J. Anim. Physiol. a. Anim. Nutr. 87 (2003), 66–74
© 2003 Blackwell Verlag, Berlin
ISSN 0931–2439

Receipt of Ms.: 03. 06. 2002
Accepted: 23. 10. 2002

Institute of Nutrition, University of Veterinary Medicine, Vienna, Austria

Influence of environmental humidity and dietary protein on pyramidal growth of carapaces in African spurred tortoises (*Geochelone sulcata*)

By C. S. Wiesner and C. Iben

Summary

The carapaces of captive-raised tortoises (terrestrial chelonians of the zoological family *Testudinidae*, often develop pyramidal-shaped osseous growth centrally within the horny plates. With very few exceptions (e.g. *Geochelone elegans*, *Psammobates* sp.), this conical growth pattern is considered to be pathologic. This very common defect is believed to be an important indicator of the quality of captive tortoise management. This study was designed to examine the effect of dietary protein level and environmental humidity on the degree of pyramidal growth in the carapaces. Fifty recently hatched African spurred tortoises (*G. sulcata*) were raised for 5 months under artificial conditions of varying environmental humidity and dietary protein content (14% vs. 19% vs. 30% crude protein in dry matter). Humps of the carapaces that developed and blood values of calcium, phosphorus and haematocrit were measured and compared among groups. Dry environmental conditions (24.3–57.8% and 30.6–74.8% relative humidity) produced taller humps than humid conditions (45-99% relative humidity). Hump formation differed significantly ($p \leq 0.001$) between these three groups kept under different humidity conditions. Variable dietary protein had a minor, positive impact on this pathological formation of humps (pyramidal growth syndrome, PGS). Analysis of blood (calcium, phosphorus and haematocrit) offered no further explanation as to the development of the humps.

Zusammenfassung

Bei in Gefangenschaft gehaltenen Schildkröten entwickelt sich häufig im Zentrum der Hornplatten des Rückenpanzers ein pyramidisch geformtes Knochenwachstum. Mit wenigen Ausnahmen (z.B. *Geochelone elegans*, *Psammobates* sp.) wird dieses kegelförmige Wachstum als pathologisch angesehen und es besteht die Annahme, dass dieses Wachstumsverhalten ein Parameter zur Beurteilung der Haltungsbedingungen der Tiere ist. In vorliegendem Versuch sollte der Einfluß der relativen Luftfeuchtigkeit sowie des Rohproteingehaltes im Futter auf die Höckerbildung untersucht werden. Fünfzig Schlüpflinge von afrikanischen Sporenschildkröten (*G. sulcata*) wurden fünf Monate lang unter unterschiedlich feuchten Umweltbedingungen gehalten sowie mit Futtermitteln, welche sich durch ihren Eiweißgehalt unterschieden (14% vs. 19% vs. 30% Rohprotein in der Trockensubstanz), ernährt. Die während dieser Zeit gebildeten Panzerhöcker wurden anschließend vermessen und die Kalzium, Phosphor- und Hämatokritwerte im Blut untersucht und zwischen den Versuchsgruppen verglichen. Trockene Haltung (24.3–57.8% bzw. 30.6–74.8% relative Luftfeuchtigkeit) führte zu stärkerer Höckerbildung als feuchte Haltung (45–99% relative Luftfeuchtigkeit). Die Höckerbildung war zwischen den drei

Gruppen, die bei unterschi
hiedlich ($p \leq 0{,}001$). Der
nicht abgesicherten Einfl
Panzerhöckerbildung (Pyr
keinen klärenden Beitrag z

The carapaces of captive-
Testudinidae) often develo
plates (Fig. 1). With very f
conical growth pattern is
captivity. This undesirabl
indicator of the quality of
explain this phenomenon
(1972) suggested that the l
range of possible causes ha
such as excess dietary pr
calcium : phosphorus (Ca
radiation have been suggest
1996 (cited by Mader, 199
2000; Wiechert, 2000). Mo
development of pyramidal
such as osteodystrophia fib
disease (MBD). Some auth
pyramidal growth syndro
(Jackson and Cooper, 19
Eggenschwiler, 2000; Sasse

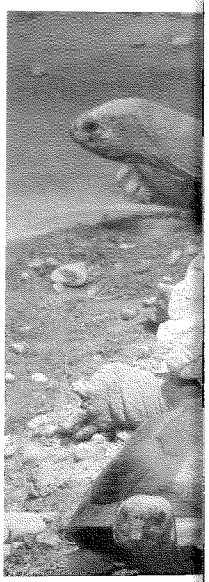


Fig. 1. Aldabra giant tor

Receipt of Ms.: 03. 06. 2002
Accepted: 23. 10. 2002

Gruppen, die bei unterschiedlicher Luftfeuchtigkeit gehalten wurden, signifikant unterschiedlich ($p \leq 0{,}001$). Der Proteingehalt des Futters hatte einen geringen und statistisch nicht abgesicherten Einfluß auf den Grad dieser pathologischen pyramidenförmigen Panzerhöckerbildung (Pyramidal Growth Syndrome, PGS). Die Blutwerteanalyse konnte keinen klärenden Beitrag zu diesen Ergebnissen liefern.

Introduction

The carapaces of captive-raised tortoises (terrestrial chelonians of the zoolgical family Testudinidae) often develop pyramidal-shaped osseous growth centrally within the horny plates (Fig. 1). With very few exceptions (e.g. *Geochelone elegans, Psammobates* sp.) this conical growth pattern is considered pathological and occurs mostly in tortoises in captivity. This undesirable, but very common defect is believed to be an important indicator of the quality of captive tortoise management. The long history of attempts to explain this phenomenon already demonstrates this. As early as 1972, Obst and Meusel (1972) suggested that the humps were the result of a previous rickety condition. A wide range of possible causes have been mentioned in the literature, like nutritional imbalances such as excess dietary protein, deficiency of calcium and vitamin D or an improper calcium : phosphorus (Ca : P). Also rapid growth rate and deficiencies of ultraviolet radiation have been suggested as the primary cause (Frye, 1991; Highfield, 1996; McArthur, 1996 (cited by Mader, 1996); Beyon et al., 1997; Kirsche, 1997; Walls, 1997; Sassenburg, 2000; Wiechert, 2000). Most of these authors have not made an attempt to associate the development of pyramidal growth with other very common osseous diseases of chelonians such as osteodystrophia fibrosa, rickets, secondary hyperparathyroidism or metabolic bone disease (MBD). Some authors, however, have either explicitly or implicitly suggested that pyramidal growth syndrome (PGS) is, in fact, due to the same cause as these diseases (Jackson and Cooper, 1981; Gabrisch and Zwart, 1995; Köhler, 1996; Kirsche, 1997; Eggenschwiler, 2000; Sassenburg, 2000; Wiechert, 2000). A more thorough understanding

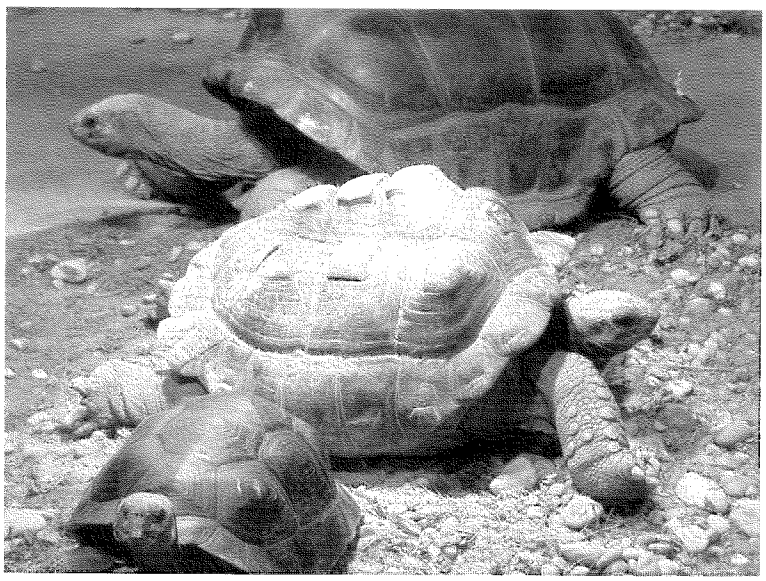


Fig. 1. Aldabra giant tortoise (*Geochelone dussumieri*) with extensive hump development

of the causes of PGS is necessary as it often appears in otherwise healthy tortoises. Furthermore, tortoises with signs of MBD like soft carapace, lordosis, or extensive growth of the costal plates, relative to the central (also named vertebral) plates, often show no signs of PGS. Although any explanation cannot be found concerning a possible influence of environmental humidity in the scientific literature, private tortoise breeder experience suggests that PGS is related to the humidity under which the tortoises are kept (Weser, 1988). In view of the above, an experiment was designed to ascertain two possible causes of hump formation in tortoises. This study was designed to examine the effect of dietary protein level and environmental humidity on the degree of pyramidal growth in the carapaces. Information gained from the study should provide the basis for advice to turtle keepers in order to avoid this problem in future.

Materials and methods

Experimental animals

African spurred tortoises (*G. sulcata*) were selected for this experiment as PGS is common in this species in captivity. Hatchlings of African spurred tortoises also grow very fast. As the females can produce clutches of more than 20 eggs, age and genetics can be controlled in the hatchlings. Fifty half-sibling tortoises were hatched at the farm of a non-commercial Austrian breeder (parents: two dames, one sire) during late December to late January. They were selected from three clutches of two dames containing 21, 29 and 27 hatchlings. The hatchlings were placed into transport boxes immediately after hatching. Within 2 days of hatching they were transferred to terraria at the Institute of Nutrition at the University of Veterinary Medicine, Vienna.

Experimental design and sample collection

After excluding individuals with deformations of the carapace or the horny plates at the breeding farm, the first 50 tortoises hatched were taken for the study group. At the University, the 50 tortoises were randomly distributed to five terraria and kept under identical conditions for 5 months except for dietary protein content and environmental humidity (Table 1). At the end of the feeding trial, the formed carapace humps were measured (Fig. 2) and blood samples were taken from the vena jugularis (to measure haematocrit, calcium and phosphorus levels). Weights were measured twice a month.

Diet

In each terrarium, water and sepia (squid-sceleton) calcium were supplied by three ceramic bowls (diameter 13 cm) *ad libitum*. Every morning, the tortoises were fed a mixture of

Table 1. **Environmental humidity and dietary protein concentrations for the five experimental groups of *Geochelone sulcata***

	Group A	Group B	Group C	Group D	Group E
Environmental humidity	24.3–57.8	27.4–55.5	30.6–74.8	47.9–99	45–99
Feed	Type 1	Type 2	Type 2	Type 2	Type 3

Environmental humidity: mean of eight weekly measured values of the maximum and minimum relative humidity in percentage

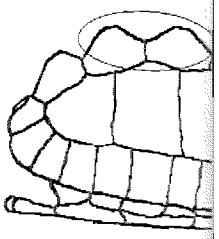


Fig. 2. Measurement of the H(u
plates 2, 3)

Table 2. **Nutritional com**

	Days 1–105
Crude protein	14.4
Crude fat	5.8
Crude fibre	13.4
Ca (mg/100 g)	2340
Ca : P ratio	4 : 1

dried pellets with defined nut
Germany) and endive salad
afterwards 2 : 1 until day 15
selectively, the soaked pellet
increase feed acceptance. Cal
(Table 2). This feeding progra
secondary hyperparathyroidi
technological reasons, values
treatments, but this was not
balance differences by differe

Weende analyses were use
using an atomic absorption
Germany), and phosphorus

The terraria consisted of gla
25 cm above the ground. Tw
front pane and at the ceiling
each terrarium, the tortoises

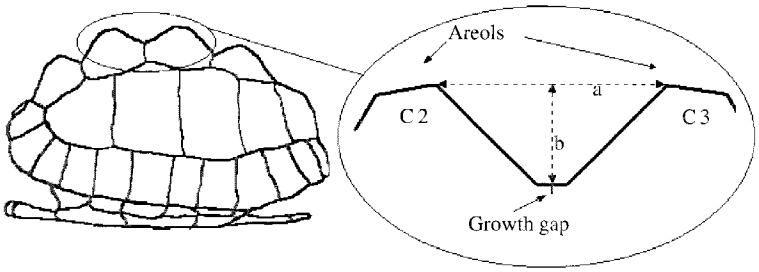


Fig. 2. Measurement of the H(ump)-index. C1–C5: Central plates 1–5; H-index = [H-value (central plates 2, 3) + H-value (central plates 3, 4)]/2; H-value = b/a

Table 2. **Nutritional composition of the diets fed (percentage of dry matter, analysed)**

	Type of feed					
	1		2		3	
	Days 1–105	Days 106–150	Days 1–105	Days 106–150	Days 1–105	Days 106–150
Crude protein	14.4	13.7	19.4	19	30.7	30.7
Crude fat	5.8	5.2	4.8	4.8	5.1	5.1
Crude fibre	13.4	13	13.4	13	11.4	10.9
Ca (mg/100 g)	2340	2411	2505	2582	2571	2649
Ca : P ratio	4 : 1	4 : 1	3.9 : 1	3.9 : 1	3.7 : 1	3.7 : 1

dried pellets with defined nutrient contents (prepared by ssniff Spezialdiäten GmbH, Soest, Germany) and endive salad in the proportion of 1 : 1 (pellets : endive) until day 105, afterwards 2 : 1 until day 150 (all in fresh weight). To prevent the turtles from feeding selectively, the soaked pellets were mixed with thinly cut endive. Endive was used to increase feed acceptance. Calcium and phosphorus were fed at a ratio of higher than 3 : 1 (Table 2). This feeding program was designed to prevent deficiencies and pathogeneses (e.g. secondary hyperparathyroidism) which have been suggested as causes of PGS. Due to technological reasons, values of calcium and the Ca : P ratio differed slightly between treatments, but this was not considered to be crucial, as the animals could theoretically balance differences by different sepia calcium consumption.

Weende analyses were used for the detection of crude nutrients. Calcium was analysed using an atomic absorption spectrophotometer (3030 B; Perkin Elmer, Überlingen, Germany), and phosphorus was measured with a photometer.

Environmental conditions

Cages

The terraria consisted of glass (100 × 80 × 80 cm) with two sliding panes at the front, 25 cm above the ground. Two air slots for ventilation were located at the bottom of the front pane and at the ceiling pane. The substrate consisted of 4–5 cm of bark humus. In each terrarium, the tortoises could hide in caves made of bricks (30 × 65 × 10 cm).

Lighting

Each terrarium was illuminated by three different light sources. Under the top pane, a 150-W HQI-lamp (Teclumen, Castel Coffredo, Italy) was fixed, which supplied the animals with the necessary light intensity for activity. The connected intermediate unit (containing the transformator) was located outside of the terraria. At the left side of the terrarium and about 25 cm above the ground, a halogen heater lighted and heated the area below. Also at this height, an ultraviolet radiating fluorescent tube (UV-A and UV-B, Reptisun 5.0; Zoo Med Laboratories Inc., San Luis Obispo, CA, USA) was also provided at this height. The HQI-lamp was on 11 h daily from 8 am to 7 pm. Heating light and UV-tube were activated for 3 h each morning (9–12 am) and 90 min each afternoon (3–4.30 pm). At the bottom of the central area of the terrarium 7000 lux, and under the halogen lamp, 14 000–15 000 lux, were measured, respectively.

Humidity control system

Humidity was provided by plastic-bowls (40×40×15 cm), filled with demineralized water with atomizers to produce fog. The bowls were located on top of the caves. Electric control units were used to regulate the atomizers, maintaining the level of relative humidity in the terraria. A connected sensor was located inside the caves. High humidity in terrarium D and E lead to humid soil. The humidity values provided in Table 1 were measured directly under the top pane. Values measured inside the caves of the three humid terrariums were approximately 10–15% higher.

Measurement of humps

The wedge-shaped indentations between the second and the third, and the third and fourth central plate of the carapace were measured. In this area, hump formation is most distinct. The H-value was defined as the ratio of the depth (b) of the indentations at the growth-gap to the distance (a) between two opposite edges of areols (Fig. 2). The mean of the two H-values was considered to be the H(ump)-index to express the degree of hump formation of the tortoises. A perfectly well-shaped carapace would have a negative H-index, due to negative depths (b) and consequently negative H-values.

Statistics

To evaluate the differences between the groups with respect to H-indices, weight, haematocrit, plasma calcium and plasma phosphorus appropriate non-parametrical tests of Kruskal–Wallis test and Mann–Whitney *U*-test were used. The selected level of significance was $p < 0.05$. All statistical tests were conducted by using SPSS 9.0 (SPSS, Chicago, IL, USA).

Results

The H-indices of groups B, C and D, raised under different levels of relative humidity but identical dietary protein concentration, were compared and had formed distinctly different humps (Figs 3, 4–6; Table 3). Tortoises of group B ('dry') showed very prominent humps whereas the carapaces of tortoises of group E ('humid') were almost smooth. The humps of group C were between these two extremes. These three very different levels of hump development were significant ($p \leq 0.001$). Groups A and B both raised under dry conditions, but fed different levels of dietary protein, (B: 14.4/13.7 in % of dry matter vs. A: 19.4/19; Table 2) also produced different sized humps. Although the statistical significance probability of error ($p = 0.06$) of this difference was above the chosen level

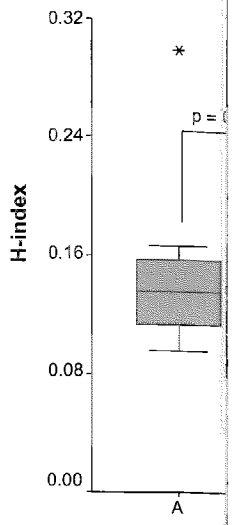


Fig. 3. This figure shows the differen kept under different levels of relati different levels of dietary protein (gro are the median, the 25th and 75th p outlier values. '+' Value is more t

($p < 0.05$), some influence of di raised under humid conditions b 30.7) showed no statistically pro first sight, the bigger African sp impression however reflected on the humps were actually measu differ among the groups but pla higher than for groups B, C). Th (group A). As dietary protein co weight of groups B, C, D (same

The combination of dry enviro induced by a nutritionally dens tortoises of this study. Humid c ably. Lowering the level of diet development of PGS. Considerin literature regarding growth failu they differ considerably from th reported his experience from kee influence on hump formation. H considers some of the natural hist have a highly variable food supp during a year and between years.

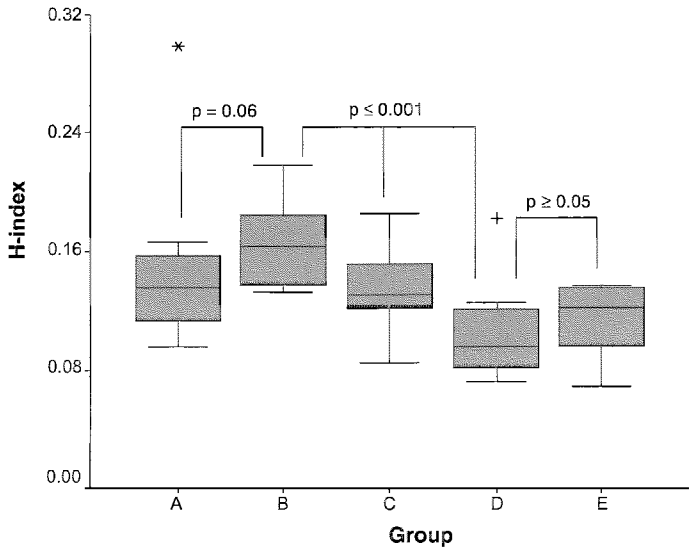
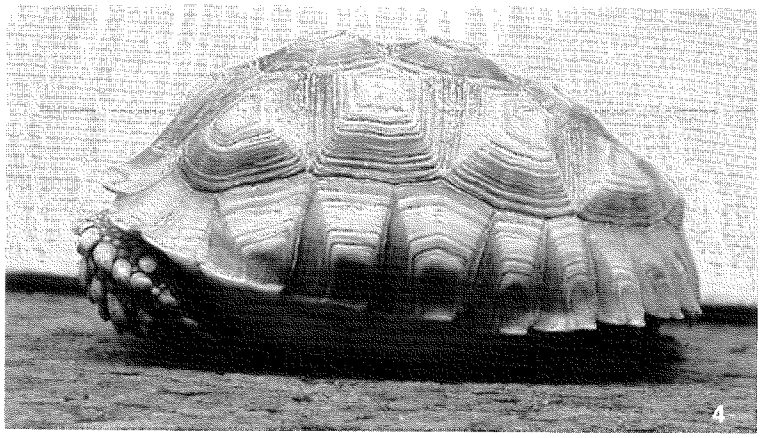


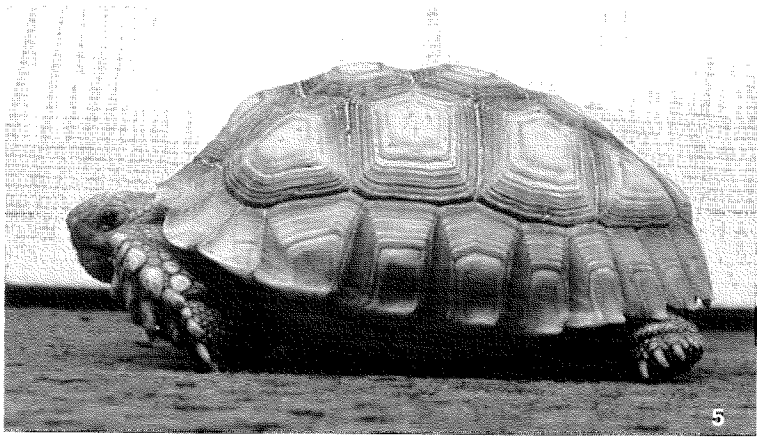
Fig. 3. This figure shows the differences in hump formation (H-indices) of the five groups of tortoises kept under different levels of relative humidity (group B, C and D; Kruskal–Wallis test) and fed different levels of dietary protein (group A vs. B, group D vs. E; Mann–Whitney *U*-test). Values shown are the median, the 25th and 75th percentiles (interquartile range) and the highest and lowest non-outlier values. '+' Value is more than 1.5-fold and '*' value is more than threefold above the interquartile range

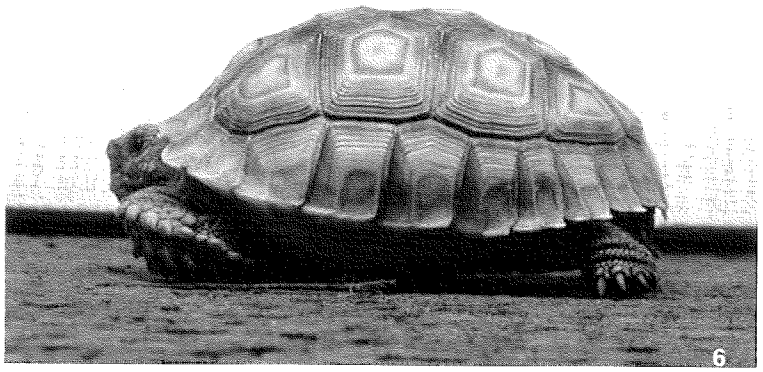
($p < 0.05$), some influence of dietary protein is probable. Groups D and E, which were raised under humid conditions but fed different levels of dietary protein (D: 19.4/19 vs. E: 30.7) showed no statistically provable difference in hump size. It should be noted that at first sight, the bigger African spurred tortoises were believed to have bigger humps. That impression however reflected only the absolute hump size and was disproven later when the humps were actually measured. Regarding blood parameters, haematocrits did not differ among the groups but plasma calcium levels did (Ca-level of group A, D, E was higher than for groups B, C). The P-levels were between 0.82 (group C) and 0.95 mmol/l (group A). As dietary protein content increased body weight increased; however, the body weight of groups B, C, D (same level of dietary protein) did not differ.

Discussion

The combination of dry environmental conditions and comparatively high growth rates induced by a nutritionally dense diet led to pyramidal growth in the African spurred tortoises of this study. Humid conditions suppressed the development of PGS considerably. Lowering the level of dietary protein had a questionable suppressing effect on the development of PGS. Considering the published reports in the veterinary and herpetologic literature regarding growth failure in chelonia, the results presented here are surprising as they differ considerably from the commonly propagated explanations. Only Weser (1988) reported his experience from keeping tortoises under humid condition and suspected some influence on hump formation. However, the results presented are understandable if one considers some of the natural history of wild tortoises. Nearly all species of extant tortoises have a highly variable food supply both in quality and quantity of nutritional components during a year and between years. During humid seasons, tortoises are able to select from a







Figs 4–6. Tortoises with three levels of hump formation. Figures 4–6 show one tortoises from each of group B (dry environment), C (intermediate humidity) and D(wet environment)

Table 3. **Results of the weight ga**

Group		Weig
A	Mean (N : 10)	
	SD	
B	Mean (N : 10)	
	SD	
C	Mean (N : 10)	
	SD	
D	Mean (N : 10)	
	SD	
E	Mean (N : 10)	
	SD	

This table shows the results of the
three blood values (haematocrit, ca
are not significant except the diffe
(intermediate protein diet) vs. gr
[a,b,c] Means of groups not sharing a

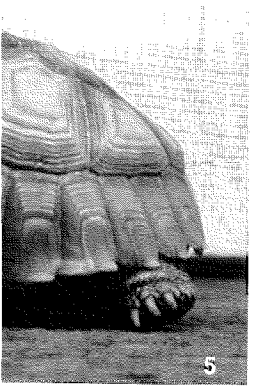
variety of new growth plants, ri
rapid growth. During very long s
for tortoises are dry plants charac
value. During these periods torto
but grow very little. Faster-grow
above the soil, providing a higher
tortoises live most of their life hi
or on the ground surrounded by
and habitats of tortoises in n
understandable that the abnorma
level of protein may lead to healt
very common both in private and
prevalence of PGS in tortoises
regarding the pathological mec
histological research, will it b
development of PGS and other
rickets or osteodystrophia fibros
could be that dehydration reduc
cartilagineous tissue at the growi
be caused by this low pressure.
becomes ossified and the collapse
permanently. During each period
higher humps. But this hypothes
in intake or excretion of minerals
the development of PGS. The
supported or rejected such an ex

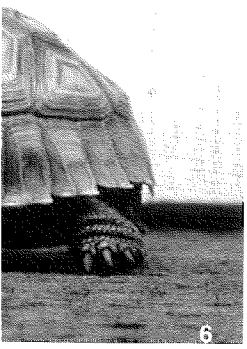
The results presented indicate
cause of PGS, except that it m
previously mentioned, faster gro
forming bigger humps. This m
tortoises produce bigger humps.
level and degree of PGS, keeping
be useful because of other protei
from this study is that, in order t

Table 3. **Results of the weight gains and blood values of the five groups of sulcated tortoises**

Group		Weight gain (g)	Hkt (%)	Ca (mmol/l)	P (mmol/l)
A	Mean (N : 10)	118[a]	19.2	3.36	0.95
	SD	33	1.5	0.50	0.14
B	Mean (N : 10)	184[b]	17.2	2.69	0.87
	SD	38	0.9	0.13	0.15
C	Mean (N : 10)	230[b]	17.8	2.97	0.82
	SD	38	1.6	0.17	0.07
D	Mean (N : 10)	205[b]	16.5	3.61	0.88
	SD	56	1.7	0.17	0.12
E	Mean (N : 10)	284[c]	15.1	3.25	0.90
	SD	55	1.2	0.16	0.23

This table shows the results of the weight gain (end weight minus start weight of the tortoises) and three blood values (haematocrit, calcium and phosphorus values). Differences between the groups are not significant except the different weight gain of group A (low protein diet) vs. group B–D (intermediate protein diet) vs. group E (high protein diet) (Mann–Whitney *U*-test, $p < 0.05$). [a,b,c] Means of groups not sharing a superscript a, b or c are significantly different





4–6 show one tortoises from each of
and D(wet environment)

variety of new growth plants, rich in nutritional contents corresponding to the period of rapid growth. During very long seasons of dryness and food scarcity, the main food source for tortoises are dry plants characterized by a high fibre content and low overall nutritional value. During these periods tortoises show little activity and probably osseous rebuilding, but grow very little. Faster-growing hatchlings live under the cover of grass and directly above the soil, providing a higher level of environmental humidity. Finally, many species of tortoises live most of their life hidden either in caves (e.g. *Testudo horsfieldii, Gopherus* sp.) or on the ground surrounded by high humidity even during arid conditions (for behaviour and habitats of tortoises in nature, see Ernst et al., 1994). Considering this, it is understandable that the abnormal combination of a dry environment and a persistent high level of protein may lead to health disorders, such as PGS. Such management conditions are very common both in private and institutional situations, which probably explains the high prevalence of PGS in tortoises in captivity. Not until further information is available regarding the pathological mechanism of how low humidity leads to PGS, such as histological research, will it be possible to evaluate any connection between the development of PGS and other diseases of the osseous tissue in turtles, such as MBD, rickets or osteodystrophia fibrosa. One possible explanation for the development of PGS could be that dehydration reduces the intracellular and intercellular pressure on the soft cartilagineous tissue at the growing gap area. A collapse of this tissue around the gap might be caused by this low pressure. If tortoises are dehydrated for a longer period, the tissue becomes ossified and the collapsed 'valleys' between the central parts of the plates are fixed permanently. During each period of growth the development of new valleys would create higher humps. But this hypothesis needs to be supported by further research. Differences in intake or excretion of minerals such as calcium or phosphorus might also help to explain the development of PGS. The results of blood assays, in the current study, neither supported or rejected such an explanation.

The results presented indicate that the level of dietary protein is probably not the main cause of PGS, except that it may predispose the tortoise to more rapid growth. As previously mentioned, faster growing tortoises can provoke the erroneous impression of forming bigger humps. This might explain the widespread belief that faster growing tortoises produce bigger humps. Even if there is no connection between dietary protein level and degree of PGS, keeping the level of dietary protein in tortoise diets low might still be useful because of other protein-related diseases, such as gout. The decisive conclusion from this study is that, in order to reduce the incidence of PGS in growing tortoises, one

needs to provide a sufficient level of environmental humidity. In particular, in order to keep the development of PGS to a minimum, areas with a relative humidity of nearly 100% for hiding should be provided to the tortoises at all times.

Acknowledgement

We thank Prof. Dr Howard B. Hulan and Mag. Cornelia Gabler for their support and assistance. We also have to thank the World Turtle Association and the Austrian Herpetological Society (Österreichische Gesellschaft für Herpetologie) for providing financial support of this study.

References

BEYON, P.; LAWTON, P. C.; COOPER; J. C. 1997: *Kompendium der Reptilienkrankheiten, Haltung, Diagnostik, Therapie*. Schlütersche, Hannover, p. 158.

EGGENSCHWILER, U., 2000: *Schildkröten in der tierärztlichen Praxis*. Schöneck, Siblingen, p. 74.

ERNST, C. H.; LOVICH, J. E.; BARBOUR, R. W., 1994: *Turtles of the United States and Canada*. Smithsonian Institution Press, Washington, London, p. 443.

FRYE, L. F., 1991: *Biomedical and Surgical Aspects of Captive Reptile Husbandry*. Krieger Publishing Company, Malabar, p. 400.

GABRISCH, K.; ZWART P., 1995: Schildkröten. In: GABRISCH, K.; ZWART P., (eds). *Krankheiten der Heimtiere*, 3. Auflage, Schlütersche, Hannover, pp. 730–731.

HIGHFIELD, A. C., 1996: *Practical Encyclopedia of Keeping and Breeding Tortoises and Freshwater Turtles*. Carapace Press, London, p. 97.

Jackson, O. F.; COOPER J. E., 1981: Nutritional diseases. In: COOPER, J. E.; JACKSON E. F. (eds). *Diseases of the Reptilia*, Vol. *2*, Academic Press, San Diego, pp. 411.

KIRSCHE, W., 1997: *Die Landschildkröten Europas, Biologie, Pflege, Zucht und Schutz*. Mergus Verlag, Melle, p. 183.

KÖHLER, G., 1996: *Krankheiten der Reptilien und Amphibien*. Ulmer, Stuttgart, p. 108.

MCARTHUR, S., 1996: *Veterinary Management of Tortoises and Turtles*. Blackwell Sience, Oxford, p. 40.

MADER, D., (ed.) 1996: *Reptile Medicine and Surgery*. W.B. Saunders, Philadelphia, p. 389.

OBST, F. J.; MEUSEL W., 1972: *Die Landschildkröten Europas*. A. Ziemsen, Wittenberg Lutherstadt, p. 65.

SASSENBURG, L., 2000: *Schildkrötenkrankheiten*. bede.Verlag, Ruhmannsfelden, p. 36.

WALLS, J. G., 1997: *Landschildkröten, Ökologie, Pflege und Zucht im Terrarium.*. bede-Verlag, Ruhmannsfelden, p. 27.

WESER, R., 1988: Zur Höckerbildung bei Schildkröten. Sauria *10*, 23–25.

WIECHERT, J., 2000: Die mediterrane Landschildkröte in der tierärztlichen Praxis. In: WERNING, H. (ed.). *Mediterrane Landschildkröten*, Draco Terraristik-Themenheft Nr. 2 Jahrgang 1, Natur und Tier-Verlag, Münster, pp. 68–71.

Authors' address: C. S. WIESNER and C. IBEN, Institut für Ernährung, Veterinärmedizinische Universität Wien, Veterinärplatz 1, 1210 Vienna, Austria.