. Because of a 100% Dutch response rate, good insight could be gained into all the Dutch zoo elephant diets in terms of their ingredients and thus also the energy and nutrient levels of the diets. However, the overall results could have been better if the quality of the response was better.

The main research objective was to compare the current ex-situ diets with the two ex-situ requirements listings found in the literature and with the in-situ diet composition. Yet, even though such a comparison was made, the fact that certain values were missing from the results may have affected the energy and nutrient levels calculations. Therefore an entirely complete and accurate picture of the current ex-situ diets could not be obtained.

6. Conclusion

In reflecting on the research questions, the data collected during this study results in the following conclusions. The sub-questions are answered first in order to answer the main research question of this study.

1. What are the nutritional requirements for both species?

The two sub-questions below show that one in-situ composition and two ex-situ requirement lists were used for comparison with the current elephant diet results.

1.1 What is the nutritional composition of the in-situ diet of the African elephant and the Asian elephant?

This study provides ranges for the in-situ diet composition for both species compiled from various studies conducted in the past. Several studies involving the Asian and the African elephant were used to compile these ranges, and therefore two different compositions (one for each species) was compiled.

1.2 What is are nutritional requirements described in the literature for an ex-situ diet for the African elephant and the Asian elephant?

The literature describes two different sets of requirements for the ex-situ diet for both elephant species together, one by Dierenfeld (1994) and one by BIAZA (2010). Both are based on horse recommendations, because the elephant digestive tract shows similarities to that of the horse. The latter is based on a recommendation by Ullrey et al. (1997) and completed by using recommendations from an earlier BIAZA report from 2006.

Both requirements show similarities in terms of energy, dry matter, and nutrient levels, though there is one major difference. Dierenfeld (1994) gives a recommended calcium level of 15mg and BIAZA of 3mg. Dierenfeld, however, takes the natural situation of the elephants into consideration when looking at the requirements for tusk growth and lactation.

Both sets of requirements have a few missing values such as fibre fractions, ash and biotin. In addition, BIAZA does not give recommendations for the total amount of energy and the energy density of a diet.

2. What is the current nutritional composition of the diets at Dutch zoos?

The current zoo diets show several similarities and also several differences. Most zoos feed the same food ingredients, such as grass hay, apples, carrots, browse items, and concentrates, however the latter is not of the same brand at every zoo.

The biggest differences are in the amounts in which these ingredients are fed. These vary enormously between some zoos. Zoos 1 and 5 switch between grass hay and fresh grass for certain months of the year, resulting in a higher total amount of ingredients to compensate for the decrease in dry matter content of the fresh grass versus grass hay.

What the zoos have in common is the fact that roughage makes up the largest portion of the diet. For this reason, roughage contains the highest percentage of nutrient distribution throughout all the various ingredient types, with the exception of vitamin E and biotin.

Almost 42% of the vitamin E is contained in concentrates/supplements (versus almost 57% in roughage). Furthermore, 98% of the biotin is derived from the supplements.

The nutritional composition of the zoo diets show very varying results, which is supported by the calculated standard deviation for each nutrient. Compared with the other zoos, zoo 8 shows the greatest difference in the amount of ingredients, dry matter and energy. However, for all three the overall differences between the zoos are great. The nutrients also vary widely between zoos, with the biggest differences found in the minerals and vitamins with biotin showing the most marked variation.

The main question of this study was formulated as follows:

How much does the current nutritional composition of the diets for African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants at Dutch zoos comply with recent nutritional guidelines for elephants?

The results show that most diets do not differ extremely from the requirements. There are a few exceptions, however. Zoo 8 does not comply with the ex-situ requirements for African elephants in terms of the total amount of dry matter and the total energy offered, which results in a lower mean for the zoos with African elephants. This mean then also does not comply with the requirements. If zoo 8 is disregarded with respect to dry matter and energy, the mean for African elephants lies within the required range for both.

The energy density for all zoos is higher than the requirement given by Dierenfeld (1994). This is due to the relatively large amount of concentrates in most diets and the fact that zoo diets tend to be richer in energy compared with the natural elephant diets.

All the zoo diets show a much higher fat content than the requirements state. The protein content is also higher. The amount of NDF in several of the zoo diets is quite a bit lower than the requirements, however a number of NDF values is missing from the ingredient analysis. This can account for lower values. This is also the case for several other nutrients, such as vitamin E, biotin and calcium.

Both calcium and vitamin E are present in varying levels in the current diets, with some levels turning out to be far below or far above required amounts. The phosphorus level at one zoo turned out to be twice the required amount due to the high level in the concentrate used. All three of these nutrients are quite critical, and incorrect amounts can have severe negative effects on elephant health.

7. Recommendations

The recommendations resulting from this report can be divided into two parts. First, the recommendations for the zoos with regard to their elephant diets. Second, the recommendations related to the possible follow-up or continuation of this study.

7.1 Recommendations for the zoos

- Feed should be weighed on a regular basis, before and after feeding. This will make it easier to register the composition of the diet. In addition, the keepers will know how much to feed of each ingredient on nutritional basis, and it would be possible to keep track of the amounts that are actually consumed. Any changes in food consumption can be noticed sooner.
- Monitoring the weight and body condition of the elephants on a regular basis is a necessity. In this way any changes in body condition will be noticed sooner and this can help prevent obesity. Monitoring, in combination with good diet record keeping, can help determine where any problems lie and then diets can be adjusted accordingly when necessary. Elephants should be weighed and measured on a regular basis using a calibrated weigh-bridge. If a weigh-bridge is not available, using the Body Condition Scoring (BCS) method to visually assess the body condition is the second best option.
- Zoos should analyse their roughage regularly. Ideally, every new batch of roughage should be analysed. If this proves to be too expensive, an analysis should be made as often as possible. This will give the keepers good insight into the nutritional composition of the roughage, allowing diets to be calculated accordingly. In this way the fat and energy content in particular can be regulated to avoid offering these nutrients in excess.
- Concentrates and supplements should only be offered as an addition to the roughage in order to complement any deficient nutrients. Not only will this be a great deal less expensive for the zoos because of the decrease in the amount of concentrates/supplements needed, but in particular the decrease of concentrates will lower the energy density of the diets. A lower energy density will help prevent obesity. This relates to the recommendation above regarding the importance of the roughage analysis.
- Nutrient levels of the diets should be monitored closely for any deficiencies or excesses. Critical nutrients such as calcium, phosphorus and vitamin E, in particular, together with energy and fat, should be monitored to avoid any health problems.

7.2 Recommendations for further study

- It is important to inform zoos about the necessity of good diet record keeping. It is very difficult do to research into the nutrient composition of diets if the ingredient amounts that the zoos provide are not correct or are not given in correct units. Furthermore, good record keeping is not only necessary for further research, but also for good husbandry and animal welfare as mentioned in the paragraph above.
- Together with good record keeping, zoos should be thoroughly briefed on the expected quality of the data (units to be used, recordkeeping should be recent, BCS should be

objective rather than subjective, etc.). Without good quality data, the results of the study can never be of good quality.

- When there is time, it would be advisable to approach zoos personally. This, of course, can only be achieved if zoos are open to the suggestion of a personal visit. A personal visit to the zoo can result in good objective data for a BCS and correct units and amounts for diet ingredients. In addition this would make it possible to ask questions directly instead of via email which could take longer.

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Appendix I – Internet sites, literature sources and search words

All internet sites and literature sources that were used during this study

Internet sites and literature sources
Google Scholar
Intrabibliothecair Leenverkeer (IBL)
WUR- library
Sam-hao catalogue
African elephant specialist group database: http://african-elephant.org/aed/index.html
Elephant care international database: http://www.elephantcare.org/database.htm
Encyclopedia Brittannica

All the search words used during the literature study to look for information on the elephant.

Search words 1st degree:	**Search words 2nd degree:**	**In combination with:**	
Elephants	Zoo	Anatomy	Amount
Asian elephant	Ex-situ	Body condition score	Biotin
Elephas maximus	Captivity	Behaviour	Bone structure
African elephant	Wild	Biology	Browse
Loxodonta africana	In-situ	Biome	Colic
		Convert	Composition
		Diet	Concentrates
		Dietary	Desert
		Digestive tract	Energy
		Food	Foot/hoof
		Habitat	Grashooi
		Health	Guidelines
		International unit (UI)	Horse
		Inventory	Hypocalcaemia
		IUCN	Ingredients
		Management	Intake
		Non-ruminant	Intestine
		Nutrients/nutrienten	Ituri Forest
		Nutrition	Keratin
		Physiology	Namib
		Plant	Norms
		Problems	Obesity
		Range	Presentation
		Species	Requirements
		Taxonomy	Roughage
		Units	Savannah
		Vegetation	Supplements
		Voedingswaarde	Tropical forest
			Vers gras
			Vitamin E

Appendix II – Letter of recommendation from Joeke Nijboer

Diergaarde BLIJDORP rotterdam zoo

D. Blijdorp
Van Aerssenlaan 49
3038 KE ROTTERDAM

Rotterdam, 13 maart 2012

Betreft: **Inventarisatie olifantenvoeding**

Beste collega,

Graag breng ik bijgaande enquête onder de aandacht.

Zowel in 1995 als 2000 is er een enquête uitgevoerd over voeding van olifanten in gevangenschap in Europese dierentuinen. Deze informatie is toentertijd ook verspreid onder de dierentuinen.

Sindsdien is het inzicht in olifantenvoeding groter geworden. Twee studenten van Hogeschool van Hall Larenstein (Ingrid van Baarlen en Mercedes Gerritsen) onder leiding van hun docent Tjalling Huisman zijn bereid gevonden om een inventarisatie van de huidige voeding van olifanten in Europese dierentuinen uit te voeren en de verkregen informatie te vergelijken met inzichten in de huidige olifanten literatuur.

De berekende analyse van uw olifanten rantsoen en de vergelijking ervan met normen voor olifanten zal zo spoedig mogelijk na afronding van het project (voorjaar 2012)aan u worden gezonden. Het is ook de bedoeling dat het verslag beschikbaar komt voor een ieder die meegedaan heeft aan deze enquête. Deze informatie zal ook beschikbaar komen als presentatie voor de volgende olifanten TAG bijeenkomst.

Om het invulwerk zo minimaal te houden is gekozen voor een elektronische enquête. Een aantal gegevens van uw dieren is, wanneer beschikbaar, reeds

ingevoerd . De enquête bevat naast vragen over de samenstelling van de voeding ook vragen over de body score en gewicht. Ook zijn er enkele vragen over de totstandkoming van uw huidige rantsoen en ervaringen hiermee.

Het invullen van de enquête kost 30 tot 45 minuten, afhankelijk van het aantal olifanten in uw collectie.

Dit onderzoek wordt, zoals eerder genoemd, uitgevoerd door studenten van Hogeschool van Hall Larenstein en wordt ondersteund door Dr. Andrea Fidgett (nutritionist Chester Zoo) en Dr. Joeke Nijboer (Nutritionist) beide nutrition advisors of The European Elephant TAG. Vanwege het belang van uitwisseling van informatie en ervaringen en het identificeren van onderzoeksgebieden voor de toekomst, beveel ik deze enquête van harte bij u aan.

Hoogachtend,

Dr. Joeke Nijboer

Nutritionist Rotterdam
Nutrition advisor European Elephant TAG

Appendix III: Explanation of the Body Condition Score

One way to assess the body condition of an elephant is using a (usually) 5 point scoring system known as the Body Condition Score or BCS. With this method one can assess the weight of the animal without it having to be weighed. The condition of the body and dietary energy supply are related. If an animal does not get enough energy from food , the animal will lose weight and get skinnier. On the other hand, an animal that is fed too much energy with its diet, will develop excess body fat and will gain weight. This can result in overweight and obesity.

Scoring the body condition can be a helpful tool to evaluate the quality of the diet. The table below shows the 5 point scoring system of the BCS. This can be easily applied to any elephant in the zoo. A BCS of 1 or 2 indicates the animal being too thin and a BCS of 4 or 5 indicates the animal being overweight to obese. A BCS value of 3 is the desired score for any adult elephant in any zoo.

To help with the explanations in the table, please use the pictures of the 5 BCS values provided in the survey. The pictures show an Asian elephant, however these can also be used for African elephants as the general form of the body and the different states remain the same in both species.

The link in the survey will bring you to an interactive site that can be used for the assessment as well. Do note that this site is in Dutch and the pictures provided in the survey come directly from this site. The site does, however, provide different viewpoints of the animals. If the desire remains to use this site, follow these steps for easy use:

1. Use the link provided in the survey or the link here: http://www.inlusion.com/temp/bcv/
2. While using the mouse, scroll over '**Kies uw dier**' and click on '**Aziatische olifant**'
3. Drag the white button across the bar to show the different BCS values, the picture of the elephant will change. The score and text indicated on the left is the same as in the table below. Just compare the number between the brackets to the number in the table.
4. To view different sides of the elephant, click on '**Zijkant**' (Side) and choose one of the following options: '**Voorkant**' (Front), '**Achterkant**' (Back), '**Bovenkant**' (Top) or '**Onderkant**' (Bottom).

Body Condition Score Elephant, *Elephas maximus* Condition	**Head**	**Body**	**Hindquarters**
BCS 1 – very thin	Entire head looks hollowed and highly sculpted, bones are easily visible, hollow behind the ears, division between head and body easily visible.	Backbone, shoulder blades and pelvis clearly visible. A narrow belly and the ribs are visible. No muscular tissue or fat visible, angular body.	Backbone tapers clearly into the tail, the tail juts out above the hindquarters, angular hips.
BCS 2 – thin	Head has sculpted appearance, bones are easily visible, hollow behind the ears and under the eyes.	Shoulder blades, backbone and pelvis visible. A slender body.	Backbone tapers into the tail, the tail juts out above the hindquarters.
BCS 3 – good condition (desired score)	Bones on the head are clearly visible, but no hollowed areas.	Shoulder blades, backbone and pelvis visible during movement, a rounded belly.	Backbone tapers into the tail, the tail juts out somewhat above the hindquarters.
BSC 4 – fat	Rounded head, little sculpting evident, division between head and body not easily visible.	Backbone still somewhat visible, no other bones visible, bulging belly.	Backbone still somewhat visible, rounded hindquarters, tail droops over hindquarters.
BCS 5 – obese	Rounded head, bones hardly visible, division between head and body not easily visible.	No bones visible, bulging belly, rounded back, no backbone visible, no loose flaps of skin under the belly.	Rounded hindquarters, tail droops into crack between buttocks, a protruding rounded belly visible.

Appendix IV – Elephant Nutrition Survey

Introduction

Before starting with this survey, it is advisable to first review the Word version supplied with the email or click through it here. This way you can gather all the information required ahead of time before starting the survey. When you have gathered everything you need, you can visit this page again to complete and submit the survey.

Contact information

1) Please fill in your contact information.
First Name: _____
Last Name: _____
Job description: _____
Your institution: _____
City: _____
Country: _____
Email Address: _____

2) What species of elephant do you have in your collection?
( ) The African elephant (*Loxodonta africana*)
( ) The Asian elephant (*Elephas maximus*)

3) Does your elephant population consist of more than one group? Meaning, are any elephant of the population housed separately?
( ) YES
( ) NO

Contact information (continued)

With the previous question you indicated that your elephant population consists of more than one group. For this reason we would like to ask you to fill out one survey for each group (so 1 survey if your population consists out of 1 group, 2 entire surveys for 2 groups, etc.) so we can get a clear picture of the composition of your population. All following questions in this survey will refer to the group in question and not for the entire population. Thank you.

General information

A few questions will now follow regarding general information about the elephants in the group (see question 3). Please keep to the same number sequence when filling in the answers so all the information corresponds with the same animal (for example: elephant 1 in every question will always correspond to the same elephant, etc.).

4) Please fill in the information about the elephants in the group. Below you can find an example.

	Age (in years/months)	Sex (male/female)	Stage of gestation (in months)	Lactating (yes/no)
Elephant A	4/3	male	-	-
Elephant B	10/7	female	15	no

	Age (in years & months)	**Sex (male/female)**	**Stage of gestation (in months)**	**Lactating (yes/no)**
Elephant 1				
Elephant 2				
Elephant 3				
Elephant 4				
Elephant 5				
Elephant 6				
Elephant 7				
Elephant 8				
Elephant 9				
Elephant 10				

5) Do you have more than 10 elephants in the group?

( ) Yes (an additional table will follow)

( ) No

General information (continued)

6) Please fill in the information about the elephants in the group.

	Age (in years & months)	**Sex (male/female)**	**Stage of gestation (in months)**	**Lactating (yes/no)**
Elephant 11				
Elephant 12				
Elephant 13				
Elephant 14				
Elephant 15				
Elephant 16				
Elephant 17				
Elephant 18				
Elephant 19				
Elephant 20				

General information (continued)

7) Please fill in the weight in kilograms, if this weight is obtained through weighing or through estimation and the last time the elephant was weighed. Please use the same sequence as the previous question. Below you can find an example.

	Weight (in kilograms)	Weight obtained through (estimation/weighing)	Date last weighing
Elephant A	4336	weighing	15/03/2011
Elephant B	2000	estimation	03/01/2011

	Weight (in kilograms)	**Weight obtained through (estimation/weighing)**	**Date last weighing**
Elephant 1			
Elephant 2			
Elephant 3			
Elephant 4			
Elephant 5			
Elephant 6			
Elephant 7			
Elephant 8			
Elephant 9			
Elephant 10			

Question 7 continued

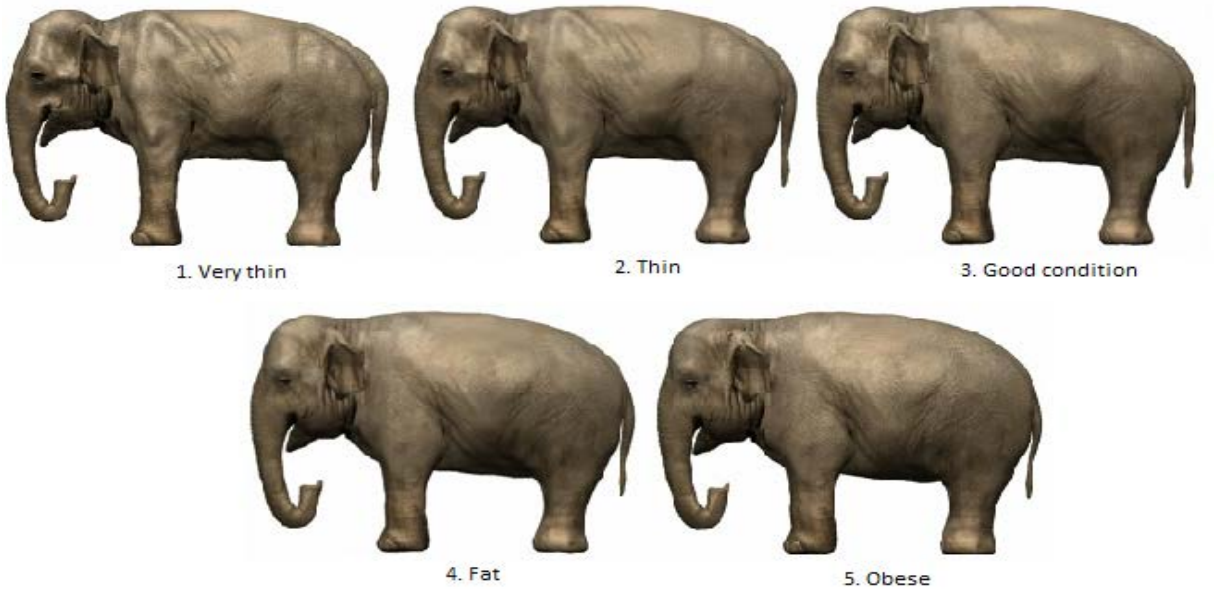
	Weight (in kilograms)	**Weight obtained through (estimation/weighing)**	**Date last weighing**
Elephant 11			
Elephant 12			
Elephant 13			
Elephant 14			
Elephant 15			
Elephant 16			
Elephant 17			
Elephant 18			
Elephant 19			
Elephant 20			

Body condition score

8) The following picture shows the different stages in a Body Condition Score (BCS) of the Asian elephant, which can also be used for the African elephant. These pictures come from the link below. Please visit the below link and indicate per elephant at your zoo how you would score it, using the same sequence as the previous questions.

Note that the site is in Dutch. For instructions on how to use the BCS indicator, please read the instructions attached to the email. You can also find a written manual about the BCS in English attached to the same email.

http://www.inlusion.com/temp/bcv/ (If this link does not work, copy this link and paste it into your browser)



	1. Very thin	2. Thin	3. Good condition	4. Fat	5. Obese
Elephant 1					
Elephant 2					
Elephant 3					
Elephant 4					
Elephant 5					
Elephant 6					
Elephant 7					
Elephant 8					
Elephant 9					
Elephant 10					

Question 8 continued

	1. Very thin	2. Thin	3. Good condition	4. Fat	5. Obese
Elephant 11					
Elephant 12					
Elephant 13					
Elephant 14					
Elephant 15					
Elephant 16					
Elephant 17					
Elephant 18					
Elephant 19					
Elephant 20					

Diet inventory

The next part of the survey relates to the diet of the elephants at your zoo. Please fill in the questions as detailed as possible and in order of importance (i.e. product number 1 is fed the most/has the most weight, product number 5 is fed the least/has the least weight) to help us create a complete and detailed inventory of the diet. Also, please fill in the answers in KILOGRAMS per DAY, if possible an average of 7 days. Each question gives you the possibility to fill in 5 different products. If you feed more than 5 different products, please specify the 4 most fed and fill in 'Other' next to number 5 and sum up the amount given for the remainder of the products (i.e. cabbage 3kg + celery 2kg = 5kg). Below you can find two examples for vegetables.

	Type of vegetables	Amount (in kilograms)		Type of vegetables	Amount (in kilograms)
A.	Carrot	100	A.	Carrot	100
B.	Cucumber	50	B.	Cucumber	50
C.	Fodder beet	10	C.	Fodder beet	10
D.	Sugar beet	5	D.	Turnip	7,5
E.	Turnip	5	E.	Other	5

Diet inventory

9) Please indicate the AVERAGE DAILY amount of roughage you feed your elephants in KILOGRAMS per GROUP. Please fill in the first column what type of roughage you feed and in the second column the daily average amount. You can find an example below.

	Type of roughage	Amount (in kilograms)
A.	Grass hay	100
B.	Fresh grass	50

	Type of roughage	**Amount (in kilograms)**
1.		
2.		
3.		
4.		
5.		

10) Please indicate the AVERAGE DAILY amount of browse you feed your elephants in KILOGRAMS per GROUP. Please fill in the first column what type of browse you feed and in the second column the daily average amount.

	Type of browse	Amount (in kilograms)
A.	Willow branches without leaves	10
B.	Oak leaves	5

	Type of browse	**Amount (in kilograms)**
1.		
2.		
3.		
4.		
5.		

11) Please indicate the AVERAGE DAILY amount of <u>leafy vegetables</u> you feed your elephants in KILOGRAMS per GROUP. Please fill in the first column what type of leafy vegetables you feed and in the second column the daily average amount.

	Type of leafy vegetables	Amount (in kilograms)
A.	Lettuce	100
B.	Endives	75

	Type of leafy vegetables	**Amount (in kilograms)**
1.		
2.		
3.		
4.		
5.		

12) Please indicate the AVERAGE DAILY amount of <u>other vegetables</u> you feed your elephants in KILOGRAMS per GROUP. Please fill in the first column what type of other vegetables you feed and in the second column the daily average amount.

	Type of other vegetables	Amount (in kilograms)
A.	Carrot	100
B.	Cucumber	50

	Type of other vegetables	**Amount (in kilograms)**
1.		
2.		
3.		
4.		
5.		

13) Please indicate the AVERAGE DAILY amount of <u>fruit</u> you feed your elephants in KILOGRAMS per GROUP. Please fill in the first column what type of fruit you feed and in the second column the daily average amount.

	Type of fruit	Amount (in kilograms)
A.	Apple	100
B.	Banana	50

	Type of fruit	Amount (in kilograms)
1.		
2.		
3.		
4.		
5.		

14) Please indicate the AVERAGE DAILY amount of other food products you feed your elephants in KILOGRAMS per GROUP. With other food products we mean anything that does not fall under the above categories, like bread. Please fill in the first column what type of other products you feed and in the second column the daily average amount.

	Type of other food products	Amount (in kilograms)
1.		
2.		
3.		
4.		
5.		

15) Please indicate the AVERAGE DAILY amount of concentrates you feed your elephants in KILOGRAMS per GROUP. Please fill in the first column the brand name of concentrates you feed, in the second column the type, the third column the variety and in the last column the daily average amount.

	Brand name concentrates	Type	Amount (in kilograms)
A.	Mazuri	White rhino	24

	Brand name concentrates	Type	Amount (in kilograms)
1.			
2.			
3.			
4.			
5.			

16) Please indicate the AVERAGE DAILY amount of supplements you feed your elephants in grams per GROUP. Please fill in the first column the brand name of supplements you feed, in the second column the type, the third column the variety and in the last column the daily average amount.

	Brand name supplements	Type	Amount (in grams)
A.	Calcitec	calcium	1000

	Brand name supplements	Type	Amount (in grams)
1.			
2.			
3.			
4.			
5.			

Source of the diet

17) How did you establish the current diet composition? Did you base it on a different diet, animal species, existing norm, or did you compile it yourself? Please elaborate and give as many details as possible entailing the origin of the current diet composition for your elephants.

18) Since when did you start feeding the current diet? Please state date.

_____

19) What was the reason for the most current dietary changes?

20) Did you make use of the current feeding guidelines with relation to elephants?

( ) YES
( ) NO

21) What was the reason for choosing to use or not use these guidelines in establishing the current diet? Please explain your choice in detail.

Roughage analysis

22) Does your zoo conduct a visual quality inspection of the roughage and any other plant materials that are fed to the elephants? If YES, could the most recent inspection report be sent to the email address found at the end of this survey.

( ) YES
( ) NO

23) What are the most important quality indicators you look for during a visual inspection?

24) Does your zoo send any samples of roughage or any other plant materials to a laboratory for a chemical analysis? If YES, could the most recent inspection report be sent to the email address found at the end of this survey.

( ) YES
( ) NO

Health problems

The following part of the survey will contain questions about the current health of the elephants in the group and any current problems regarding their physical health. Please fill out the questions as detailed as possible so a complete health status of the group can be acquired.

25) Please indicate if there were any physical health problems within the elephant group, dating back to five years ago, and the frequency in which these problems have occurred within this time span. Examples of health problems can be obesity, foot problems or bone structural problems.

Additional comments

26) Are there any additional comments or questions, please do not hesitate to mention these below.

27) May we contact you with questions regarding your elephants or answers you give in this survey?

( ) YES
( ) NO

Thank You!

Thank you for taking the time to complete this survey. Your responses will be valuable in making a complete inventory of the elephant diet in zoos. As a reminder, please do not forget to send the following to the email address below:

1. A copy of the label of the concentrates you feed your elephants;
2. A copy of the label of the supplements you feed your elephants;
3. The report of the nutritional analysis (chemical analysis) of the roughage and plant materials if your zoo conducts such and analysis if applicable;
4. Recent photos of the elephants in your collection;
5. And any other related material or information.

The email address you can send this information to is elephantnutritionsurvey@gmail.com

Also, do not forget to fill out this same survey again if your elephant population consists of more than one group. Just use the same link in the email again.

Once again thank you for your time and cooperation. If you have any questions about this survey, do not hesitate to contact us using the same email address.

Appendix V – Nutritional composition of the ingredients

Ingredients	DM (g/kg product)	Energy (MJ ME/kg product)	Protein (g/kg DM)	Fat (g/kg DM)	CF (g/kg DM)	NFC (g/kg DM)	NDF (g/kg DM)	ADF (g/kg DM)	Ash (g/kg DM)	Ca (g/kg DM)	P (g/kg DM)	Mg (g/kg DM)	Vit. E (mg/kg DM)	Biotin (µg/kg DM)	Zoo
Roughage															
Fresh grass	169	1.43	202**	39.00	240.00	143.00	511	274	105	6.20	4.30	2.70	184	-	1,5
Grass hay	826	6.42	130.00	28.00	309.00	89.00	671	390	82	5.00	2.70	1.80	18	-	1,2,3,4,5,6,7,8
Silage	474	3.67	173.00	40.00	258.00	-	-	-	114	5.00	4	-	16.67	-	4
Straw (barley)	860	5.81	49.00	26.00	395.00	-	-	-	86	4.00	0.80	-	-	-	1
Browse															
Oak leaves (*Q. robur*)	402	-	110.00	65.00	307.00	-	-	-	63	8.8	2.7	-	-	-	5
Willow bark (*S. alba*)	471	11.18	9.40	-	-	-	442	-	86	22.80	1.50	1.30	-	-	3,6,7,8
Vegetables															
Beet	141	0.21	120.57	21.28	16.31*	-	-	-	56.74	1.99	2.57	1.06	56.74	0	2
Beetroot	143	1.17	80.00	10.00	61.00	-	-	-	92.00	1.50	2.00	-	-	-	5
Carrot	109	1.62	73.39	36.70	247.70*	728.69	97	89	64.22	3.30	2.66	0.95	50.46	311.93	1,2,3,4,5,6,7
Cucumber	33	0.45	212.12	30.30	212.12*	450.37	186	155	121.21	6.27	7.67	2.80	45.45	121.21	5,7
Endives	62	0.78	20.97	32.26	145.16*	-	-	-	225.81	8.39	4.52	2.42	48.39	-	1,3,7
Lettuce	43	0.65	232.56	23.26	255.81*	482.16	169	131	93.02	3.77	5.23	1.72	69.77	-	7
Onion	123	1.91	130.08	24.39	154.47*	702.88	102	74	40.65	1.86	3.26	0.78	5.69	73.17	4,7
Sweet pepper (green)	62	0.88	145.16	48.39	290.32*	545.93	196	170	64.52	1.38	4.42	1.79	88.71	-	5
Fruit															
Apple	124	1.92	24.19	24.19	177.42*	825.43	102	60	24.19	0.31	1.40	3.55	44.35	24.19	1,2,3,4,5,6,7,8
Other															
Bread (brown)	631	10.04	129.95	31.70	83.99*	-	-	-	33.28	0.77	4.25	0.62	4.75	95.09	1,2,4,5,6,7,8
Peanuts	977	26.14	257.93	529.17	69.60	-	-	-	22.52	0.57	4.67	2.21	65.51	-	7
Walnuts	972	28.47	147.12	661.52	57.61*	-	-	-	17.50	0.85	3.90	1.48	15.43	195.47	7

Ingredients	DM (g/kg product)	Energy (MJ ME/kg product)	Protein (g/kg DM)	Fat (g/kg DM)	CF (g/kg DM)	NFC (g/kg DM)	NDF (g/kg DM)	ADF (g/kg DM)	Ash (g/kg DM)	Ca (g/kg DM)	P (g/kg DM)	Mg (g/kg DM)	Vit. E (mg/kg DM)	Biotin (µg/kg DM)	Zoo
Barley	869	8.41	119.68	19.56	52.93	620.9	215.69	63.44	24.17	0.69	4.03	1.1	16	140	[5]
Bran	918	12.16	176.47	57.73	437.91*	-	-	-	58.82	0.81	11.49	5.23	17.43	261.44	[6,8]
Horse biscuit	900	-	89.11	63.44	23.89	-	-	-	13.00	-	-	-	-	-	[1]
Kasper Fauna Food elephant pellets	900	10.10	184.44	50.00	111.11	321.12	295.56	153.33	148.88	16.67	7.22	4.44	555.56	5555.56	[1,4,6,8]
Kiezebrink elephant training biscuit	875	-	91.66	65.26	24.57	-	-	-	13.37	0.23	2.97	-	-	-	[6]
Linseed	951	20.24	262.88	325.97	189.27	-	-	-	31.55	2.11	5.75	3.69	86.23	-	[7]
Totalin Stricker	900	15.64	57.78	26.67	43.33	-	-	-	81.11	-	61.11	5.56	555.56	-	[8]
Treurniet elephant pellets	900	10.78‡	155.56	44.44	60.56	272.89	153.89	83.00	373.22	100.00	13.33	8.89	555.56	9444.44	[3]
Treurniet horse pellets	900	13.84	155.56	33.33	82.33	538.67	233.33	103.56	39.11	13.33	8.89	9.22	333.33	11	[3]
Tropische grazerbrokken	900	8.40	195.56	53.33	124.44	-	-	-	-	8.44	6.67	6.33	222.22°	-	[7]

DM = dry matter, CF = crude fibre, NFC = non-fibrous carbohydrate, NDF = neutral detergent fibre, ADF = acid detergent fibre, Ca = calcium, P = phosphorus, Mg= magnesium, Vit. E = vitamin E

* dietary fibre

** RE-ex

° converted from IU (vit E natural d-alpha tocopheryl). www.etoolsage.com

‡ Average of Kasper Fauna Food elephant pellets, Treurniet horse pellets, and Tropische grazerbrokken

Zoo	Number	Zoo	Number
Natura Artis Magistra	1	Dierenpark Emmen	5
Burger’s Zoo	2	Dierenrijk Europa	6
Diergaarde Blijdorp	3	Ouwehands Dierenpark	7
Dierenpark Amersfoort	4	Safaripark Beekse Bergen	8

Diet with grass hay

Natura Artis Magistra
3 Asian elephants (excl. 1 calf)

Group 1
females

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Grass hay	30	24,780.00	192.60	3,221.40	693.84	7,657.02	2,205.42	16,627.38	9,664.20	2,031.96	123.90	66.91	44.60	446.04	-
Straw	3,333	2,866.66	19.37	140.47	74.53	1,132.33	-	-	-	246.53	11.47	2.29	-	-	-
Willow bark	9,583†	4,513.59	107.14	42.43	-	-	-	1,995.01	-	388.17	102.91	6.77	5.87	-	-
Endives	2,667	165.33	2.08	3.47	5.33	24.00*	-	-	-	37.33	1.39	0.75	0.40	8.00	-
Carrot	6,667	726.67	10.80	53.33	26.67	180.00*	529.54	70.49	64.68	46.67	2.40	1.93	0.69	36.67	226.68
Apple	1,667	206.67	3.20	5.00	5.00	36.67*	170.59	21.08	12.40	5.00	0.06	0.29	0.73	9.17	5.00
Bread (brown)	267	168.27	2.68	21.87	5.33	14.13*	-	-	-	5.60	0.13	0.72	0.10	0.80	16.00
Horse biscuit	933	840.00	-	74.85	53.29	20.07	-	-	-	10.92	-	-	-	-	-
Kasper Fauna Food elephant pellets	3	2,700.00	30.30	497.99	135.00	300.00	867.02	789.01	414.00	401.98	45.01	19.49	11.99	1,500.01	15,000.01
Total	**54,117**	**36,967.19**	**368.17**	**4,060.81**	**998.99**	**9,364.22**	**3,772.52**	**19,502.97**	**10,155.28**	**3,174.16**	**287.27**	**99.15**	**64.38**	**2,000.69**	**15,247.69**

Diet with fresh grass

Artis Natura Magistra
3 Asian elephants (excl. 1 calf)

Group 1
females

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Fresh grass	150	25,350.00	214.50	5,120.70	988.65	6,084.00	3,625.05	12,953.85	6,945.90	2,661.75	157.17	109.01	68.45	4,664.4	-
Straw	3,333	2,866.66	19.37	140.47	74.53	1,132.33	-	-	-	246.53	11.47	2.29	-	-	-
Willow bark	9,583†	4,513.59	107.14	42.43	-	-	-	1,995.01	-	388.17	102.91	6.77	5.87	-	-
Endives	2,667	165.33	2.08	3.47	5.33	24.00*	-	-	-	37.33	1.39	0.75	0.40	8.00	-
Carrot	6,667	726.67	10.80	53.33	26.67	180.00*	529.54	70.49	64.68	46.67	2.40	1.93	0.69	36.67	226.68
Apple	1,667	206.67	3.20	5.00	5.00	36.67*	170.59	21.08	12.40	5.00	0.06	0.29	0.73	9.17	5.00
Bread (brown)	267	168.27	2.68	21.87	5.33	14.13*	-	-	-	5.60	0.13	0.72	0.10	0.80	16.00
Horse biscuit	933	840.00	-	74.85	53.29	20.07	-	-	-	10.92	-	-	-	-	-
Kasper Fauna Food elephant pellets	3	2,700.00	30.30	497.99	135.00	300.00	867.02	789.01	414.00	401.98	45.01	19.49	11.99	1,500.01	15,000.01
Total	**178,117**	**37,537.19**	**390.07**	**5,960.11**	**1,293.80**	**7,791.20**	**5,192.20**	**15,829.44**	**7,436.98**	**3,803.95**	**320.54**	**141.25**	**88.23**	**6,219.05**	**15,247.69**

DM = dry matter, CF = crude fibre, NFC = non-fibrous carbohydrate, NDF = neutral detergent fibre, ADF = acid detergent fibre, Ca = calcium, P = phosphorus, Mg= magnesium, Vit. E = vitamin E
* Dietary fibre
** RE-ex
†Because elephants only eat the bark, which accounts for approximately ¼ (no source) of the total amount, this value is only a quarter of the total amount

Burger's Zoo
2 Asian elephants

Group 1
females

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Grass hay	22,500	18,585.00	144.45	2,416.05	520.38	5,742.77	1,654.07	12,470.54	7,248.15	1,523.97	92.93	50.18	33.45	334.53	-
Carrot	19,000	2071.00	30.78	151.99	76.01	512.99*	1,509.12	200.89	184.32	133.00	6.83	5.51	1.97	104.50	646.01
Beet	6,000	846.00	1.26	102.00	18.00	13.80*	-	-	-	48.00	1.68	2.17	0.90	48.00	0.00
Apple	6,000	744.00	11.52	18.00	18.00	132.00*	614.12	75.89	44.64	18.00	0.23	1.04	2.64	33.00	18.00
Bread (brown)	3,500	2208.50	35.14	286.99	70.01	185.49*	-	-	-	73.50	1.70	9.39	1.37	10.49	210.01
Total	**57,000**	**24,454.50**	**223.15**	**2,975.03**	**702.40**	**6,587.04**	**3,777.30**	**12,747.31**	**7,477.11**	**1,796.47**	**103.37**	**68.29**	**40.33**	**530.52**	**874.01**

Diergaarde Blijdorp
5 Asian elephants

Group 1
6 females, 1 male

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Grass hay	30,000	24,780.00	192.60	3,221.40	693.84	7,657.02	2,205.42	16,627.38	9,664.20	2,031.96	123.90	66.91	44.60	446.04	-
Willow branches	1,000†	471.00	11.18	4.43	-	-	-	208.18	-	40.51	10.74	0.71	0.61	-	-
Carrot	1,600	174.40	2.59	12.80	6.40	43.20*	127.08	16.92	15.52	11.20	0.58	0.46	0.17	8.80	54.40
Endives	4,000	248.00	3.12	5.20	8.00	36.00*	-	-	-	56.00	2.08	1.12	0.60	12.00	-
Apple	3,000	372.00	5.76	9.00	9.00	66.00*	307.06	37.94	22.32	9.00	0.16	0.52	1.32	16.50	9.00
Treurniet elephant pellet	4,000	3,600.00	43.12‡	560.02	160.00	218.02	982.40	554.00	298.80	1,343.59	360.00	47.99	32.00	2,000.02	33,999.98
Treurniet horse pellet	400	360.00	5.54	56.00	12.00	29.64	193.92	84.00	37.28	14.08	4.80	3.20	3.32	120.00	3.96
Total	**44,000**	**30,005.40**	**263.91**	**3,868.85**	**889.24**	**8,049.88**	**3,815.88**	**17,528.42**	**10,038.12**	**3,506.34**	**502.26**	**120.19**	**82.62**	**2,603.36**	**34,067.34**

Dierenpark Amersfoort
4 Asian elephants (excl. 1 calf)

Group 1
females

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Grass hay	56,275	46,483.15	361.29	6,042.81	1,301.53	14,363.29	4,137.00	31,190.19	18,128.43	3,811.62	232.42	125.50	83.67	836.70	-
Silage	5,100	2,417.40	18.72	418.21	96.70	623.69	-	-	-	275.58	12.09	9.67	-	40.30	-
Carrot	1,375	149.88	2.23	11.00	5.50	37.12*	109.21	14.54	13.34	9.62	0.49	0.40	0.14	7.56	46.75
Onion	1,975	242.93	3.77	31.60	5.92	37.52*	170.75	24.78	17.98	9.87	0.45	0.79	0.19	1.38	17.77
Apple	850	105.40	1.63	2.55	2.55	18.70*	87.00	10.75	6.32	2.55	0.03	0.15	0.37	4.67	2.55
Bread (brown)	525	331.28	5.27	43.05	10.50*	27.82	-	-	-	11.02	0.26	1.41	0.21	1.57	31.50
Kasper Fauna Food elephant pellets	1,625	1,462.50	16.41	269.74	73.13	162.50	469.64	432.26	224.25	217.74	24.38	10.56	6.49	812.51	8,125.01
Total	**67,725**	**51,192.53**	**409.32**	**6,818.96**	**1,495.83**	**15,270.65**	**4,973.60**	**31,672.52**	**18,390.31**	**4,338.01**	**270.12**	**148.48**	**91.07**	**1,704.69**	**8,223.58**

Dierenpark Amersfoort *Group 1*
1 Asian elephant *male*

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Grass hay	75,000	61,950	481.50	8,053.50	1,734.60	19,142.55	5,513.55	41,568.45	24,160.50	5,079.90	309.75	167.27	111.51	1,115.10	-
Apple	500	62	0.96	1.50	1.50	11.00*	51.18	6.32	3.72	1.50	0.02	0.09	0.22	2.75	1.50
Bread (brown)	1,000	631	10.04	82.00	20.00	53.00*	-	-	-	21.00	0.49	2.68	0.39	3.00	60.00
Kasper Fauna Food elephant pellets	4,500	4050	45.45	746.98	202.50	450.00	1,300.54	1,197.02	620.99	602.96	67.51	29.24	17.98	2,250.02	22,500.02
Total	**81,000**	**66,693**	**537.95**	**8,883.98**	**1,958.60**	**19,656.54**	**6,865.26**	**42,771.79**	**24,785.21**	**5,705.36**	**377.77**	**199.27**	**130.10**	**3,370.86**	**22,561.52**

Diet with grass hay

Dierenpark Emmen *Group 1*
9 Asian elephants(excl. 4 calfs) *3 males; 6 females*

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Grass hay	24,444	20,191.11	156.93	2,624.84	565.35	6,239.05	1,797.01	13,548.24	7,874.53	1,655.67	100.96	54.52	36.34	363.44	-
Oak leaves	14,815∞	5,955.63	-	655.12	387.12	1,828.38	-	-	-	375.20	52.41	16.08	-	-	-
Produce average	6,222	586.11	7.52	62.70	17.53	115.88*	373.71	85.13	69.45	42.92	1.50	2.13	1.33	33.55	89.35
Bread (brown)	1,389	876.39	13.94	113.89	27.78	73.61*	-	-	-	29.17	0.67	3.72	0.54	4.16	83.34
Barley	889	772.44	7.48	92.45	15.11	40.89	479.61	166.61	49.00	18.67	0.53	3.11	0.85	12.36	108.14
Total	**47,759**	**28,381.69**	**185.87**	**3,548.99**	**1,012.89**	**8,297.81**	**2,650.33**	**13,799.98**	**7,992.99**	**2,121.63**	**156.07**	**79.56**	**39.07**	**413.51**	**280.83**

Diet with fresh grass

Dierenpark Emmen *Group 1*
9 Asian elephants (excl. 4 calfs) *3 males; 6 females*

Ingredient	Amount (g)	DM (g)	Energy (MJ ME)	Protein (g/DM)	Fat (g/DM)	CF (g/DM)	NFC (g/DM)	NDF (g/DM)	ADF (g/DM)	Ash (g/DM)	Ca (g/DM)	P (g/DM)	Mg (g/DM)	Vit. E (mg/DM)	Biotin (µg/DM)
Fresh grass	111,111	18,777.76	158.89	3,793.11	732.33	4,506.66	2,685.22	9,595.43	5,145.11	1,971.66	116.42	80.74	50.70	3,455.11	-
Oak leaves	14,815∞	5,955.63	-	655.12	387.12	1,828.38	-	-	-	375.20	52.41	16.08	-	-	-
Produce average	6,222	586.11	7.52	62.70	17.53	115.88*	373.71	85.13	69.45	42.92	1.50	2.13	1.33	33.55	89.35
Bread (brown)	1,389	876.39	13.94	113.89	27.78	73.61*	-	-	-	29.17	0.67	3.72	0.54	4.16	83.34
Barley	889	772.44	7.48	92.45	15.11	40.89	479.61	166.61	49.00	18.67	0.53	3.11	0.85	12.36	108.14
Total	**134,426**	**26,968.33**	**187.82**	**4,717.26**	**1,179.87**	**6,565.42**	**3,538.54**	**9,847.18**	**5,263.56**	**2,437.63**	**171.54**	**105.79**	**53.42**	**3505.18**	**280.83**

Dierenrijk Europa *3 Asian elephants*			*Group 1* *males*												
Ingredient	**Amount** (g)	**DM** (g)	**Energy** (MJ ME)	**Protein** (g/DM)	**Fat** (g/DM)	**CF** (g/DM)	**NFC** (g/DM)	**NDF** (g/DM)	**ADF** (g/DM)	**Ash** (g/DM)	**Ca** (g/DM)	**P** (g/DM)	**Mg** (g/DM)	**Vit. E** (mg/DM)	**Biotin** (µg/DM)
Grass hay	50,000	41,300.00	321.00	5,369.00	1,156.40	12,761.70	3,675.70	27,712.30	16,107.00	3,386.60	206.50	111.51	74.34	743.40	-
Willow bark	167†	78.66	1.87	0.74	-	-	-	34.77	-	6.76	1.79	0.12	0.10	-	-
Carrot	6,667	726.70	10.80	53.33	26.67	180.00*	529.54	70.49	64.68	46.67	2.40	1.93	0.69	36.67	226.68
Apple	1,667	206.71	3.20	5.00	5.00	36.67*	170.62	21.08	12.40	5.00	0.06	0.29	0.73	9.17	5.00
Bread (brown)	333	210.12	3.34	27.31	6.66	17.65*	-	-	-	6.99	0.16	0.89	0.13	1.00	19.98
Bran	3,333	3,059.69	40.53	539.94	176.64	1,339.87	-	-	-	179.97	2.48	35.16	16.00	53.33	799.93
Kasper Fauna Food elephant pellets	3,000	2,700.00	30.30	497.99	135.00	300.00	867.02	798.01	413.99	401.98	45.01	19.49	11.99	1,500.01	15,000.01
Kiezebrink elephant training biscuit	167	146.13	-	13.39	9.54	3.59	-	-	-	1.95	0.03	0.43	-	-	-
Total	**65,334**	**48,428.01**	**411.04**	**6,506.70**	**1,515.90**	**14,639.48**	**5,242.89**	**28,636.65**	**16,598.07**	**4,035.93**	**258.44**	**169.83**	**103.98**	**2,343.58**	**16051.60**

Ouwehands Dierenpark *1 African elephant*			*Group 2* *male*												
Ingredient	**Amount** (g)	**DM** (g)	**Energy** (MJ ME)	**Protein** (g/DM)	**Fat** (g/DM)	**CF** (g/DM)	**NFC** (g/DM)	**NDF** (g/DM)	**ADF** (g/DM)	**Ash** (g/DM)	**Ca** (g/DM)	**P** (g/DM)	**Mg** (g/DM)	**Vit. E** (mg/DM)	**Biotin** (µg/DM)
Grass hay	62,500	51,625.00	401.25	6,711.25	1,445.50	15,952.13	4,594.63	34,640.38	20,133.75	4,233.25	258.13	139.39	92.93	929.25	-
Willow bark	520	244.92	5.81	2.30	-	-	-	108.25	-	21.06	5.58	0.37	0.32	-	-
Carrot	600	65.40	0.97	4.80	2.40	16.20*	47.66	6.34	5.82	4.20	0.22	0.17	0.06	3.30	20.40
Onion	750	92.25	1.43	12.00	2.25	14.25*	64.84	9.41	6.83	3.75	0.17	0.30	0.07	0.52	6.75
Apple	3,075	381.30	5.90	9.22	9.22	67.65*	314.74	38.89	22.88	9.22	0.12	0.53	1.35	16.91	9.22
Bread (brown)	750	473.25	7.53	61.50	15.00	39.75*	-	-	-	15.75	0.36	2.01	0.29	2.25	45.00
Walnuts	10	9.72	0.28	1.43	6.43	0.56*	-	-	-	0.17	0.01	0.04	0.01	0.15	1.90
Peanuts	10	9.77	0.26	2.52	5.17	0.68	-	-	-	0.22	0.01	0.05	0.02	0.64	-
Tropische grazerbrok	6,000	5,400.00	50.40	1,056.02	287.98	671.98	-	-	-	-	45.58	36.02	34.18	1,199.99°	-
Linseed	143	135.99	2.89	35.75	44.33	25.74*	-	-	-	4.29	0.29	0.78	0.50	11.73	-
Total	**74,358**	**58,437.60**	**476.74**	**7,896.80**	**1,818.29**	**16,788.93**	**5,021.86**	**34,803.28**	**20,169.28**	**4,291.92**	**310.46**	**179.66**	**129.74**	**2,164.74**	**83.28**

Ouwehands Dierenpark *4 African elephant*			*Group 1* *females*												
Ingredient	**Amount** (g)	**DM** (g)	**Energy** (MJ ME)	**Protein** (g/DM)	**Fat** (g/DM)	**CF** (g/DM)	**NFC** (g/DM)	**NDF** (g/DM)	**ADF** (g/DM)	**Ash** (g/DM)	**Ca** (g/DM)	**P** (g/DM)	**Mg** (g/DM)	**Vit. E** (mg/DM)	**Biotin** (µg/DM)
Grass hay	31,300	25,853.80	200.95	3,360.99	723.91	7,988.82	2,300.99	17,347.90	10,082.98	2,120.01	129.27	69.81	46.54	465.37	-
Willow Bark	520	244.92	5.81	2.30	-	-	-	108.25	-	21.06	5.58	0.37	0.32	-	-
Endive	400	24.80	0.31	0.52	0.80	3.60*	-	-	-	5.60	0.21	0.11	0.06	1.20	-
Carrot	600	65.40	0.97	4.80	2.40	16.20*	47.66	6.34	5.82	4.20	0.22	0.17	0.06	3.30	20.40
Onion	750	92.25	1.43	12.00	2.25	14.25*	64.84	9.41	6.83	3.75	0.17	0.30	0.07	0.52	6.75
Apple	3,075	381.30	5.90	9.22	9.22	67.65*	314.74	38.89	22.88	9.22	0.12	0.53	1.35	16.91	9.22
Bread (brown)	750	473.25	7.53	61.50	15.00	39.75*	-	-	-	15.75	0.36	2.01	0.29	2.25	45.00
Walnuts	10	9.72	0.28	1.43	6.43	0.56*	-	-	-	0.17	0.01	0.04	0.01	0.15	1.90
Peanuts	10	9.77	0.26	2.52	5.17	0.68	-	-	-	0.22	0.01	0.05	0.02	0.64	-
Tropische grazerbrok	3,300	2,970.00	27.72	580.81	158.39	369.59	-	-	-	-	25.07	19.81	18.80	659.99°	-
Linseed	143	135.99	2.89	35.75	44.33	25.74*	-	-	-	4.29	0.29	0.78	0.50	11.73	-
Total	**40,858**	**30,261.20**	**254.07**	**4,071.85**	**967.90**	**8,526.84**	**2,728.22**	**17,510.80**	**10,118.51**	**2,184.28**	**161.30**	**93.98**	**68.03**	**1,162.06**	**83.28**

Safaripark Beekse Bergen *5 African elephants*			*Group 1* *1 male, 4 females*												
Ingredient	**Amount** (g)	**DM** (g)	**Energy** (MJ ME)	**Protein** (g/DM)	**Fat** (g/DM)	**CF** (g/DM)	**NFC** (g/DM)	**NDF** (g/DM)	**ADF** (g/DM)	**Ash** (g/DM)	**Ca** (g/DM)	**P** (g/DM)	**Mg** (g/DM)	**Vit. E** (mg/DM)	**Biotin** (µg/DM)
Grass hay	16,000	13,216.00	102.72	1,718.08	370.05	4,083.75	1,176.22	8,867.94	5,154.24	1,083.71	66.08	35.68	23.79	237.89	-
Willow bark	1,500†	706.50	16.77	6.64	-	-	-	312.27	-	60.76	16.11	1.06	0.92	-	-
Apple	1,000	124.00	1.92	3.00	3.00	22.00*	102.35	12.65	7.44	3.00	0.40	0.17	0.44	5.50	3.00
Bread (brown)	200	126.20	2.01	16.40	4.00	10.60*	-	-	-	4.20	0.10	0.54	0.08	0.60	12.03
Bran	1,000	918.00	12.16	162.00	53.00	402.00*	-	-	-	54.00	0.74	10.55	4.80	16.00	240.00
Kasper Fauna food elephant pellets	400	360.00	4.04	66.40	18.00	40.00	115.60	106.40	55.20	53.60	6.00	2.60	1.60	200.00	2,000.00
Totalin	36	32.40	0.56	1.87	0.86	1.40	-	-	-	2.63	-	1.98	0.18	18.00	-
Total	**20,136.00**	**15,483.10**	**140.18**	**1,974.39**	**448.91**	**4,559.75**	**1,394.17**	**9,299.26**	**5,216.88**	**1,261.90**	**89.43**	**52.58**	**31.81**	**477.99**	**2,255.03**

DM = dry matter, CF = crude fiber, NFC = non-fibrous carbohydrate, NDF = neutral detergent fiber, ADF = acid detergent fiber, Ca = calcium, P = phosphorus, Mg= magnesium, Vit. E = vitamin E

* dietary fiber

** RE-ex

° converted from IU (vit E natural d-alpha tocopheryl). www.etoolsage.com

ǂ Average of Kasper Fauna Food elephant pellets, Treurniet horse pellets, and Tropische grazerbrokken

†Because elephants only eat the bark, which accounts for approximately ¼ (no source) of the total amount, this value is only a quarter of the total amount.

∞Because elephants only eat the bark, which accounts for approximately $^{1}/_{3}$ (no source) of the total amount, this value is only a third of the total amount.

Appendix VII – Sources used for the nutritional composition

Ingredients	Type	Source	Zoo
Roughage			
Fresh grass	Gras vers (NL) Ongewogen gemiddelde Timothy (fresh)	Blgg Oosterbeek analysys, 2008 [Brown, 1953]	1,5
Grass hay	Grashooi Ongewogen gemiddelde	Blgg Oosterbeek analysys, 2007	1,2,3,4,5,6,7,8
Silage	Graskuil, jaargemiddelde	CVB, 2010	4
Straw (barley)	Gerstestro	CVB, 2010	1
Browse			
Oak (*Q. robur*)	Herfsbladeren Zomereik (*Quercus robur*)	[Kool & Smit, 2000] Harpij browse identificatie boek, 2010	5
Willow bark (*S. alba*)	Bast, (*S. Alba*)	[Kool & Smit, 2000]	3,6,7,8
Vegetables			
Beet	No.0232	Danish food table	2
Beetroot	Voederbieten, gereinigd + bewaard	CVB, 2010	5
Carrot	no. 1128 Carrots	Danish food table, Schmidt et al., 2005	1,2,3,4,5,6,7
Cucumber	no. 0002 Cucumber	Danish food table, Schmidt et al., 2005	5,7
Endives	no. 0672 Andijvie rauw	Danish food table, NEVO 2011	1,3,7
Lettuce	no. 0668 Iceberg	Danish food table, Schmidt et al., 2005	7
Onion	no. 0148 yellow	Danish food table, Schmidt et al., 2005	4,7
Sweet pepper (green)	No. 0206	Danish food table	5
Fruit			
Apple	no. 0804 Apple (red delicious)	Danish food table, Schmidt et al., 2005	1,2,3,4,5,6,7,8
Other			
Bread (brown)	no. 0529	Danish food table	1,2,4,5,6,7,8
Peanuts	Noten pinda ongezout	NEVO 2011	7
Walnuts	no. 0198	Danish food table	7
Concentrates/supplements			
Grains (barley)	Gerst Barley	CVB, 2010 Sauvant et al., 2004	5
Bran	no. 0086	Danish food table	6,8
Horse biscuit	K1157 Paardensnoep rond groen	www.brandenburch.com	1
Kasper fauna food elephant pellets	6318, 8mm	Kasper Faunafoods	1,4,6,8
Kiezebrink elephant training biscuit	Trainings bisquit green, 30mm	Kiezebrink	6
Linseed	no. 0480	Danish food table	7
Totalin Stricker		Rotterdam Zoo	8
Treurniet elephant pellets		Supplied by zoo	3
Treurniet horse pellets		Supplied by zoo	3
Tropische grazerbrokken		Van Gorp	7

Zoo	Number	Zoo	Number
Natura Artis Magistra	1	Dierenpark Emmen	5
Burger's Zoo	2	Dierenrijk Europa	6
Diergaarde Blijdorp	3	Ouwehands Dierenpark	7
Dierenpark Amersfoort	4	Safaripark Beekse Bergen	8

Appendix VIII – Energy calculations per animal per zoo

Animal (number)	Age	Sex (M/F)	Lact. Yes/No	BW (in kg)	Date last wgh./est.	BCS (1-5)	EO per day (ME MJ)	MMR (ME MJ)	Rel. diff. (%)
Artis Natura Magistra with grass hay									
1	44,8	F	No	3,650	10/12/'11	3	368.17	274.94	133.91
2	22	F	Yes	3,620	.4/12/'11	3	368.17	273.24	134.74
3	6,4	F	No	2,050	11/12/'11	3	368.17	178.37	206.41
Artis Natura Magistra with fresh grass									
1	44,8	F	No	3,650	10/12/'11	3	390.07	274.94	141.88
2	22	F	Yes	3,620	.4/12/'11	3	390.07	273.24	142.76
3	6,4	F	No	2,050	11/12/'11	3	390.07	178.37	218.68
Burger's Zoo									
1	46	F	No	3,100	.18/06/'92	3	223.15	243.24	91.74
2	43	F	No	3,400	Est.15/09/'11	4	223.15	260.69	85.60
Diergaarde Blijdorp									
1	42	F	No	2,700	Est.	3	263.91	219.30	120.34
2	14	M	N.A	3,800	1/12/'11	3	263.91	283.37	93.13
3	26	F	Yes	3,000	Est.	4	263.91	237.33	111.20
4	11	F	Yes	2,500	Est.	3	263.91	207.00	127.49
5	8	F	No	2,200	Est.	3	263.91	188.07	140.32
Dierenpark Amersfoort male									
1	20,3	M	N.A	5,300	-.5/7/'11	4	537.95	363.68	147.92
Dierenpark Amersfoort females									
1	23,6	F	No	3,000	-	2	409.32	237.33	172.47
2	29,4	F	No	4,000	-	4	409.32	294.48	139.00
3	27	F	No	3,500	-	3	409.32	266.42	153.64
4	12,4	F	Yes	3,500	-	3	409.32	266.42	153.64
Dierenpark Emmen with grass hay									
1	45	M	N.A	7,200	Est. 2002	4	185.87	457.63	40.62
2	30	F	Yes	3,200	Est.	2	185.87	249.10	74.62
3	30	F	Yes	3,400	Est.	3	185.87	260.69	71.30
4	19	F	Yes	3,900	Est.	3	185.87	288.94	64.33
5	13	F	No	3,400	Est.	3	185.87	260.69	71.30
6	12	F	Yes	3,000	Est.	3	185.87	237.33	78.32
7	4	F	No	1,600	Est.	3	185.87	148.12	125.49
8	3	M	N.A	1,400	Est.	3	185.87	134.00	138.71
9	3	M	N.A	1,200	Est.	3	185.87	119.37	155.71
Dierenpark Emmen with fresh grass									
1	45	M	N.A	7,200	Est. 2002	4	187.82	457.63	41.04
2	30	F	Yes	3,200	Est.	2	187.82	249.10	75.40
3	30	F	Yes	3,400	Est.	3	187.82	260.69	72.05
4	19	F	Yes	3,900	Est.	3	187.82	288.94	65.00
5	13	F	No	3,400	Est.	3	187.82	260.69	72.05
6	12	F	Yes	3,000	Est.	3	187.82	237.33	79.14
7	4	F	No	1,600	Est.	3	187.82	148.12	126.81
8	3	M	N.A	1,400	Est.	3	187.82	134.00	140.16
9	3	M	N.A	1,200	Est.	3	187.82	119.37	157.34
Dierenrijk Europa									
1	7,10	M	N.A	3,000	Est. 9/7/'08	3	411.04	237.33	173.19
2	9,3	M	N.A	3,500	Est. 9/7/'08	3	411.04	266.42	154.28
3	9,8	M	N.A	3,500	Est. 10/7/'08	3	411.04	266.42	154.28
Ouwehands Dierenpark male									
1	19	M	N.A	4,500	Est. 2007	3	488.70	321.68	151.92

Ouwehands Dierenpark females									
2	41	F	No	5,000	Est. 2006	5	257.44	348.13	73.95
3	16	F	No	3,250	Est. 2006	3	257.44	252.01	102.15
4	-	F	No	-	-	-	-	-	-
5	-	F	No	-	-	-	-	-	-
Safaripark Beekse Bergen									
1	33	M	N.A	6,250	2004	3	140.18	411.55	34.06
2	24	F	No	2,800	Est.	3	140.18	225.36	62.20
3	18	F	No	3,000	2008	3	140.18	237.33	59.07
4	26	F	No	3,500	Est.	4	140.18	266.42	52.62
5	25	F	No	4,000	Est.	3	140.18	294.48	47.60

M/F = male or female, Lact. = Lactating, BW = Body weight, Est./Wgh. = Estimated or weighed, BCS = Body condition score, EO = Energy offered, MMR = Maintenance metabolic rate, Rel. diff. = Relative difference.

Appendix IX – Legend for the numbers corresponding to responding zoos

Zoo	Number	Zoo	Number
Natura Artis Magistra	1	Dierenpark Emmen	5
Natura Artis Magistra (grass hay diet)	1gh	Dierenpark Emmen (grass hay diet)	5gh
Natura Artis Magistra (fresh grass diet)	1fg	Dierenpark Emmen (fresh grass diet)	5fg
Burger's Zoo	2	Dierenrijk Europa	6
Diergaarde Blijdorp	3	Ouwehands Dierenpark	7
Dierenpark Amersfoort	4	Ouwehands Dierenpark group 1 (females)	7f
Dierenpark Amersfoort group 1 (females)	4f	Ouwehands Dierenpark group 2 (males)	7m
Dierenpark Amersfoort group 2 (male)	4m	Safaripark Beekse Bergen	8

Appendix X – In-situ diet compositions

Chemical analysis of the plants consumed by the African elephant studied by Dougall & Sheldrick (1964), all given in grams/ kg dry matter.

Family & species	Description	Times browsed	CP	EE	CF	NFE	Silica	Ash	SFA	Ca	P	Na	K
ACANTHACEAE													
Barleria taitensis	Small hard twigs with leaves	1	1338	22.2	340.0	393.3	3.3	110.7	106.4	20.7	1.4	0.34	19.3
Justicia hetorocarpa	many fine stems, small leaves and burrs	1	143.7	36.2	255.9	384.6	4.7	179.6	174.9	26.5	2.8	0.28	44.3
Justicia whytei	fine stems with leaves	1	141.3	27.4	316.8	333.6	12.8	180.9	168.1	27.7	2.1	0.68	35.9
AIZOACEAE													
Zaleya pentandra	brittle twigs and small leaves	4	191.8	21.3	208.5	390.2	25.1	188.2	162.8	22.5	2.8	0.59	43.0
AMARANTHACEAE													
Achyranthes aspera	thin twigs, few leaves, some flowers	1	163.2	8.6	299.5	369.8	8.9	158.9	150.0	23.0	1.5	3.00	36.1
Aerva persica	hard stems, soft leaves, flowers	5	211.7	13.7	406.4	253.3	4.6	114.9	110.3	16.4	1.6	0.28	20.8
Amaranthus spinosus	succulent stems, very few leaves, flowering heads	1	202.7	16.9	208.8	367.6	8.3	204.0	195.7	14.5	3.4	0.36	73.6
Digera alternifolia	brittle stems, small leaves, flowers	2	185.3	19.3	274.6	355.6	6.6	165.2	158.6	20.9	1.8	0.39	49.5
Pupalia lappacea	thin twigs, few leaves, some flowers	32	106.3	24.2	356.4	397.2	7.1	115.9	108.8	13.9	1.8	0.28	36.1
ABCLEPIADACEAE													
Pergularia daemia	twigs with few leaves, some flowers	1	174.8	58.9	268.4	380.1	2.8	11.78	115.0	16.0	2.6	0.78	37.1
BURSERACEAE													
Commiphora riparia	Twigs with very few leaves	4	96.7	32.9	304.3	491.7	11.1	7.44	63.3	12.8	1.5	0.20	16.2
CAESALPINIACEAE													
Bauhinia taitensis	Thin, hard twigs and few leaves	3	104.0	11.9	407.0	407.0	0.2	7.01	69.9	18.6	1.0	0.36	7.5
Caesalpinia pulcherrima	Few thick stems, many fine stems with leaves; flowering	2	114.0	28.0	229.6	572.8	1.7	5.56	53.9	6.6	2.4	0.19	13.6
COMBRETACEAE													
Combretum molle	Small twigs with large green leaves	9	123.8	36.5	323.5	417.2	0.9	9.90	98.1	28.9	1.1	0.35	5.6
Terminalia orbicularis	Stems with few large, dry leaves	2	131.6	47.8	340.4	415.6	1.6	6.46	63.0	4.4	1.5	0.17	12.5
COMMELINACEAE													
Commelina benghalensis	Soft stems and leaves; flowers	16	141.6	23.8	231.7	378.1	58.6	22.48	166.2	21.7	2.1	0.65	51.8
COMPOSITAE Pluchea dioscoridis	Twigs with leaves and flowers	3	132.6	20.0	257.7	439.4	7.4	15.03	142.9	13.5	5.80	16.68	15.0
CONVOLVULACEAE													
Ipomoea mombassana	-	1	-	-	-	-	-	-	-	-	-	-	-
CUCURBITACEAE													
Cucumis dipsaceus	Stems and pods; no leaves	1	148.4	32.9	274.0	373.1	25.5	17.16	146.1	18.3	1.4	0.84	37.8
Gerrardanthus lobatus	Stems with few leaves; seeding	1	198.6	43.8	405.4	234.0	1.3	11.82	116.9	13.4	1.6	0.36	33.0
CYPERACEAE													
Cyperus articulatus	Thick stems, very few leaves, flowering heads	2	74.5	5.7	307.9	537.3	36.3	7.46	38.3	3.7	2.1	2.76	8.3
Cyperus dives	Harsh board leaves and large flowers	1	69.9	13.0	288.0	502.9	56.7	12.62	69.5	6.7	2.3	6.94	15.3

Family & species	Description	Times browsed	CP	EE	CF	NFE	Silica	Ash	SFA	Ca	P	Na	K
EUPHORBIACEAE													
Acalypha fruticosa	Twigs with very few leaves	17	86.6	10.5	430.1	414.7	0.9	58.1	57.2	14.9	1.5	0.21	7.6
Euphorbia sp.	Thin, brittle green stems, no leaves	3	62.5	56.0	299.2	416.9	0.6	120.4	119.8	18.2	2.7	1.81	27.9
Phyllanthus maderaspatensis	Fine stems, many green leaves & pods	8	133.5	38.1	264.4	488.6	15.9	75.4	59.5	11.7	1.4	0.21	11.1
GRAMINEAE													
Brachiaria deflexa	Stemmy: some 'burn'	2	108.7	16.8	299.5	487.7	29.2	87.3	58.1	5.4	1.4	0.27	20.9
Chloris roxburghiana	Flowering stage	1	77.7	22.9	387.4	432.8	47.3	79.2	31.9	7.6	1.8	0.10	9.6
Cynodon dactylon	Stemmy: flowering	2	106.3	16.9	338.3	467.7	1.4	70.8	69.4	7.6	1.4	0.11	18.9
Cynodon dactylon	Stemmy:	2	90.2	19.3	315.3	494.5	39.1	80.7	41.6	5.9	1.1	0.21	13.5
Cynodon plectostachyus	Stemmy: some 'burn'	2	112.1	18.9	301.1	466.9	48.3	101.0	52.7	6.1	1.3	0.27	19.1
Echinochloa haploclada	Stemmy: some green leaf; flowering	4	116.2	12.9	345.6	402.0	3.2	123.3	120.1	6.3	2.7	0.68	18.9
Eragrostis horizontalis	Very stemmy: few leaves; flowering	1	95.2	19.6	340.0	467.2	36.4	78.0	41.6	4.4	1.6	0.10	15.3
Panicum deustum	Very stemmy: few leaves	9	111.6	17.1	305.5	450.3	52.7	115.0	62.8	8.3	0.9	0.16	25.2
Panicum maximum	Very stemmy:	2	67.5	16.8	364.7	444.7	50.7	106.3	55.6	5.1	3.6	0.39	12.5
Tetrapogon tenellus	Stemmy: seeding; some 'burn'	1	93.6	18.6	311.4	474.8	45.4	101.6	56.2	6.9	1.9	0.28	18.9
LIBIATAE													
Becium sp.	Brittle twigs; few leaves; many flowers	2	120.8	39.9	351.9	401.0	2.3	86.4	84.1	13.1	1.5	0.21	26.1
LILIACEAE													
Sansevieria ehrenbergii	-	3	-	-	-	-	-	-	-	-	-	-	-
MALPHIGHIACEAE													
Caucanthus albidus	Twigs with leaves	1	106.3	20.1	400.2	399.8	0.7	73.6	72.9	17.2	0.9	0.47	11.1
MALVACEAE													
Abutilon mauritianum	Very stemmy: few leaves	7	145.5	25.1	272.6	462.5	5.0	94.3	89.3	15.2	1.6	0.36	20.9
Hibiscus micranthus	Thin, hard stems with green leaves	1	118.7	23.1	425.3	326.3	4.4	106.6	102.2	20.7	2.5	0.35	15.0
Hibiscus palmatus	Much stem: few green leaves	2	126.8	24.4	330.6	418.7	8.9	99.5	90.6	17.4	2.1	0.28	15.1
Hibiscus vitifolius	Hard stems: few small, green leaves	1	108.3	12.8	372.3	439.9	1.8	66.7	64.9	13.5	1.3	0.36	13.9
Pavonia elegans	-	15	-	-	-	-	-	-	-	-	-	-	-
MENISPERMACEAE													
Cocculus hirsutus	Small stems; many green leaves	1	96.7	17.1	363.8	440.7	1.7	81.7	80.0	11.1	1.1	0.35	19.3
MIMOSACEAE													
Acacia elatior	-	1	-	-	-	-	-	-	-	-	-	-	-
Entada leptostachya	Brilliant, green leaves; small twigs	1	199.1	15.2	282.1	440.8	2.1	82.8	80.7	15.1	1.8	0.17	13.9
MORACEAE													
Ficus sycomorus	Few twigs & large, green leaves	3	116.8	25.7	233.0	464.7	49.1	159.8	110.7	26.4	2.1	2.00	17.4
NYCTAGINACEAE													
Boerhaavia erecta	Fine twigs; few leaves; some flowers	5	148.3	22.8	238.7	456.8	4.7	133.4	128.7	14.2	2.6	0.10	41.0
PAPILIONACEAE													
Clitoria ternatea	Fine stems with green leaves & pods	1	118.6	19.4	388.5	406.3	5.6	67.2	61.6	6.5	2.7	0.10	15.3
Indigofera costata	Thin, hard stems; no leaves	1	91.6	43.9	494.1	326.7	0.3	43.7	43.4	15.1	0.8	0.36	4.1
Indigofera vohemarensis	Stemmy; senile leaves; some pods	2	123.2	19.9	367.2	407.9	2.7	81.8	79.1	20.3	1.0	0.21	9.5
Rhynchosia sublobata	Small, hard stems; few small, green leaves	1	114.2	15.2	342.9	464.1	9.3	63.6	54.3	11.9	1.8	0.10	10.7
Sesbania sesban	Fine, small twigs; many small, green leaves	4	226.3	24.3	208.0	439.6	21.1	101.8	80.7	11.1	2.3	1.64	22.5
Vigna unguiculata	Brittle stems with some green leaves	3	136.4	24.7	319.7	359.2	29.3	160.0	130.7	19.0	2.4	0.31	35.3

Family & species	Description	Times browsed	CP	EE	CF	NFE	Silica	Ash	SFA	Ca	P	Na	K
RUBIACEAE													
Dirichletia glaucescens	Small, hard twigs; no leaves	10	61.4	17.3	491.9	375.9	1.1	53.5	52.4	8.9	0.8	0.25	9.5
SOLANACEAE													
Solanum renschii	Few hard twigs & many green leaves	1	177.1	27.1	297.7	369.4	12.8	128.7	115.9	23.8	1.6	0.29	21.3
STERCULIACEAE													
Waltheria indica	Coarse stems; many leaves; some flowers	1	75.1	22.8	451.8	395.8	2.3	54.5	52.2	8.8	2.5	3.47	11.0
Melhania ovata	Many small twigs and few leaves	3	117.5	16.2	309.5	505.2	4.4	51.6	47.2	11.2	2.3	0.21	9.7
TILIACEAE													
Grewia bicolor	Small hard twigs and some green leaves	4	117.0	23.5	309.2	466.0	9.1	84.3	75.2	19.7	1.2	0.37	12.0
Grewia fallax	Twigs with few large, green leaves	2	110.6	36.9	321.4	422.0	2.4	109.1	106.7	23.4	1.1	1.60	13.6
Grewia forbesii	Twigs with leaves	8	101.6	47.1	317.8	427.7	2.4	105.8	103.4	29.4	3.4	0.36	5.5
Grewia lilacina	-	1	-	-	-	-	-	-	-	-	-	-	-
Grewia villosa	Small, hard twigs, many green leaves	6	136.1	23.8	318.1	421.4	4.0	100.6	96.6	24.6	1.5	0.48	15.0
ZYGOPHYLLACEAE													
Tribulus terrestris	Brittle stems with many green leaves	3	165.0	17.4	276.6	376.2	17.9	164.8	146.9	36.1	1.7	0.58	15.0

Acid detergent fibre (ADF) and sodium (Na) concentrations of wild foods consumed by African elephants in Kibale National park, Uganda as analysed by Rode et al. (2006).

Species	**Part**	**ADF (g)**	**Na (mg)**
Acalypha sp.	Leaves and stems	250	119
Aframomum sp.	Leaves	430	210
Alangium chinense Lour.	Bark	570	28
Alangium chinense	Leaves	220	115
Albizia grandibracteata Taub.	Bark	550	72
Albizia grandibracteata	Leaves	420	160
Aningeria altissima A. Chev.	Leaves	370	236
Antiaris toxicara Leschenault	Leaves	380	28
Blighia unijugata Bak.	Leaves	480	162
Brillantaisia sp.	Leaves	230	82
Dasylepis sp.	Fruit	140	184
Dichrostachys cinerea L.	Leaves	320	152
Diospyros abyssinica Hiern.	Leaves	290	80
Dombeya mukole Mast.	Bark	440	188
Dovyalis abyssinica A. Rich.	Fruit	290	52
Dracaena laxissima Engl.	Leaves	420	122
Erythrophleum sp.	Leaves	240	192
Ficus asperifolia Miq.	Leaves and stems	300	114
Funtumia latifolia Preuss	Ripe fruits	230	211
Kigelia moosa Sprague	Ripe fruits	330	164
Leea guineensis G. Don.	Leaves	410	107
Lovoa sp.	Young leaves	220	313
Maesa lanceolata Forssk.	Young leaves	290	122
Maesa lanceolata	Fruits	440	496
Marantochloa leucantha K. Schum	Leaves and stems	320	136
Millettia dura Dunn	Fruits	570	119
Mimusops bagshawei S. Moore	Leaves	480	164
Myrianthus holstii Engl.	Fruit	570	98
Oncoba routledgei Sprague	Leaves	370	271
Oxyanthus sp.	Fruit	280	33
Pancovia turbinata Radlk.	Leaves	320	148
Pennisetum purpureum Schum.	Leaves	410	168
Phoenix reclinata Jacq.	Leaves	590	470
Pseudospondias microcarpa A. Rich.	Leaves	310	63
Pterygota mildbraedii Engl.	Leaves	280	147
Rothmannia urcelliformis Hiern	Fruit	260	178
Setaria sp.	Leaves	360	86
Teclea nobilis A. R. Delile	Fruit	420	131
Trema orientalis L.	Fruit	230	51
Trichilia sp.	Leaves	460	125

Species	Part	ADF (g)	Na (mg)
Trilepisium madagascariense DC.	Leaves	370	8
Urera trinervis Hochst.	Leaves	380	83
Uvariopsis congensis Robyns & Ghesquiere	Leaves	400	56
Uvariopsis congensis	Fruit	260	600
Vernonia sp.	Leaves	230	131

Plant species consumed by Asian elephants and their proportion in the diet in different seasons by Jin et al. (2006)

Scientific name	Proportion in different seasons (%)		Average proportion (%)	LF	AR	LH	FT
	Dry	Rainy	Mean±SD				
ANACARDIACEAE	1.3	2.1	1.8±1.1	tree	no	LS	Br
Spondias pinnate							
APOCYNACEAE							
Amalocalyx yunnanensis	2.8	3.1	3.1±0.7	vine	yes	LS	Br
Chonemorpha eriostylis	1.4	0.9	1.2±0.9	vine	yes	LS	Br
ARALIACEAE							
Heteropanax fragrans	1.6	1.8	1.8±0.9	tree	yes	LS	Br
Macropanax dispelmus	2.2	2.2	2.3±0.7	tree	no	LS	Br
Trevesia palmata	1.9	2.9	2.5±1.0	tree	yes	LS	Br
BIGNONIACEAE							
Oroxylum indicum	2.0	2.1	2.0±1.3	tree	yes	ES	Br
BORAGINACEAE							
Cordia furcans	1.6	1.1	1.5±0.8	tree	no	ES	Br
COMBRETACEAE							
Combrentum punctatum	1.0	1.1	1.0±0.8	vine	yes	ES	Br
CYPERACEAE							
Carex baccans	1.6	1.6	1.7±0.7	herb	yes	ES	Gr
EURPHORBIACEAE							
Bridelia tomentosa	1.2	1.0	1.1±0.9	tree	no	ES	Br
Croton argyratus	1.0	1.3	1.2±1.1	tree	no	ES	Br
FAGACEAE							
Castanopsis fleuryi	2.4	2.1	2.3±1.1	tree	yes	ES	Br
C. mekongensis	1.6	0.6	1.1±1.2	tree	no	ES	Br
GRAMINEAE							
*Bamboo**	3.9	4.5	4.5±1.1	herb	yes	ES	Br
Microstegium ciliatum	2.3	4.2	3.5±1.7	herb	yes	ES	Gr
Thysanolaena maxima	1.6	1.9	1.8±1.1	herb	yes	ES	Gr
HYPOXIDACEAE							
Curculigo capitulata	0.7	2.1	1.6±1.1	herb	yes	ES	Gr
MARANTACEAE			1.5±0.7				
Phrynium capitatum	1.3	1.6		herb	yes	ES	Br
MENISPERMACEAE							
Parabaena sagittata	2.5	1.9	2.3±1.1	vine	yes	LS	Br
MIMOSACEAE							
Acacia megaladena	2.4	0.5	1.4±1.7	vine	yes	ES	Br
Acacia pennata	1.7	0.7	1.1±1.2	vine	yes	ES	Br
MORACEAE							
Ficus auriculata	2.1	2.6	2.4±1.0	tree	no	ES	Br
F. fistulosa	2.2	2.5	2.5±0.6	tree	no	ES	Br
F. racemosa	2.3	2.2	2.4±0.6	tree	no	ES	Br
F. semicordata	1.5	1.6	1.7±0.8	tree	no	ES	Br
MUSACEAE							
Musa acuminata	4.0	3.8	4.2±1.3	herb	yes	ES	Br

Scientific name	Proportion in different seasons (%)		Average proportion (%)	LF	AR	LH	FT
	Dry	Rainy	Mean±SD				
MYRSINACEAE							
Measa indica	2.1	2.1	2.1±1.0	shrub	no	ES	Br
PAPILIONACEAE							
Derris caudatilimba	2.1	2.1	2.2±0.6	vine	yes	ES	Br
Millettia leptobotrya	1.1	1.2	1.1±1.0	tree	yes	ES	Br
Shuteria hirsuta	2.5	2.7	2.8±0.6	vine	yes	ES	Br
ROSACEAE							
Rubus ellipticus var. obcordatus	1.8	1.8	1.9±0.7	shrub	yes	ES	Br
R. pyrifolius var. Cordatus	0.7	1.3	1.1±0.9	shrub	yes	ES	Br
RUBIACEAE							
Uncaria laevigata	1.9	0.8	1.3±1.1	vine	yes	ES	Br
U. scandens	1.5	0.9	1.3±1.0	vine	yes	ES	Br
SOLANACEAE							
Solanum torvum	2.2	2.2	2.3±0.7	shrub	yes	ES	Br
STAPHYLEACEAE							
Turpinia pomifera	1.5	0.4	1.0±0.8	tree	no	LS	Br
STERCULIACEAE							
Byttneria grandifolia	1.5	0.7	1.1±0.9	vine	yes	LS	Br
ULMACEAE							
Celtis timorensis	2.6	2.8	2.8±0.6	tree	no	LS	Br
URITCACEAE							
Boehmeria clidemioides	2.0	1.6	1.9±0.8	shrub	no	ES	Gr
VITACEAE							
Leea indica	2.3	2.5	2.4±1.0	shrub	yes	LS	Br
Tetrastigma planicaulum	2.6	1.9	2.4±1.0	vine	yes	LS	Br
ZINGIBERACEAE							
Amomum glabrum	1.0	2.3	1.8±1.2	herb	yes	LS	Br
Costus speciosus	1.1	1.1	1.2±0.8	herb	yes	LS	Br

LF = life form; AR = ability of regrowth; if the plant has the ability for asexual propagation and re-grow after being eaten, it is 'yes', otherwise it is 'no'; LH = life history, LS = late successional plants, ES = early successional plants; FT = foraging type, Br = browse, Gr = graze

Dry season: November – April, Rainy season: May – October

*Bamboo here includes *Dinochloa bannaensis, Gigantochloa nigrociliata* and *Dendrocalamus membranaceus*

Only those species which constitute at least 1% of diet have been included

The analysis of the 29 commonly consumed species by Jin et al. (2006)

Scientific name	**Energy (MJ)**	**Protein (g)**	**Fat (g)**	**H (g)**	**Fibre (g)**	**Ash (g)**	**Protein/ fibre**	**N (g)**	**P (g)**	**K (g)**	**Na (μg/g)**	**Ca (g)**	**Mg (g)**	**Fe (μg/g)**	**Zn (μg/g)**	**Cu (μg/g)**
Acacia megaladena	0.12	35	9	16	404	36	0.1	5.6	0.6	3.8	52.0	5.3	0.4	168	20	10
Acacia pennata	0.07	32	2	8	513	42	0.1	5.1	0.4	5.9	15	11.9	2.3	76	0	9
Boehmeria sp.	0.47	171	23	56	263	134	0.7	27.4	2.2	4.3	55	28.8	3.6	365	32	6
Calamus sp.	0.18	80	9	7	400	64	0.2	12.7	1.4	4.6	47	2.6	1.5	151	18	19
Carex baccans	0.03	77	21	45	277	136	0.3	12.3	1.4	5.8	55	2.3	1.3	87	20	8
Castanopsis calathiformis	0.12	37	7	21	335	41	0.1	6	0.4	2.5	51	1.1	0.8	651	10	3
Castanopsis fleuryi	0.10	32	6	14	444	48	0.1	5.1	0.4	2.4	47	0.8	1	499	15	2
Celtis timorensis	0.51	195	16	77	212	142	0.9	31.2	2.6	11.6	62	56.1	2.7	179	25	7
Costus speciosus	0.29	92	33	6	188	138	0.5	14.7	1.5	23.6	51	10.7	4.4	154	139	6
Curculigo capitullata	0.42	80	18	13	345	97	0.2	12.7	1.2	21.8	60	14.7	5.4	103	30	10
Dendrocalamus barbatus	0.20	100	8	1	401	68	0.3	16.1	1.6	10.7	80	04.8	1.9	529	25	5
Dinochloa dannaenlis	0.21	89	12	7	342	81	0.3	14.3	2.3	15.1	76	03.5	1	497	20	2
Ficus auriculata	0.32	114	31	8	264	145	0.4	18.2	5	41.0	45	15.7	44	127	15	11
Ficus racemosa	0.48	207	27	9	146	114	1.4	33	4.7	22.4	29	19.2	5.7	166	35	16
Harpullia cupanioides	0.37	109	13	86	277	115	0.4	17	1.8	10.1	62	32.0	7.2	125	56	5
Heteropanax fragrans	0.24	93	17	12	438	85	0.2	15	2.9	29.9	30	08.1	2.6	135	33	23
Mallotus barbatus	0.66	159	55	109	184	66	0.9	26	2.4	14.4	43	21.9	1.3	224	33	7
Micorstegium ciliatum	0.24	77	12	41	274	94	0.3	12	2	14.0	59	4.7	2.2	210	63	5
Musa acuminata	0.45	107	26	106	236	90	0.5	17	3.5	183.9	47	4.1	3.3	600	103	33
Parabaena sagittata	0.42	112	38	56	200	121	0.6	18	1.5	12.8	59	30.5	3.5	282	63	3
Phrynium capitatum	0.43	97	7	145	338	90	0.3	15	1.7	25.8	55	6.3	3.2	311	22	6
Pleioblastus amarus	0.30	122	19	13	265	149	0.5	19	1.3	11.6	56	3.3	1.7	298	30	6
Rubus ellipticus var. *obscordatus*	0.24	101	17	4	351	71	0.3	16	2	16.6	48	17.8	3.9	110	109	9
Shuteria hirsuta	0.32	139	22	4	294	95	0.5	22	2	20.2	69	23.2	2.1	371	32	7
Tetrastigma planicaulum	0.67	91	27	249	229	135	0.4	15	1.6	20.5	69	16.0	5.2	199	28	8
Thysanolaena maxima	0.44	76	13	158	340	76	0.2	12	1.9	22.0	47	3.1	2.1	111	38	5
Trevesia palmata	0.59	120	21	187	335	120	0.4	19	2.6	33.2	77	12.0	6.1	377	57	10
Turpinia pomifera	0.40	74	25	107	282	119	0.3	12	1.7	16.9	51	31.6	5.6	59	25	5
Zingiber orbiculatum	0.31	107	27	17	304	129	0.4	17	4.1	42.5	39	8.7	3.5	149	31	12
Mean±1SD	0.34±0.16	101±44	19±11	59±66	306±87	98±34	0.4±0.3	16±7	2±1.6	23.4±32.4	53±14	13.8±12.7	3.1± 1.8	252±168	39±31	9±7