Goldschmid-Lange, U. (1976): Über die morphologischen Unterschiede im Bau der facialen Vibrissen einiger Säugetierarten. Zool. Anz. **196**, 417–427.

Gottschaldt, K.-M.; Iggo, A.; Young, D. W. (1973): Functional characteristics of mechanoreceptors in sinus hair follicles of the cat. J. Physiol. (London) **235**, 287–315.

Hensel, H.; Andres, K. H.; Düring, M. von (1974): Structure and function of cold receptors. Pflüg. Arch. **352**, 1–10.

Iggo, A. (1976): Is the physiology of cutaneous receptors determined by morphology? In: Somatosensory and visceral receptor mechanisms. Ed. by. A. Iggo and O. B. Ilyinsky. Amsterdam, Oxford, New York: Elsevier. Pp. 15–31.

Iggo, A.; Andres, K. H. (1982): Morphology of cutaneous receptors. Ann. Rev. Neurosci. **5**, 1–32.

Iggo, A.; Gottschaldt, K.-M. (1974): Cutaneous mechanoreceptors in simple and complex structures. In: Symposium Mechanoreception. Ed. by. J. Schwartzkopff. Opladen: Westdeutscher Verlag. Pp. 153–174.

Iggo, A.; Muir, A. R. (1969): The structure and function of a slowly-adapting touch corpuscle in hairy skin. J. Physiol. (London) **200**, 763–796.

Kürten, L. (1984): Vergleichende Untersuchungen zur Anatomie und Physiologie des Tast- und Wärmesinnes im Nasenaufsatz der Vampirfledermaus *Desmodus rotundus.* Diss. Bonn.

Kürten, L.; Schmidt, U. (1982a): Thermoperception in the common vampire bat *(Desmodus rotundus).* J. Comp. Physiol. **146**, 223–228.

Kürten, L.; Schmidt, U. (1982b): Die Nasengruben der Vampirfledermaus *Desmodus rotundus*: Sinnesorgane zur Wahrnehmung von Wärmestrahlung. Z. Säugetierkunde **47**, 193–197.

Kürten, L.; Schmidt, U.; Schäfer, K. (1984): Warm and cold receptors in the nose of the vampire bat *Desmodus rotundus.* Naturwissenschaften **71**, 327–328.

Möhres, F. P. (1953): Über die Ultraschallorientierung der Hufeisennasen (Chiroptera – Rhinolophinae). Z. vergl. Physiol. **34**, 547–588.

Munger, B. L.; Halata, Z. (1983): The sensory innervation of primate facial skin, I. Hairy skin. Brain Res. Rev. **5**, 45–80.

Patrizi, G.; Munger, B. L. (1966): The ultrastructure and innervation of rat vibrissae. J. Comp. Neurol. **126**, 423–425.

Perl, E. R. (1984): Characterization of nociceptors and their activation of neurons in the superficial dorsal horn. In: Neural mechanisms of pain, Advances in pain research and therapy. Ed. by L. Kruger and J. C. Liebeskind. New York: Raven Press. Vol. **6**, 23–52.

Schmidberger, G. (1932): Über die Bedeutung der Schnurrhaare bei Katzen. Z. vergl. Physiol. 17, 387–407.

Schmidt, U. (1978): Vampirfledermäuse. Wittenberg-Lutherstadt: Ziemsen.

Schneider, H. (1963): Die Sinushaare der Großen Hufeisennase *Rhinolophus ferrumequinum* (Schreber, 1774). Z. Säugetierkunde **28**, 342–349.

Sych, L. (1960): Sensitivity of the large mouse-eared bat *Myotis myotis* (Borkhausen) to air currents in laboratory conditions. Folia Biol. **8**, 135–147.

Zucker, E.; Welker, W. (1969): Coding of somatic sensory input by vibrissae neurons in the rat's trigeminal ganglion. Brain Res. 12, 138–156.

Anschrift des Verfassers: Dr. Ludwig Kürten, Zoologisches Institut der Universität Bonn, Poppelsdorfer Schloß, D-5300 Bonn 1

Food digestibility and water requirements in the Djungarian hamster *Phodopus sungorus*

By B. Schierwater and H. Klingel

Receipt of Ms. 27. 9. 1984

Abstract

Studying the digestibility of a defined food mixture and the effects of negative water balance, very high digestion coefficients and a remarkable resistance against reduced water intake were found in the Djungarian hamster. Coefficients of digestibility were determined as 90.6 % for dry matter, 91.2 % for carbon, 80.2 % for crude protein and 91.9 % for energy. Assimilation level was estimated as 88.4 % of

U.S. Copyright Clearance Center Code Statement: 0044-3468/85/5001-0035 $ 02.50/0
Z. Säugetierkunde 50 (1985) 35–39

ISSN 0044-3468 / InterCode: ZSAEA 7

the ingested energy. Differences between reproductive and nonreproductive females were not significant. Reduced water intake resulted in weight loss of up to 50 %, whereby water content rose significantly, i.e. fat content dropped. The water requirements were low.

Introduction

The Djungarian hamster, *Phodopus s. sungorus* (Pallas, 1770), is adapted to living in cold steppes of Western Siberia. Because of high reproduction rates and cheap maintainence it has become a popular laboratory animal. *Phodopus sungorus* can be fed exclusively with food-pellets and apples and does not require additionally water (Figala et al. 1973). No data on food digestion and water requirements exist in the literature. Relevant data are useful for studying energy metabolism using the "food ration" method in the laboratory or for estimating energy and material flow through *Phodopus* populations in their natural environment.

Material and methods

The hamsters were kept under laboratory conditions with the light rhythm 16L:8D at a temperature of 20 ± 1 °C and at 80 ± 10 % rel. humidity.

Digestibility of food: 8 ♀♀ of age between 3 and 8 months were kept in metabolic cages as long as body weight was maintained constant. They were given daily 10g of a commercial hamster-food (nicki-Heimtierprodukte GmbH Bielefeld, Art. Nr. 8602) containing sunflower-seeds (about 16 %), maize (about 15 %), pellets (about 12 %), peanuts (about 1 %), barley-, oat- and wheat-seeds (about 54 %). Food pellets and shells of sunflower-seeds were not ingested by the hamsters and the food was accordingly analysed without the rejected components. The uneaten food and faeces were collected once a day. Water contents were determined by oven-drying to weight constance. For determining caloric values of food and faeces samples were burnt in a calorimeter bomb (IKA-Kalorimeter C-400 adiabatisch). Carbon content was determined with a Wösthoff-Gasanalysator (H. Wösthof oHG, Bochum). N-content was measured with the micro-Kjeldahl method (s. Lieb 1931). Nitrogen values were converted to crude protein by multiplying with 6.25 (Kleiber 1967). Digestibility for a substance (S) is defined as $([S_{ing} - S_{ex}]/S_{ing})$, where ing means ingested with the food and ex means excreted with faeces.

Reduced water intake: 5 females and 2 males were given exclusively nicki-hamsterfood (water content 10.6 %) ad libitum, meal-worms (*Tenebrio molitor* larvae), vitamins and minerals ("Osspulvit", Dr. Madaus & Co., Köln) once a week. Body weight was measured every three days. After 92 days animals were fed additionally with apples ad libitum (convalescence-phase). In vivo body water was determined by HTO (tritium labeled water) dilution (Hollemann and Dieterich 1973, 1975). Individuals were injected 10 µCi HTO in 150 µl sterile saline (140 mM) intraperitoneally. Blood samples were taken after an equilibration time of 2.5 h from the ophthalmic venous plexus (Riley 1960). Total body fat was estimated from the equation body % fat = 100 − (% body water/0.732) (Kodama 1971). Water flux rates were calculated using the equations given by Nagy and Costa (1980).

Table 1

Dry matter and energy ingested with the food and excreted with faeces (n = 8 ♀♀, mean ± SD body weight 34.8 ± 3.9 g); carbon and crude protein content in % of dry matter

	dry matter g/d ind	energy kJ/d ind	carbon %	protein %
food	2.45 ± 0.20	55.14 ± 4.58	51.74 ± 0.18	14.2 ± 0.4
faeces	0.23 ± 0.03	4.45 ± 0.58	45.10 ± 0.33	30.6 ± 0.8
DC %	90.6	91.9	91.2	80.2

DC = digestion coefficient; values are given as means ± SE

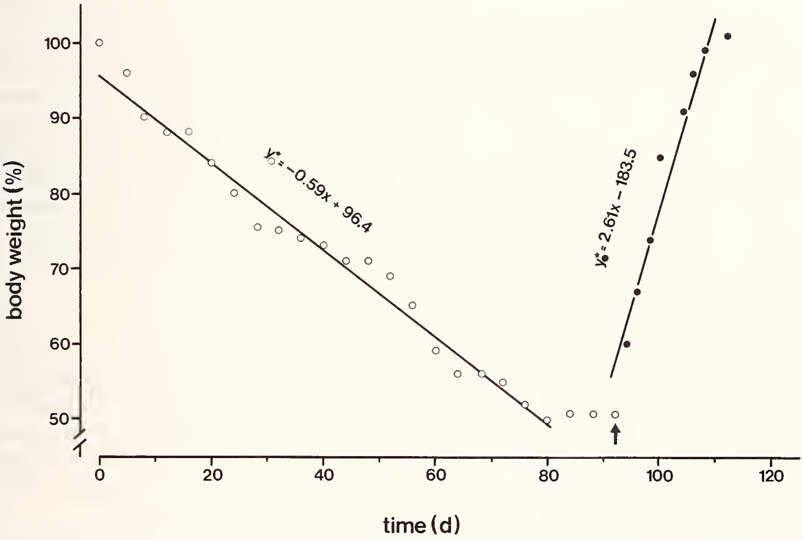
Results

Digestion coefficients: Caloric values were 22540 ± 92 J/g dry weight (mean ± one standard error, SE) for the food and 19351 ± 131 J/g dry weight for faeces.

Additionally, energy-, carbon- and protein content in faeces of pregnant or lactating females were measured. Reproductive females and controls were given additionally 1g of apple per day. Differences between the three groups were not significant (Kruskal-Wallis-test).

The amount of eliminated urine was 1.4 ± 0.3 ml/d ind (mean ± SE). Accepting a caloric value of 1.39 kJ/ml (determined by Drozdz [1968] for the yellow-necked field mouse *Apodemus flavicollis* fed with mixed seed-food), energy loss in urine is estimated as 1.94 kJ/d ind. Consequently the assimilation level (relation of ingested minus via faeces and urine excreted energy to ingested energy) can be estimated as 88.4 %.

Reduced water intake: Within 78 days the seven experimental animals lost 50 % of their body weight. Mean daily weight loss was 0.59 % of the initial body weight (34.7 ± 5.1g, mean ± standard deviation, SD). During the convalescence phase all animals regained their initial body weight within 20 days. Average daily body weight gain was 2.6 % of the initial body weight (s. linear regressions in the figure).



Body weight development of 7 hamsters under the condition of reduced water intake and during convalescence in per cent of the initial body weight (34.7 ± 5.1g, mean ± SD); the arrow marks the begin of the convalescence phase; Y* = linear regressions

In vivo body water was determined at the beginning of the experiment (day 0), after 78 days, and on the 18th day of convalescence (day 110 in Fig. 1). No differences were found between the values at the beginning (54.2 ± 6.9 % body water, i.e. 26.0 ± 5.6 % body fat, means ± SD) and the end of the experiment (53.3 ± 7.7 % body water, i.e. 27.2 ± 8.5 % body fat) (Wilcoxon matched pairs sign rank test, two-sided). On day 78 the water content was significantly increased (65.5 ± 3.1 %), i.e. the fat content was significantly lowered (10.5 ± 4.0 %) ($p < 0.05$, same test).

During 6 days of convalescence phase when body weight rose from 25.4 ± 2.8 to 31.5 ± 3.9 g total water influx was 5.9 ± 1.1 ml d^{-1} ind^{-1}, while water efflux rate was

5.3 ± 1.0 ml d^{-1} ind^{-1} (means ± SD). Water flux rates in 9 normal fed hamsters (apple and carrots ad lib.) maintaining constant body weight (30.3 ± 3.1 g) over 7 days were 3.7 ± 0.6 ml d^{-1} ind^{-1}.

Discussion

In order to assess the energy and material flow through a rodent population it is necessary to investigate which part of the ingested food is utilized by the animals and which part joins the turnover in form of excretions (Drozdz 1968). The coefficients of digestibility for dry matter (90.6 %), carbon (91.2 %) and protein (80.2 %) found are higher than most values determined for other Muroidea. For *Microtus arvalis, Clethrionomys glareolus, Apodemus agrarius* and *Apodemus flavicollis* digestion coefficients for different diets ranged from 73.9 to 93.5 % for dry matter, from 74.5 to 94.0 % for carbon and from 63.2 to 87.5 % for crude protein (Drozdz 1968). Utilization of the energy in the food was also very high compared with the digestion and assimilation coefficients reported elsewhere (Kaczmarski 1966; Drozdz 1968; Migula 1969; Myrcha et al. 1969; Peterson and Baumgardt 1971; Drozdz et al. 1972; Smith and McManus 1975; Randolph et al. 1977; Heasley 1983; Gettinger 1984). The terms digestibility and assimilation are not always used in the same manner in the literature and often only one coefficient is given. In most cases assimilation level is about 2 to 4 % less than digestion level in small rodents. The energy digestibility of 91.9 % is very high compared to other studies, where values fluctuated between limits of 56 % and 94 %. A direct quantitative comparison of the different data however is not possible because of the different diets used. Digestibilities can depend decisively on water and fibre content in the food (Nehring et al. 1965; Drozdz 1968; Peterson and Baumgardt 1971). The result that no differences in faeces analysis were found between reproductive and non-reproductive females are interpreted to mean that the digestion coefficients are not influenced by the higher energy turnover during reproduction. This is in accordance with the results of Kaczmarski (1966), Migula (1969), Myrcha et al. (1969) and Randolph et al. (1977). Summarising the results these indicate that the digestion of mixed seed-food is in the Djungarian hamster not less efficient than in phylogenetically younger Microtinae and Muridae.

In this study the Djungarian hamster depended on taking preformed water with the food to maintain a leveled water balance. Despite the fact that body weight was reduced to 50 % and body fat was lowered to below that value for normal fed hamsters weighing less than 25 g (Schierwater, unpubl.), the hamsters remained remarkably tolerant to water deprivation. Body weight and body fat depot regained the normal level in less than three weeks. The fact that two experimental animals propagated successfully within three weeks after the experiment indicates that the three months water deprivation caused no substantial irreversible damage to the animals.

Presuming an average daily metabolic rate of 1700 kJ kg^{-1} d^{-1}, oxidation-water production can be estimated as 48.7 ml kg^{-1} d^{-1} (Schierwater, unpubl.). Accepting this value the intake of preformed water with the food was 4.5 ml d^{-1} ind^{-1} during convalescence phase and 2.2 ml d^{-1} ind^{-1} in normal fed animals. For maintaining constant body weight the water requirements were much lower. Feeding experiments, where the animals were fed with 0.9 ml preformed water d^{-1} ind^{-1} showed that this was enough for 9 animals to maintain constant body weight (33.8 ± 3.9 g, mean ± SD) over 30 days. This is interpreted as the maximum value to maintain a leveled water balance under the chosen laboratory conditions because ingestion is not necessarily equal to hoarding. Smith and McManus (1975) found for the house mice, *Mus musculus*, an about 10 fold higher water requirement. The results indicate an ecological advantage for the Djungarian hamster in dry habitats over the sympatric Microtinae and Muridae with much greater water requirements.

Acknowledgements

We are grateful to Prof. Dr. U. SCHAIRER and Prof. Dr. W. SEBALD of the Gesellschaft für Biotechnologische Forschung, Stöckheim, and to Dr. D. GÄDEKEN of the Bundesforschungsanstalt für Landwirtschaft, Völkenrode, for supporting our work with laboratory equipment.

Zusammenfassung

Zur Futterverdaulichkeit und zum Wasserbedarf des Dshungarischen Zwerghamsters Phodopus sungorus

Untersucht wurden verschiedene Parameter der Verdaulichkeit eines definierten Mischfutters und der Einfluß reduzierter Wasserzufuhr beim Dshungarischen Zwerghamster. Die ermittelten Verdaulichkeitskoeffizienten von 90,6 % für Trockensubstanz, 91,2 % für Kohlenstoff, 80,2 % für Roh-Protein und 91,9 % für Energie, liegen im Vergleich zu anderen Vertretern der Mäuseartigen sehr hoch. Die Ergebnisse deuten an, daß der Dshungarische Zwerghamster die Nahrung zumindest ähnlich effizient ausnutzt wie stammesgeschichtlich modernere Vertreter der Mäuse und Wühlmäuse. Ein Einfluß des Fortpflanzungsgeschehens auf die Verdaulichkeitskoeffizienten wurde nicht festgestellt. Unter Bedingungen reduzierter Wasserzufuhr verringerten die Versuchstiere in drei Monaten ihr Körpergewicht um 50 % und ihren relativen Fettgehalt um mehr als 50 %. Innerhalb von drei Wochen Rekonvaleszenz wurden die ursprünglichen Verhältnisse bezüglich Körpergewicht und Fettgehalt wiederhergestellt.

Literature

DROZDZ, A. (1968): Digestibility and assimilation of natural foods in small rodents. Acta theriol. **13,** 367–389.

DROZDZ, A.; GORECKI, A.; SAWICKA-KAPUSTA, K. (1972): Bioenergetics of growth in common voles. Acta theriol. **17,** 245–257.

FIGALA, J.; HOFFMANN, K.; GOLDEN, G. (1973): Zur Jahresperiodik beim Dshungarischen Zwerghamster, *Phodopus sungorus,* Pallas. Oecologia **12,** 89–118.

GETTINGER, R. D. (1984): Energy and water metabolism of fre-ranging pocket gophers, *Thomomys bottae.* Ecology **65,** 740–751.

HEASLEY, J. E. (1983): Energy allocation in response to reduced food intake in pregnant and lactating laboratory mice. Acta teriol. **28,** 55–71.

HOLLEMAN, D. F.; DIETERICH, R. A. (1973): Body water content and turnover in several species of rodents as evaluated by the tritiated water method. J. Mammalogy **54,** 456–465.

— — (1975): An evaluation of the tritiated water method for estimating body water in small rodents. Can. J. Zool. **53,** 1376–1378.

KACZMARSKI, F. (1966): Bioenergetics of pregnancy and lactation in the bank vole. Acta theriol. **11,** 409–417.

KLEIBER, M. (1967): Der Energiehaushalt von Mensch und Haustier. Hamburg u. Berlin: Paul Parey.

KODAMA, A. M. (1971): In vivo and in vitro determinations of body fat and body water in the hamster. J. Appl. Physiol. **31,** 218–222.

LIEB, H. (1931): Die Bestimmung des Stickstoffes. In: Handbuch der Pflanzenanalyse. Hrsg. von G. Klein. Wien: Springer. Bd. **1,** 162–170.

MIGULA, P. (1969): Bioenergetics of pregnancy and lactation in European common vole. Acta theriol. **14,** 167–179.

MYRCHA, A.; RYSZKOWSKI, L.; WALKOWA, W. (1969): Bioenergetics of pregnancy and lactation in white mouse. Acta theriol. **14,** 161–166.

NAGY, K. A.; COSTA, D. P. (1980): Water flux in animals: Analysis of potential errors in the tritiated water method. Am. J. Physiol. **238,** R454–465.

NEHRING, K.; SCHIEMANN, R.; HOFFMANN, L.; KLIPPEL, W.; JENTSCH, W. (1965): Utilization of the energy concentrates in relation to their nutrient composition. In: Energy Metabolism. Hrsg. von K. L. Blaxter. London, New York: Acad. Press.

PETERSON, A. D.; BAUMGARDT, B. R. (1971): Food and energy intake of rats fed diets varying in energy concentration and density. J. Nutr. **101,** 1057–1068.

RANDOLPH, P. A.; RANDOLPH, J. C.; MATTINGLY, K.; FOSTER, M. M. (1977): Energy costs of reproduction in the cotton rat, *Sigmodon hispidus.* Ecology **58,** 31–45.

RILEY, V. (1960): Adaptation of orbital bleeding technic to rapid serial blood studies. Proc. Soc. Biol. Med. **104,** 751–754.

SMITH, W.; MCMANUS, J. J. (1975): The effects of litter size on the bioenergetics and water requirements of lactating *Mus musculus.* Comp. Biochem. Physiol. **51,** 111–115.

Anschrift der Verfasser: BERND SCHIERWATER, Prof. Dr. HANS KLINGEL, Zoologisches Institut,
Technische Universität, Pockelstr. 10a, D-3300 Braunschweig

Zeitschrift/Journal: Mammalian Biology (früher Zeitschrift für Säugetierkunde)

Jahr/Year: 1984

Band/Volume: 50

Autor(en)/Author(s): Schierwater Bernd, Klingel Hans

Artikel/Article: Food digestibility and water requirements in the Djungarian hamster Phodopus sungorus 35-39