Babirusa SSP Husbandry Manual

NUTRITION

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Cite Reference:
Leus, K., Morgan, C.A. and E.S. Dierenfeld (2001), Nutrition. In: *Babirusa (*Babyrousa babyrussa*) Husbandry Manual.* M. Fischer, Ed. American Association of Zoos and Aquariums

Background Information to the Feeding Ecology

Information from the Wild
Information on the diet of wild babirusa is largely descriptive and qualitative in nature. A detailed review of all information available from the literature can be found in Leus (1996). The lack of quantitative information does not allow much more to be said than that babirusa appear to show a preference for fruits and seeds but that they also consume a variety of leaves, grasses, fungi, invertebrates and small vertebrates, and garden products.

Very few wild food items are mentioned by name in the older literature: leaves of the "waringi" tree (most likely a fig species (Ficus sp.)), "canari" seeds (almond-like seeds of the fruits produced by trees of the genus Canarium) (Valentijn, 1726), Elatostema sp. (a non-stinging member of the nettle family Urticaceae), acorns (Lithocarpus sp.) (Selmier, 1978, 1983), "pangi" (Pangium edule - a large fruit of the family Flacourtiaceae) (Whitten et al., 1987). Among the garden products consumed were mentioned: coconuts, mangos, maize plants, millet, sweet potatoes, sugar cane and small herb trees. More recent investigation of stomach contents and faeces of wild babirusa in North Sulawesi (Clayton, 1996) indicated that the wild babirusa diet indeed mainly consists of fruit and/or seeds as well as some animal material, leaves, grasses and soil and rock fragments. The following genera/species of fruit/seeds could be clearly identified: Mangfrra sp. (mango and its relatives - Anacardiacae); Dracontomelum mangq'erum (Anacardiacae), Pothoidiurn lobbianum (Araceae), Dillenia serrata (Dilleniaceae), Pangium edule (Flaeourtiaceae), Calophyllum soullatri (Guttiferae), Agloia sp. (Meliaceae), Lansiurn sp. (Meliaceac), Artocarpus sp. (Moraceae), Ficus sp. (Moraceae), Streblus sp. (Moraceac), Arenga pinnata (Palmaceae), Calarnus sp. (Palmaceae) and Alpinia sp. (Zingiberaceae) (Clayton, 1996).

Hunters and guides of Lore Kalamanta claim to be able to distinguish between furrows made by Sus celebensis (the Sulawesi warty pig) and those produced by babirusa. Babirusa are said to make shallow, straight-lined furrows whereas Sus celebensis dig deeper and thrust their snouts in lines that radiate from one spot (Selmier, 1978). Babirusa in captivity appear equally unable to root in compact ground and only appear to turn over loose soil or wet mud (Leus et al., 1992; Leus and Vercarnrnen, 1996). The lack of a well developed rostral bone in the nose of the babirusa (Macdonald, 1993) may explain their limited ability to root in more compact substrates and may imply that roots are a less important category in the diet of the babirusa compared to that of the other wild pigs.

Babirusa in the wild visit volcanic salt licks to drink large quantities of the salty water, to lick the stones and to ingest the soil (Patry et al., 1995; Clayton, 1996). Results of the analyses of the water of the "Marisa" salt lick and the sediment of the "Lantolo" salt lick in North Sulawesi can be found in Table 1 (Patry pers. comm., 1989 – for details of locations see Patry et al., 1995). Additional analyses of soil and water samples from salt licks in the same region by Clayton were compared with results from control samples (soil taken 25m away from the salt lick and water taken from the Nantu river) (Clayton, 1996). Results from these two studies indicate that the soil from these salt licks appears to contain higher quantities of 504, Iron, Sodium, Zinc and Manganese than the surrounding soil and that the water contains higher quantities of particularly Chloride, SO4, Boron, Sodium and Calcium. This may well imply that babirusa have very specific mineral requirements or that their largely frugivorous diet is lacking in one or more components. Indeed soil and stones were common in the stomachs investigated by Clayton (1996).

Information from Captivity

Foraging behavior: The foraging behavior of the babirusa mainly consists of walking around with the nose close to the ground while probing through the loose soil and leaf litter (Leus and Vercammen, 1996). Captive babirusa in a semi-natural enclosure showed the ability to very carefully select and obtain certain plants and plant parts such as individual flower buds, grass ears, bramble leaves, cherry fruits, etc. (Leus and Vercammen, 1996). Valentijn (1726) writes that wild babirusa stand on their hind legs while leaning against a tree to "sample the smells of approaching enemies". An equally likely explanation for this behavior is that the animals are foraging for fruits or leaves on trees. In fact, babirusa in captivity have frequently been observed browsing leaves on trees while standing on their hind legs unsupported or with their front legs leaning against the tree trunks or uprights in their enclosure (e.g. Macdonald and Leus, 1995).

Digestive anatomy: Although consisting of one large compartment without any narrow constrictions separating one part from the other, the babirusa stomach contains an enlarged area of mucus-producing cardiac glands (>70% of internal surface area v. 30% in Sus scrofa) with a near-neutral pH and large populations of microorganisms (Leus, 1994; Leus et al., in press). A frequently discussed function of such microorganisms is bacterial fermentation of plant structural components by means of enzymes, which the host is unable to produce itself. The cardiac gland area of the babirusa is therefore likely to be a fermentation area. The anatomy of the intestinal tract of the babirusa appears to be very similar to that of the domestic pig and other wild pigs although no detailed studies have been carried out (Mitchell, 1905, 1916).

Two groups of animals appear to share with the babirusa the possession of an enlarged and elongated stomach part lined almost exclusively with cardiac glands: the Colobinae monkeys and Macropodidae marsupials. Forestomach fermenters usually show a system of folds, blindsacs or narrow constrictions in the stomach which slow down the passage of digesta and which separate the fermentation chamber from the low p11 of the gastric gland area. Apart from the relatively small diverticulum (typical for the stomach of all pigs but larger in the babirusa), no such structures were found in the babirusa stomach. Passage time experiments on captive babirusa suggested that no part of the digestive tract selectively held digesta longer than any other part and that the transit time of digesta for the babirusa is not longer than that for the domestic pig (Leus, 1990; Conklin and Dierenfeld, 1994). Thus, bacterial fermentation in the babirusa stomach may be somewhat less efficient than is the case for other forestomach fermenters.

Digestion: Two digestibility studies were carried out on the babirusa (Conldin and Dierenfeld, 1994; Leus, 1994, 1997) and in both cases the animals did not readily consume the amount of hay or dried grass offered as a source of fiber. These therefore appear not to be palatable fiber sources for the babirusa.

When consuming a zoo diet (mostly composed of low fiber grain and fresh produce), the babirusa digested the NDF and ADF fractions of the diet equally well (Conklin and Dierenfeld, 1994). Babirusa consuming a barley-soy basal diet

with dried grass added as a source of fiber digested NDF slightly better than ADF although the difference appeared to become smaller the more grass was added (Leus, 1994). In comparison to the domestic pig (Large White x Landrace) the babirusa appeared to digest NDF equally well (for dried grass fiber) or better (for barley-soybean + dried grass fibers) than the domestic pigs but ADF equally well (for barley-soybean + dried grass) or worse (for dried grass fiber) than the domestic pig (Leus, 1994, 1997). The low metabolic fecal nitrogen losses in babirusa consuming a zoo diet, together with the absence of a secondary marker excretion peak in the transit time study, suggest that hindgut fermentation may be less important in the babirusa than in the other pigs (Conklin and Dierenfeld, 1994). In the domestic pig almost all cellulose and 80% of hemicellulose digestion occurs in the large intestine (Keys and DeBarthe, 1974). Similarly, in the peccary, another forestomach fermenter and close relative of the pigs, practically no cellulose digestion occurred in the forestomach (Shively et al., 1985; Lochmiller et al., 1989). If hindgut fermentation is indeed less important in the babirusa and if in pigs and peccaries digestion of cellulose occurs mainly in the caecum and colon, then we would expect less efficient digestion of cellulose by the babirusa.

All of the above strongly suggests that the babirusa is a non-ruminant forestomach fermenting frugivore/concentrate selector specialized in the fermentation of more easily digestible fibers and other cell components.

ZOO DIET SURVEY

Between March 1991 and May 1993, all zoos with babirusa (16 in Europe, 7 in the USA and 2 in Indonesia) were sent a questionnaire requesting information on the constituents of the diet, the daily amounts fed, the preferences and dislikes of the animals and the way in which the food was offered. Results from 13 zoos in Europe and 6 in the USA (containing 38 male and 41 female babirusa) were of a sufficiently detailed nature to be used in further analyses. A detailed account of the results of this questionnaire can be found in Leus (1994) and short reports were published in Leus and Morgan (1995) and Leus (in press).

a. Feeding schedule and feeding locations

One zoo that replied to the questionnaire only fed once a day, thirteen zoos fed twice a day, three zoos fed three times a day, one zoo fed four times and another five times a day. Most of the zoos that fed twice a day offered a smaller portion of the daily ration in the morning and a larger portion in the late afternoon/evening. Those zoos that fed more than twice a day offered browse and/or scatter feeding (fruit, vegetables, seeds and grains etc.) at other times of the day. Eight zoos fed the main part of the diet on the floor, eight zoos offered the meal in a trough and three offered the food on a bed of grass, hay or alfalfa on the floor.

Eight institutions had an automatic water supply whereas the remaining eleven institutions used water troughs.

b. Food items and quantities offered

For the analyses, the food items offered were divided into 4 categories: 1) fruit and vegetables (F&V), 2) commercial pellets, grains, bread, nuts and oils (P&G), 3) animal products (AP) and 4) browse (grass, hays, branches, leaves etc.). The babirusa received a very wide range of food items: 54 different F&V, 30 P&G, 9 Al' and 41 different browses were offered to the animals (Tables 2 & 3). In most zoos, the diet was built up around a relatively fixed set of core items, which were easily available all year round. These core items were then supplemented with smaller amounts of seasonal fruits, vegetables and browse.

Browse offered to the babirusa came in many forms and shapes (Table 3). A number of zoos did not specify the species of browse fed and their accounts were included under the general terms branches, grass, hay and leaves. In some zoos, alfalfa hay was eaten completely whereas others stated that the animals tried to pick out the leaves and would sometimes chew the stems but not eat them. Many zoos offered fresh branches, grass, herbs or alfalfa during the spring and summer seasons and fed dried branches and hays during the winter. The inclusion of browse in the diet was often not on a regular or controlled basis. In fact, information on the amounts and types of browse offered was too vague to allow calculation of the percentage of browse in the diet in relation to the other food categories. The data shown below are for the daily diet of adult male and adult female babirusa without the browse,

Table 4 shows the mean amounts of the different food categories offered to the babirusa. As is obvious from the large standard deviations there was a huge range in the amounts and proportions of the different food items fed. On average, the diet consisted of 2/3 fruit and vegetables and 1/3 commercial pellets and other grain products. Nine zoos added small amounts of animal products (such as chicks, eggs, and beef) to the diet on some days of the week.

In the study by Conklin and Dierenfeld (1994), the animals showed a diy matter intake of 1.2% of their body mass. The wet weight intake was about 2.3% of body weight. If we assume an average weight of 90kg for males (a wild caught full gro~vn adult male babirusa weighed 90kg (E. Wahyuni, pers. com.) and 60kg for females, then the average amount of dry matter offered to male babirusa is equal to the observed intake, whereas that offered to the females is higher. The average wet weight offered to the babirusa as a percentage of body weight (average of 4%) was almost twice the intake observed by Conklin and Dierenfeld (1994). Considering the wide variation in amounts offered, babirusa holders should consider it a priority to determine how much of the offered food the pigs are actually consuming!

c. Quantities of nutrients offered

Table 5 shows the amounts of the different nutrients contained in the diets offered to babirusa in captivity. The large variation in the amounts of different food items fed translates into a wide range of nutrient amounts offered. In fact, the range of values for the different nutrients offered is so wide that it is impossible that all these diets are meeting the nutritional requirements of the animals.

RECOMMENDATIONS

Feeding schedule and feeding locations: A foraging babirusa typically walks around with the nose to the ground or probing through the leaf litter while, slowly, bit by bit, picking up food items that it comes across. Foraging is therefore likely to occupy a significant proportion of the wild babirusa's day. To duplicate this activity level, feeding in captivity should be spread throughout the day. For example, animals could be fed about 30% of the diet in the morning, 20% (scatter feeding and browse) throughout the day and 50% in the afternoon. Feeding not too much in the morning will hopefully still result in babirusa willing to forage for scatter food rather than to snooze. However, feeding nutrient-rich items during the night may result in more obesity because of less activity during the night time hours.

In order to have sufficient control over the intake of individual animals, and because males tend to monopolise the food when fed in the company of females, food items requiring more precise dosage such as vitamin and mineral supplements and nutrient-rich items such as commercial pellets, starchy fruit and vegetables, larger quantities of nuts and seeds etc., should be offered individually, for example during the morning andlor evening meals.

Ground surfaces as well as troughs can be used for feeding the main portion of the diet as long as they are cleaned thoroughly and regularly. When using food troughs, these should be placed at ground level.

In order to prevent soiling of the drinking water it is recommended to have automatic drink nipples/pressure pads in the stables. These should be placed as close as possible to a drain so that spillage of water during drinking does not wet the rest of the stable and the bedding.

Nutrient content of diet:

Main nutrients

No data are available on the protein and energy requirements of the babirusa, Using prediction equations for the domestic pig based on the protein weight in the body (Whittemore, 1998), the babirusa maintenance requirements for digestible energy (DE) and crude protein (CP) can be calculated. A state of maintenance can be defined as a situation where the body composition of the animal remains stable, the animal is not producing any products e.g. milk and it is not performing any work on its surroundings (McDonald et al., 1995).

The maintenance DE requirement for a Large White domestic pig of 90 kg can be calculated from the equation:

ME maintenance = 1.75Pt075

with ME = Metabolisable Energy and Pt = protein weight in the body (Whittemore, 1998). The average Pt for a Large White pig is 16% of its body weight (Whittemore, 1998). The metabolisable energy is the digestible energy minus the energy contained in the urine and excreted gasses. It has been established that DE and ME relate to each other as DE ME/0. 96 and the requirement for DE can therefore be estimated from the ME value (Whittemore, 1998).

The protein content of an adult babirusa body is not known. Taking into account that the babirusa has a smaller mature size and is a non-developed pig (i.e. not intensively selected for leanness) and could thus be expected to be fatter and have a lower body protein content, we had previously estimated its Pt to be 12% of body weight (Leus and Morgan, 1995), leading to a maintenance DE requirement of 10.9 MJ/day for a 90 kg adult babirusa. However, it has since transpired that even young Chinese Meishan pigs (a Chinese domestic breed selected to be fat) had a body protein content of 15% (Kyriazakis et al., 1993). Given this evidence and the appearance of the mature wild babirusa, which shows it to be a reasonably lean animal, a reassessment of the original assumption of body protein content seems appropriate. It is more likely that the babirusa is similar to an unimproved pig in having a body protein content of around 15 to 16% (Close, 1994). A 90 kg babirusa with a Pt 16% of body weight (i.e. 14.4 kg body protein) is then predicted to have a maintenance DE requirement of 13.4 MJDE/day. For an average female babirusa of 60 kg (i.e. 9.6 kg body protein) this amounts to 9.9 MJDE/day (Table 6). These values compare favorably with those derived from the equations of AFRC (1990a) of 14.4 and 9.7 MJ DE, respectively.

Because the maintenance state relates to a state where the body is neither anabolising nor catabolising body tissues, the formula can be used to predict the energy requirements of adult, non-growing, non-gestating and non-lactating animals. In other words, very active animals, growing animals and pregnant or lactating will have higher requirements. For example, in commercial pigs, mature pregnant sows have a DE requirement about 30% greater than maintenance and each kg of milk requires 8.4MJ DE.

The maintenance requirement for crude protein in the diet can be estimated in a similar way to that for energy. The amount of ideal protein for maintenance at tissue level can be calculated from the formula: 0.004Pt (Whittemore, 1998). The balance of the different amino acids in the food is generally different from that in pig protein, but pigs still need to transfer food proteins into pig proteins. It is therefore not just the total amount of protein that indicates the quality of the diet but rather the amount and balance of those amino acids that are necessary for the construction of pig protein. That part of the total protein intake that contains the right spectrum and balance of the amino acids essential for the functions of maintenance and production is called "ideal protein" (Whittemore, 1998). Using the same Pt values (16% of body weight for babirusa) and body weight values (90kg for a babirusa male and 60 kg for a babirusa female) as above, the ideal protein requirements for maintenance for a male and female babirusa can be calculated to be 57.6 and 38.4 g respectively. In order to derive from this the requirements for CP intake, these values have to be divided by (i) the efficiency of use of ideal protein, (ii) the protein score (= the proportion of the dietary protein that is ideal) and (iii) the ileal digestibility (the proportion of the ideal protein that will be digested up to the end of the small intestine). If we estimate the efficiency of use to be 0.85, the protein score to be 0.65 (a value appropriate for lower quality diets containing a high proportion of vegetable protein sources) and the ileal digestibility to be 0.75 (high fiber diets) (Whittemore, 1998), then the required amount of crude protein in the diet for maintenance is 139 g and 93 g for a male and female babirusa respectively (Table 6).

Mature animals have a smaller need for protein because there is no longer any above maintenance lean tissue growth, but have a higher need for energy to sustain body maintenance activities (McDonald et al., 1995; Whittemore et al., 1998). Mature animals will therefore have a smaller protein:energy ratio than young growing animals. A protein:energy ratio of 13gCP/MJ DE is considered to be appropriate for pregnant adult female domestic pigs or growing domestic pigs above 80kg (Whittemore, 1998). The required protein:energy ratio for an adult non-gestating, non-lactating babirusa can therefore be expected to be somewhat lower than that. Indeed, if the ratio is calculated from the predicted CP and DE requirements (see Table 6) then we obtain 10.4 and 9.4 g CP/MJ DE for a 90 kg and 60 kg babirusa respectively. For males this corresponds well to the average CP:Energy ratio offered whereas females receive on average too much protein in relation to energy (Table 5). Proteins and amino acids fed in excess of the animal's requirements will be deaminated and will either form precursors for the formation of body fats or will be excreted in the form of urea (Whittemore, 1998). Feeding excess protein therefore puts a large strain on the animal's deamination system. In addition, the deamination of proteins is a very inefficient process and is therefore a large drain on the animal's energy supply (Whittemore, 1998).

Fats have a higher gross energy content than the other nutrients in the diet and thus make a proportionally larger contribution to the DE of the diet and the transfer of dietary fats to body fats is a very efficient process costing the animal very little energy (Whittemore, 1998). Considering the problems with obesity in captive babirusa, care should be taken not to feed large amounts of fat. In particular, preventing the feeding of animals by the public may contribute to this. For example, 5O g of peanuts (about half the average packet for sale) contributes 1.23 MJ DE. Babirusas are very fond of people and particularly those that bring food! Feeding by the public should be prevented!

In many ways, the problems of feeding of babirusa in captivity appear similar to those of feeding Asian colobines in captivity. For the colobine monkeys, zoo diets contained much less fiber and more protein than the natural food stuffs and it was therefore recommended to either include locally available browses or a specially designed commercial product (Nijboer and Dierenfeld, 1996). For the babirusa, no data on the fiber and protein content of natural food stuffs is available. However, the anatomy of their digestive system and the similarity of the stomach anatomy to that of colobine monkeys could mean that the digestive strategy of the babirusa may not be so far removed from that of these monkeys. The main difference may be that the fiber fraction in the natural diet of the babirusa is mainly derived from tropical fruits (which in some cases may be equally, or even more, fibrous than leaves (eg. Rogers et al., 1990; Remis et al., in press) rather than from leaves.

Although no data are available on the requirements for fiber, a fiber content of about 19% of dry matter appears very low for a forestomach fermenter. Because of the lack of fibrous commercial fruits, daily inclusion of common European and North American browses would significantly improve the amount of fiber consumed (Nijboer and Dierenfeld, 1996). However, care should be taken with species such as willow (Salix sp.). As is the case with langurs (Colobinae), the babirusa will ingest long strips of the bark that may form a fiber ball in the stomach, as was the case with one female babirusa in Antwerp (De Meurichy, pars. comm.). Browses cannot only be fed at ground level but can occasionally also be offered at higher levels so that the animals have to reach high, and if necessary stand on their hind legs, to reach for food. Grasses and hays appear to be less palatable to the babirusa.

Taking all of the above into account, a diet with a target nutrient composition as set out in Table 7 emerges as a diet to be tried. Because the babirusa is a non-improved pig species, which has a slower growth than domestic pigs, reaches a smaller mature size and has problems with obesity in captivity, the CP and DE levels were left at the predicted levels for maintenance requirements.

As far as dry matter is concerned, the diet in Table 7 could be achieved by feeding 1/4 swine maintenance pellets or high fiber herbivore pellets and ¾"produce/browse" composed of ¼ fruit (maximum), ¼ yellow/orange/root vegetables, ¼ green leafy vegetables and `A locally available browse. Many commercial pellets used for babirusa today are too rich in energy and/or protein so that with a 25% ration, the animals could receive too much of these nutrients. Because most of the dry matter fed is derived from the P&G fraction, further reduction of this fraction to bring down the energy and protein content of the diet makes it very difficult to obtain the required intake of DM unless large amounts of fruit, vegetables and browse are fed. The challenge will be to either locate a pellet that is not too rich in energy and protein, or to devise a new pellet that can replace the pellet and browse fractions.

Because no data are available on the nutritional composition of the diet in the wild, experimentation will be necessary to try out and refine the recommended diet. In addition, there is an urgent need for feed intake data of the current diets being fed, including the browse fraction. Equally urgent and essential are quantitative diet studies in the wild.

Vitamins and Minerals

The specific vitamin and mineral requirements of the babirusa are unknown. Their habit of visiting salt licks to drink the water and ingest the soil may however indicate that this species has either specific requirements, or that their largely frugivorous diet is deficient in one or more components. Until further research has been carried Out the domestic pig forms the best model for this species. The NRC and AFRC requirements for domestic pigs and the recommended vitamin and mineral contents of a babirusa diet based on the pig as a model can be found in Table 8.

HEALTH OR OTHER PROBLEMS RELATED TO NUTRITION

Many babirusa in captivity are seriously obese. This may cause locomotion problems, reduced reproductive output, circulation problems, excess cholesterol etc. Commercial pig pellets and items often classified as "typical pig foods"

such as boiled potatoes and yams, acorns, chestnuts etc. contain large amounts of energy. Actual intake of these food items and the contribution they make to the total energy level of the diet should be carefully monitored.

As was mentioned above, when feeding browse care should be taken with long stringy fibers such as those from willow, which may form fiber balls in the stomach.

Young, growing males may show weakness in the hind quarters ("swaying" hind legs) which in Antwerp was solved on several occasions by a temporary increase in the vit.E/Se supplement. No systematic research was carried out on this phenomenon.

There appears to be a suspiciously high incidence of "arthritic like" symptoms in both young and old captive babirusa. Males appear to be more afflicted than females. Joints of limbs and vertebrae become inflamed and slowly fuse with spondylitis-like bone growth. In the domestic pig such symptoms can be caused by osteochondrosis or degenerative joint disease (DJD), bacterial infection or by nutritional imbalance such as deficiencies or excesses of Ca, P and vitamin D (Brongo, 1999). In case of the highly inbred captive babirusa population, inbreeding may be another contributing factor, Further research is needed to either clarify or rule out the role of nutrition in the onset of this disease.

SUMMARY

The domestic pig should be considered the dietary model for this species. However, diets designed solely for commercial swine production are unsuitable considering:

- the babirusa is an unimproved breed with a slower growth rate and a smaller mature body size
- babirusa appear to browse more and root less and thus may be consuming a diet of lower nutrient density
- babirusa have a unique stomach structure containing large microbial populations
- babirusa are prone to obesity in captivity

Recommended body weights for:

- an adult male babirusa: ± 90 kg
- an adult female babirusa: ~6O kg

Thus, feeding recommendations include:

- a diet comprising approximately 1/4 swine maintenance pellets or high fiber herbivore pellets and 3/4 "produce/browse" composed of 1/4 fruit (maximum), 1/4 yellow/orange/root vegetables, 1/4 green leafy vegetables and 1/4 locally available browse
    - complete pellets are preferred to mixes of whole grains
    - produce should be fed raw and with peels and/or stones
    - total amount offered per day should equal no more than 2.5% of body mass on an as fed basis
    - crude protein concentration of dietary DM is calculated to be approximately 13% and digestible energy approximately 13 MJ/kg
    - vitamin and mineral requirements of the babirusa diet should meet the standards for domestic swine
    - a small amount of pelleted concentrate diluted with various produce items is suggested to promote natural feeding behaviors, provide bulk and reduce calorie density
    - the ration should be spread rather evenly throughout the day, for example 30% in the morning, 20% scatter-fed and 50% in the evening
    - fresh water should be available at all times

Field studies and composition of native food items consumed by the babirusa should be considered a research priority.

Acknowledgements

Many thanks to all the people who contributed to the papers that form the basis of this chapter, in particular Dr Alastair A Macdonald, Dr Ilias Kyriazakis, Mr Paul Vercammen and all the veterinary, curatorial and keeper staff of the European and North American zoos. The financial support of the Commission of the European Community and the Development Trust of the University of Edinburgh is gratefully acknowledged.

Table 1: Chemical analysis of the water of the "Marisa" salt lick and the sediment of the "Lantolo" salt lick in North Sulawesi (for precise location see Patry et al, 1995). Samples collected by Mr Maurice Patty. Analyses carried out by the Laboratoire Municipal de Brest, 16 rue A. Ribot, 29200 Brest, France, 1989.

Components	Water salt lick "Marisa"	Sediment salt lick "Lantolo"
	(Results on a dry matter basis)	
pH	7.4	
Loss after heating at 550°C		5.3 %
Insoluble hydrochloric		83.0 %
Calcium (Ca)	500 mg/l	10.5 g/kg
Magnesium (Mg)	170 mg/l	6.9 g/kg
Ammonium (NH_4)	0.33 mg/l	
Sodium (Na)	580 mg/l	0.70 g/kg
Potassium (K)	8.9 mg/l	0.50 g/kg
Manganese (Mn)		0.52 g/kg
Iron (Fe)		33 g/kg
Carbonate (CO_3)	0 mg/l	
Bicarbonate (HCO_3)	49 mg/l	
Sulphate (SO_4)	2740 mg/l	<0.2 g/kg
Nitrite (NH_2)	0 mg/l	
Nitrate (NH_3)	<0.1 mg/l	
Phosphate (PO_4)	<0.01 mg/l	

* Analyses carried out on the insoluble fraction of the sediment

Table 2: List of Fruit and Vegetables (F&V), Commercial pellets, Grains, bread, nuts and oils (P&G), and Animal Products (AP) offered to babirusa in 19 zoos in Europe and North America.

Food item	Form	No. zoos offering item
F&V		
Apple	With peel	19
Aubergine	Raw with peel	2
Avocadp	Raw with stone	1
Banana	With peel or without peel	18
Broccoli	Raw	3
Cabbage (unspecified)	Raw	4
Carrots	Raw or boiled	15
Cauliflower	Raw	3
Celery	Raw	8
Cherries	With stones	2
Chicory	Raw	2
China cabbage	Raw	2
Coconut	Raw	1
Corn-salad	Raw	1
Cucumber	Raw with peel	5
Endive	Raw	3
Fennel	Raw	3
Fodder beet	Raw	3
French beans	Raw	1
Grapefruit	Without peel	1

Grapes	With peel and seeds	4
Green cabbage	Raw	1
Kale	Raw	1
Kiwi	With peel	4
Kohlrabi	Raw	2
Lamb's lettuce	Raw	1
Leek	Raw	6
Lettuce (unspecified)	Eaw	15
Mandarins	Without peel	1
Medlar	Raw	1
Melon	With peel	2
Nectarines	Without stone	1
Onion	Raw	3
Oranges	Without peel	11
Parsley	Raw	1
Peaches	With peel and stone	4
Pears	With peel	5
Pineapple	With peel	6
Plums	With peel and stone	7
Potatoes	Raw or boiled	8
Pumpkin	Raw with peel and seeds	2
Radish	Raw	1
Red beets	Raw	2
Red cabbage	Raw	1
Salsify	Raw	1
Savoy	Raw	1
Soya sprouts	Raw	1
Spinach	Raw	3
String beans	Raw	1
Turnip	Raw	1
Water melon	Raw with peel	1
White cabbage	Raw	2
Yams	Raw or cooked	5
Zucchini	With seed and peel	1

P & G		
Acorns	Raw	2
Barley	Dry	1
Biscuits	Dry	1
Bran	Dry	4
Bread	Brown or white	7
Corn on the cob	Fresh	1
Corn	Fresh or dry	5
Corn oil	Fluid	1
Dog chow	Pellets/biscuits	5
Germinated corn	Fresh	1
Germinated wheat	Fresh	3
Herbivore pellets	Pellets dry	12
Horse pellets	Pellets dry	1
Horse-chestnuts	Raw	1
Maize meal	Dry	2
Nutritional yeast	Dry	1
Peanuts	Dry	5

Pig pellet	Pellets dry	5
Rice	Cooked	2
Rolled corn	Dry	1
Rolled oats	Dry	8
Soya meal	Dry	1
Sunflower seeds	Dry	2
Sweet chestnut	Raw	5
Textured grain	Dry	1
Toast	Brown or white	1
Vegetable oil	Fluid	1
Walnuts	With shell	1
Wheat	Dry	1
Wheat	Ground	1
AP		
Beef meat	Raw or boiled	3
Chicks (one day old)	Whole	6
Crickets	Whole	1
Eggs	Raw or boiled, with shell	5
Fish	Raw	2
Grasshoppers	Whole	1
Mice	Whole, skinned	1
Rats	Whole, skinned	1
Skimmed milk powder	Dry	1

Table 3: List of browse items offered to babirusa in 19 zoos in Europe and North America.

Scientific name	English name	Form	Parts eaten	No. zoos
	Branches	Fresh	Bark, leaves, twigs, buds	8
	Grass	Fresh	Entirely	9
	Hay	Dry	Entirely	4
	Leaves	Dry	Entirely	2
Acacia sp.	Acacia	Branches fresh	Leaves only	3
Acer pseudoplatanus	Sycamore	Branches fresh	Bark, leaves, twigs	1
Acer rubrum	Red maple	Branches fresh	?	1
Acer saccharinum	Silver maple	Branches fresh	?	1
Acer saccharum	Sugar maple	Branches fresh	?	1
Alnus sp.	Alder	Branches fresh	?	1
Avicennia germinans	Mangrove	Branches fresh	?	1
Betula sp.	Birch	Branches fresh	Bark, leaves, twigs, buds	3
Celtis occidentalis	Hackberry	Branches fresh	?	1
Corylus sp.	Hazel	Branches fresh	Leaves	1
Craaegus sp.	Hawthorn	Branches fresh	Leaves	1
Fagus grandfolia	American beech	Branches fresh	?	1
Fagus sp.	Beech	Branches fresh	Leaves	1
Ficus benjamina	Weeping fig	Branches fresh	?	1
Forsythia sp.	Forsythia	Branches fresh	?	1
Fraxinus sp.	Ash	Branches fresh	Bark, leaves, twigs	1
Gymnocladus dioicus	Kentucky coffee tree	Branches fresh	?	1
Hibiscus rosa	Hibiscus	Branches fresh	?	1
Hordeum vulgare	Hydroponic barley	Fresh	Entirely	1
Liquidambar styraciflua	Sweetgum	Branches fresh	?	1
Malus sp.	Crabapple	Branches fresh	?	1

Medicago sativa	Alfalfa	Fresh and dry	Entirely	9
Morus alba	White mulberry	Branches fresh	?	1
Morus sp.	Mulberry	Branches fresh and dry	Leaves, bark	1
Musa sp.	Banana	Leaves	?	1
Phleum pratense	Timothy hay	Dry	?	3
Phyllostachys aurea	Golden bamboo	Branches fresh	?	1
Populus alba	White poplar	Branches fresh	?	1
Populus euramericana	Poplar	Branches fresh	Bark, leaves, twigs, buds	2
Quercus rubra	American oak	Dried leaves	Leaves	1
Quercus sp.	Oak	Branches fresh and dry	Leaves, bark	2
Robinia pseudoacacia	Black locust	Branches fresh	?	1
Salix babylonica	Weeping willow	Branches fresh	?	1
Salix nigra	Black willow	Branches fresh	?	1
Salix sp.	Willow	Branches fresh	Bark, leaves, twigs, buds	4
Trifolium sp.	Clover	Fresh	Entirely	1
Viburnum sp	Fragrant honeysuckle	Branches	Fresh	1
Vitis vinifera	Grape	Branches fresh	?	1
Zea mais	Corn stems	Fresh and dried	Entirely	1
Zea mais	Corn stems with cobs	Fresh and dried	Entirely	1
Zingiber sp.	Torch ginger	?	?	1

Table 4: Average amount of food (Total fresh weight), fruit and vegetables (F&V), commercial pellets, grains, bread, nuts and oils (P&G), animal products (AP) and dry matter (DM) offered to babirusa in 19 zoos in Europe and North America. (%BW = percentage of body weight for a 90 kg male and 60 kg female)

	Total (g/day)	F&V (g/day)	P&G (g/day)	AP* (g/day)	DM (g/day)
Male	3128_928	2151_983	878_577	209_233	1069_481
% BW	3.5				1.2
Female	2733_798	1856_831	806_512	148_113	956_425
% BW	4.5				1.6

(*) Average of nine zoos that did offer animal products

Table 5: Average amount of food (Total fresh weight); dry matter (DM), crude protein (CP), Fat, englyst fiber (EF) and digestible energy (DE) offered to babirusa in 19 zoos in Europe and North America. (%BW = percentage of body weight for a 90 kg male or a 60 kg female; %DM percentage of dry matter; CP:DE = protein to energy ratio)

	Total (g/day)	DM (g/day)	CP (g/day)	Fat (g/day)	EF (g/day)	DE (MJ/day)	CP:DE
Male	3128_928	1069_481	162_109	63.9_44.9	209_136	14.4_6.6	10.6_3.2
% BW	3.5	1.2					
% DM			15.2	6.0	19.6		
Female	2733_798	956_425	142_84	54.4_32.4	184_120	13.0_5.7	10.5_3.2
% BW	4.5	1.6					
% DM			14.9	5.7	19.2		

(*) Average of nine zoos that did offer animal products

Table 6: Predicted maintenance requirements for CP and DE for an average male (90kg) and female (60kg) babirusa. Predictions according to equations in Whittemore (1998). (CP:DE ratio = protein to energy ratio) -

Maintenance Requirement for:	90 kg Babirusa	60 kg Babirusa
CP	139 g/day	93 g/day
DE	13.4 MJ/day	9.9 MJ/day

CP:DE ratio	10.4 g CP/MJ DE	9.4 g CP/MJ DE

Table 7: Proposed criteria for a test diet for an average male (90kg) and female (60kg) babirusa in captivity. BW = Body Weight; DM Dry Matter, CP Crude Protein, DE = Digestible Energy, CP:DE ratio = protein to energy ratio, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber.

	90 kg Babirusa	60 kg Babirusa
Total DM intake	1.2% BW = 1080 g	1.2% BW = 720 g
CP	129 g/kg DM	129 g/kg DM
DE	12.4 MJ/kg DM	13.8 MJ/kg DM
CP:DE ratio	10.4	9.4
NDF/ADF	Daily browse	Daily browse

Table 8: NRC and AFRC vitamin and mineral requirements for domestic pigs and the recommended vitamin and mineral contents of a babirusa diet based on the domestic pig as a model.

Nutrient Dietary Concentrations DM Basis	Adult Maint/ Breeding Swine NRC, 1998	Growing Swine NRC, 1998 (20-50 kg)	Breeding Pigs >120 kg AFRC, 1990b*	Babirusa Complete Diet
Protein, %	12-13	16-20		
Crude Fat, %				
Vitamins				
Vitamin A, IU/g	2-4	1.4	6.9	5.0
Vitamin D_3, IU/g	0.22	0.2	0.9	0.5
Vitamin E, IU/kg	48	11	17	50
Vitamin K, mg/kg	0.5	0.5	1.1	1
Vitamin B_1, Thiamin, mg/kg	1.1	1.1	1.7	2
Vitamin B_2, Riboflavin, mg/kg	4.0	2.7	3.4	4
Vitamin B_3, Niacin, mg/kg	11	11	17	20
VitaminB_6, Pyridoxine, mg/kg	1.1	1.1	1.7	2
Vitamin B_{12}, Cobalamin, µg/kg	15	11	17	20
Folacin, mg/kg	1.4	0.3		1.0
PantothenicAcid, mg/kg	13	8.8	11.5	15
Vitamin C, mg/kg				
Minerals, %				
Calcium	0.75	0.66	0.97	1.0
Chloride	0.20	0.11		0.2
Potassium	0.22	0.25	0.29	0.3
Magnesium	0.04	0.04	0.03	0.004
Sodium	0.22	0.11		0.15
Phosphorus	0.66	0.55	0.75	0.75
Salt			0.40	0.4
Concentration, mg/kg				
Copper	5.5	4.4	5.7	6
Iron	88	66	69	90
Iodine	0.14	0.14	0.57	0.5
Manganese	22	2.2	17	25
Selenium	0.15	0.15	0.17	0.2
Zinc	55	66	57	75

* calculated from AFRC: 87%DM, l3DEIkg

** ideally Fe should not exceed 300 mg/kg

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