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Digestive efficiency in captive white storks *Ciconia ciconia*

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ABSTRACT: Digestive efficiency in the white stork was studied in the Poznań Zoo in 2004–2005. Altogether 29 individuals of this species were investigated (9 males, 20 females). During 10-day-long experimental cycles, the birds were presented with food according to the 'Cafeteria' test. The diet consisted of mammals, birds, fishes, amphibians, insects and earthworms. The mean daily food intake per bird was 284.88 g (SD 113.99 g). The mean digestive efficiency was 72.06% (SD 6.19%)? The research showed that the digestive efficiency is positively correlated with the quantity of food intake and body weight increase. The daily dietary requirement of captive birds proved to be very significantly lower than in wild birds.

Introduction

The composition of the diet of the white stork was a subject of several investigations in different regions of Europe (Pinowski et al. 1991, Muzinić & Rasajski 1992, Tsachalidis & Goutner 2002, Antczak et al. 2002). It was usually performed on the basis of pellet analysis or direct observations under field conditions. The above-mentioned papers describe food preferences depending on the life cycle stage and habitat type. However, we still lack the basic understanding of the nutritive value necessary for covering the energy requirements for hunting, egg production, rearing of chicks, or migration.

Detailed research on the digestive efficiency and digestibility of different kinds of food in the white stork (and other bird species) is very difficult to achieve under field conditions due to logistic and technical problems (Barton & Houston 1993; Durant et al. 2000, Durant et al. 2004, Profus in press).

Estimations of the daily food intake and calculation of the energetic value of certain elements of the stork diet under field conditions are given by Profus (1986, in press). The data presented are based on direct observation of just one nest, and the results are extrapolated onto the energy requirements of the local population. However, for more reliable bio-energetic calculations, a deeper knowledge of the effectiveness of digestion is required (Swenson 1933, King & Farner 1961). Therefore, in this research we performed an analysis of digestive efficiency under captive conditions.

This study was aimed to assess digestive efficiency of the white stork under experimental conditions and to determine its daily dietary requirements. The basic scheme of this study follows standard procedures and is based on results of research conducted on other groups of carnivorous species, like birds of prey and owls (Barton & Houston 1993).

Material and methods

The study was conducted in the Poznań Zoo in 2004-2005 (May, June), on wild-born birds acquired by the zoo due to various traumas, mostly of the wings (Kwieciński et al. 2006). The storks were 2-5 years old. Their sex was determined by using various techniques: laparoscopy, biometric data, or DNA (Ćwiertnia et al. 2006). Altogether 29 individuals formed our research base: 9 males and 20 females. During research, all storks were individually marked with colour rings

During our research the birds were kept inside individual cages of ca. 10 m^2 in size. The boxes were wire-netted to allow the birds visual contact with other individuals. The lower 40 cm was made of plastic sheets to prevent droppings from falling into neighbouring cages. The floor was covered with plastic foil (2 mm thick) to allow easy and thorough collecting of faeces. The experiment lasted 10 days, which were divided into two 5-day-long periods differing in food composition. During the first period (days 1-5) the birds were fed with a diet regularly provided to captive birds in the zoo. It consisted of: domestic mouse *Mus musculus* (captive-bred); one-day-old chicks *Gallus gallus;* fish (sprat *Sprattus sprattus;* perch *Perca fluviatilis*) and insects (crickets *Acheta domesticus, Gryllus bimaculatus*). During the second period (days 6-10) the diet was much more varied to reflect as much as possible the natural range of food items taken by storks under field conditions. It consisted of: mammals (mole *Talpa europaea,* shrews *Sorex* spp., bank vole *Clethrionomys glareolus,* water vole *Arvicola terrestris,* pine vole *Pitymys subterraneus,* field vole *Microtus agrestris,* common vole *Microtus arvalis,* harvest mouse *Micromys minutus,* striped field mouse *Apodemus agrarius,* yellow-necked mouse *Apodemus flavicollis,* wood mouse *Apodemus sylvaticus*), birds (young chicks of partridge *Perdix perdix* and ring-necked pheasant *Phasianus colchicus*), amphibians (spadefoot toad *Pelobates fuscus,* common toad *Bufo bufo,* brown frogs *Rana temporaria, R. arvalis*), annelids (earthworms *Lumbricus* sp.) as well as insects, mostly coleopterans (family Carabidae: *Carabus nemoralis*, *Carabus granulatus* as well as smaller beetles from the families Silphidae, Neerophoridae, Tenebrionidae). The diet was based on published data on the white stork diet in the wild (Cramp & Simmons 1988, Pinowska & Pinowski 1989, Pinowska et al. 1991, Pinowski et al. 1991, Antczak et al. 2002). Water was available *ad libitum* and changed daily.

To reduce the stress caused by separation as well as close contact with humans, 4–5 birds took part in the experiment simultaneously. Before every experiment, storks were fasted for 24 hours to enable digestion of previously taken food and passing previously formed pellets.

The food was presented in shallow, plastic containers on the basis of the 'Cafeteria test' the same time every day, i.e. about 4 PM (Rychlik & Jancewicz 2002). The food items (every kind separately: mammals, birds, etc.) were weighed every day on a Pesola scale to the nearest 0.2 g. The same protocol was followed in weighing food remnants, pellets and faeces. The pellets were collected separately from each individual, weighed and put into plastic bags, each labelled with the bird code and date.

The faeces were collected into 100-ml plastic containers, weighed and labelled. Subsequently the faeces were watered and analysed under a stereomicroscope (magnification 5×) to identify the undigested particles.

The percentage of digestive efficiency (DE) was calculated on the basis of the formula developed by Berton and Houston (1993), slightly modified to fit the stork research:

$$DE = 1 - \left(\frac{\text{faeces (g)} + \text{pellet (g)}}{\text{food intake (g)}} \right) \times 100\%$$

The quantity of the food presented to birds on the first day of the experiment was 100 g of each component of the diet for every bird tested (initial food ratio). During subsequent days the quantity of food was regulated individually by the birds themselves. The quantity of consumed items as well as leftovers determined an increase or decrease of the diet components during the experiment (i.e. if storks consumed all mammal prey during one day, the quantity of mammal food was increased on the next day). The mean daily food intake was calculated on the basis of the difference between the weight of the food provided and left uneaten by storks (in grams). The mean daily food intake of different kinds of food was also calculated for mammals, birds, etc. The mean production of faeces and pellets as well as mean digestibility efficiency were estimated.

During the 10 days of the experiment, the birds were weighed 3 times with a Pesola scale to the nearest 5.0 g. The first weighing took place on the first day of the experiment (initial body weight), and the next were taken on days 5 and 10 (final body weight, Barton, Houston 1993).

The basic results are presented as mean values (with standard deviation, SD) for 10 days of the experiment jointly for all 29 individuals. The dependence of food intake and digestive efficiency on sex, age, and composition of the diet consumed will be analysed in detail in another paper (Kwieciński et al. in preparation).

Calculations were conducted by using the package SPSS for Windows. All basic statistical analyses recommended by Zar (1999) were applied.

The research was conducted in accordance with Polish regulations pertaining to keeping animals in captivity and research protocols.

Results

Digestive efficiency and quantity of food intake

The mean daily food intake (weight of the food eaten) per bird during the experiment was 284.88 g (SD 113.99). The details on consumption of different food types are presented in Table 1.

The mean weight of faeces was 59.46 g (SD 26.71 g), which accounts for 20.87% of the weight of food consumed. The mean fresh weight of the pellets was 14.91 g (SD 7.19 g), which constitutes 5.23% of the food consumed. So, the overall mean digestive efficiency in storks was 72.06% (SD 6.19%).

The birds showing higher levels of digestive efficiency showed an increase in body weight during the experiment (Fig. 1).

Table 1. Composition of the white stork diet

Group	Mean weight (g)	% of diet
Mammals	83.7 ± 32.6	26.7
Birds	133.1 ± 57.0	42.5
Amphibians	7.9 ± 1.9*	2.5*
Fish	82.6 ± 6.4**	26.6**
Insects	3.4 ± 2.1	1.1
Earthworms	1.85*	0.59

Explanations: *items given only on days 6–10; ** items given only on days 1–5

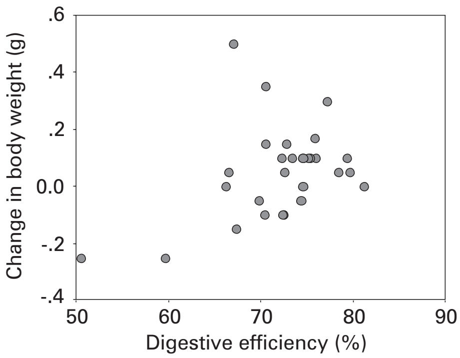

Fig. 1. Effect of digestive efficiency on changes in body weight of captive white storks ($r = 0.398$, $n = 29$, $P = 0.033$)

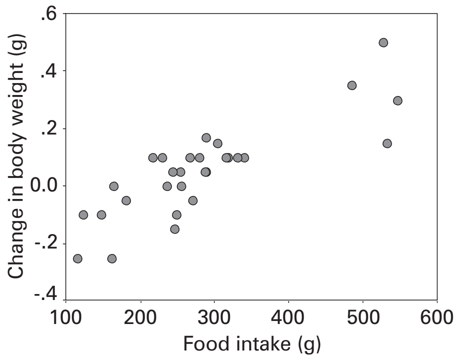

Fig. 2. Relation between food intake and changes in body weight of captive white storks ($r = 0.834$, $n = 29$, $P < 0.0001$)

Discussion

According to our knowledge the presented research results are the first analysing digestive efficiency in the white stork. Profus (in press) attempted to calculate daily dietary requirements in this species, basing on data collected by Krapivny (1957). His calculations show that a pair of storks raising one chick to cover energy requirements must acquire around 2030 g of food daily, as the adults must consume 623 g each, while a chick consumes 784 g every day during a period of peak growth. It must, however, be stressed that the quantity of food taken by adults during the breeding season must cover activities requiring large amounts of energy, like egg-laying, incubation, flight, hunting, digestion, sleep, thermoregulation (cold nights in early spring), moulting (new feather growth), and nest protection against conspecifics and predators. The peak period of chick growth is directly connected with the growth of feathers, which increases the energy requirements by another 5–30% (Payne 1972). Having in mind the results of our research, where daily intake for captive birds was calculated at a level of 284.9 g, it seems that the calculations for the wild birds are too low. Captive birds had to cover just the basic needs, like digestion, walking, standing or sleeping. The difference in daily food intake between wild and captive birds, which is just 338.1 g, is too low to cover the energy requirements of flying, searching for food, or complex activities related to reproduction (Hall & Gwiner 1987). The relatively low difference between our data and those presented by Profus (in press) may be a result of the small sample of his research or underestimation of some kinds of stork activities. It seems that the results of our research may help in estimating food requirements of wild-living storks, both in the individual and population context (see also Profus in press).

The effectiveness of food assimilation (digestive efficiency) depends on bird species, types of food items, as well as densities of prey in the habitat and prey accessibility. The efficiency of digestion should be around 70–90% (King & Farner 1961). Those values should, however, be rather treated as 'guesstimates', as they are notoriously difficult to verify under field conditions. The mean digestive efficiency of the storks in our research was 72.06%. This value comes close to the theoretical one of 75% published!!! earlier by Profus (1986). A study conducted under experimental conditions on the bioenergetics of growth in chicks of the American wood stork *Mycteria americana* show that digestive efficiency in this ecologically and taxonomically similar species might be much higher and reach 90% (Kahl 1962). To calculate the efficiency, however, the faeces production was not deducted from the overall data, so the total efficiency is surely overestimated. In general, however, it is safe to say that digestive efficiency in storks is high, which supports earlier theories based on pellet analysis (Antczak et al. 2002).

Our research has also practical implications on calculating daily dietary requirements for captive storks. The comparison with wild birds shows that under captive conditions, where some kinds of activities are significantly lower, the food intake is reduced by over 50%. It is well known that captive birds often show much higher body weights than wild ones. This leads to obesity, health problems, as well as reduced breeding. Thus the data on food intake in wild birds should not in any case be directly extrapolated into captive ones.

The quantitative results on the influence of digestive efficiency on body weight in the white stork confirm the rather obvious pattern of better digesting animals showing increasing body weights (Barton & Houston 1993).

Our data on digestive efficiency show how, under certain conditions, birds utilize the food taken. More detailed results could have been achieved by calculating the digestibility coefficient and energetic value of food items with the Kjeldahl and Soxhlet method (Barton & Houston 1993). That method, however, requires determination of proteins, fat, carbohydrates both in the food taken and in faeces and pellets. Due to financial and time constraints we were not able to use that method in our research. We are, however, fully aware that such research would give an answer on how the certain components of food are utilized and what energetic value they really have.

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Appendix

Comparison of mean values of the analysed variables of individual white storks during the 10-day-long experiment

No.	Bird code	Food intake (g)	Faeces (g)	Pellets (g)	Digestive efficiency (%)
1	B 1	245.75	63.60	17.85	67.30
2	B 2	160.95	66.25	14.50	50.51
3	B 3	303.46	69.45	18.40	70.55
4	B 4	266.15	48.50	16.95	74.52
5	B 5	278.65	55.35	19.50	73.40
6	B 6	287.60	46.10	21.60	75.73
7	B 7	255.20	71.80	14.35	66.20
8	B 8	216.45	40.90	11.15	75.84
9	B 9	235.65	48.15	10.40	74.56
10	B 10	163.20	19.60	7.65	81.12
11	B 11	115.50	23.20	4.75	59.63
12	B 11 P	318.35	54.15	11.00	79.30
13	B 12	123.55	24.25	5.10	72.32
14	B 13	146.70	27.70	10.40	72.44
15	B 14	315.80	68.60	17.20	72.22
16	B 15	286.45	45.00	12.55	79.59
17	B 16	288.40	53.90	6.65	78.31
18	B 17	331.15	64.75	18.25	74.52
19	B 18	243.55	54.60	16.00	72.60
20	B 19	270.55	66.50	3.75	74.32
21	B 20	248.35	61.30	8.65	70.38
22	B 21	299.10	59.20	15.00	75.08
23	B 22	253.95	55.90	11.75	66.54
24	B 23	179.70	31.65	7.75	69.84
25	B 25	545.50	85.55	30.30	77.16
26	B 26	339.35	59.50	20.55	75.36
27	B 27	531.85	105.55	31.05	72.80
28	B 28	484.45	113.13	24.80	70.49
29	B 29	526.15	142.05	24.45	67.01