EVALUATION OF COMMERCIAL TORTOISE AND TURTLE FEEDS

Nikoletta Hetényi*, Emese Andrásofszky

Department of Animal Nutrition and Clinical Dietetics, Institute for Animal Breeding, Nutrition and Laboratory Animal Science, University of Veterinary Medicine, 1078, István u. 2, Budapest, Hungary

*Corresponding author, E-mail: hetenyi.nikoletta@univet.hu

Abstract: Captive chelonians should be fed a natural diet to achieve a growth rate similar to that of free-ranging animals. A wide range of commercially formulated foods dedicated to chelonians is available. Feeding commercial foods has the advantage of convenience. On the other hand, species-specific information on the nutritional requirements of chelonians is not available yet. The aim of this study was to analyse and evaluate commercial pellets and feeds for chelonians. Commercial pellets ($n_{tortoise}$ = 7, n_{turtle} = 7, from 6 companies) dedicated to carnivorous aquatic turtles and herbivorous terrestrial tortoises, and other aquatic turtle feeds (lyophilised beef heart, dried aquatic invertebrates, and whole frozen fish) were bought in pet shops. Whole frozen fish served as a reference feed for carnivorous aquatic turtles. The chemical composition as well as calcium (Ca) and phosphorus (P) contents were determined. Single-sample t-test was used with the label information as null hypothesis and the results of own parallel analyses for crude protein (CP), ether extract (EE), crude fibre (CF), Ca and P. The labelling of some of the pellets was deficient as nutritive values, Ca or P data were missing (tortoise pellets: 4 out of 7; turtle pellets: 5 out of 7). The label data differed significantly (p<0.05) from the results of our own analysis for 13 out of the 14 pellets. None of the tortoise pellets met the requirements of the animals completely. Because of the inadequate Ca:P ratio only one turtle pellet could be accepted. Accordingly, none of the commercial pellets can be recommended as main or only feed.

Key words: nutrition; pellet; metabolic bone disease; chelonian

Introduction

Chelonians are commonly kept pets. Overweight, accelerated growth rate and metabolic bone disease of nutritional origin are common as a result of inadequate nutrition and housing (1, 2, 3, 4, 5). The natural diet of aquatic chelonians consists of several animal species, and seasonality is strong in the case of tortoises (6, 7, 8, 9, 10, 11, 12, 13). Captive chelonians should be fed a natural diet to achieve a growth rate similar to that of free-ranging animals (2, 3, 7, 15). The energy expenditure of reptiles is only 25–35% that of mammals (16). Feeding frequency and quantity must also be mentioned, as periodic starvation is common in the natural habitat of chelonians.

A wide range of commercially formulated foods dedicated to chelonians is available. Feeding commercial foods has the advantage of convenience. On the other hand, species-specific information on the nutritional requirements of chelonians is not available yet. Because of this, the composition of commercial pellets is not necessarily adequate for the target species. The formulation of pellets varies from manufacturer to manufacturer (14, 17). Controlled animal trials evaluating the effects of such feeds are also missing.

The aim of this study was to analyse and evaluate commercial pellets and feeds for chelonians.

Material and methods

Commercial pellets (n=14, from 6 companies, tortoise: A = Nutrin-Aquarium Tortoise Sticks; B1 = Sera Raffy Vital Herbivor; B2 = Sera Reptil Herbivor, C1= JBL Herbil; C2 = JBL Agivert; D = Exo Terra European Tortoise Adult; E1 = Tetra Tortoise; turtle: C3 = JBL Agil; C4 = JBL Tortil; JBL = Rugil; E2 = Tetra ReptoMin Sticks; E3 = Tetra ReptoMin Energy; E4 = Tetra ReptoMin Baby, F = Panzi) dedicated to carnivorous aquatic turtles and herbivorous terrestrial tortoises, and other aquatic turtle feeds including whole frozen fish (European smelt; *Osmerus eperlanus*) and dried aquatic invertebrates (Baltic prawn [*Palaemon adspersus*] and dried freshwater crab [*Gammarus roeseli*]) were bought in pet shops. The whole frozen fish served as a reference feed for carnivorous aquatic turtles.

The chemical composition as well as calcium (Ca) and phosphorus (P) content of the pellets, lyophilised beef heart, dried aquatic invertebrates and whole frozen fish were determined according to the AOAC (16) prescriptions (10 analyses/pellet for nutrients and 2 analyses/pellet for Ca and P).

All statistical tests were conducted using R 3.5.1 software (R Development Core Team, 2009, Vienna, Austria). Single-sample *t*-test was used with the label information as null hypothesis and the results of own parallel analyses for crude protein (CP), ether extract (EE), crude fibre (CF), Ca and P. The level of significance was p < 0.05.

Results

The nutrient content of tortoise and turtle pellets is shown in Tables 1 and 2. In the case of tortoise pellets our own data differed significantly (p<0.05) from the label information on several occasions. The CP contents were significantly higher (A, B2, D and E1) or lower (B1 and C2) than those indicated on the label. This can be explained by the ingredients of animal origin (fish and fish derivatives, molluscs and shellfish) in 3 products (B1, D and E1) and the presence of alfalfa meal (A) or algae (B2). Compared to the declared value, CF was significantly higher in 4 pellets (A, C1, C2 and E1) and lower in 3 pellets (B1, B2 and D). The EE was significantly lower in 4 and higher in 3 pellets than the data on the label. The crude ash (CA) content was also significantly lower than the declared value, with the exception of two samples (A and C2). The nitrogen-free extracts (NFE) varied between 48.2–71.2% and the two cereal grain free pellets (C1 and E) had the lowest carbohydrate content).

The Ca and P contents of tortoise and turtle pellets are shown in Tables 3 and 4. Four tortoise feed labels did not declare Ca and P contents. From the remaining 3 pellets, two had significantly lower (B2 and C1) and one significantly higher (B1) Ca level than the declared value. The P concentrations were also significantly lower than those declared on the label (B1, B2 and C1). The Ca:P ration was approximately the same in all pellets.

Table 1: Nutrient content of the complete tortoise pellets on dry matter basis

Feed	CP % label[1]	CP % own[2]	CF % label	CF % own	EE % label	EE% own	CA % label	CA % own	NFE % own
A	10.0	12.9±0.17*	14.0	16.3±0.37*	2.0	1.4±0.15*	6.0	6.0±0.08	63.4
B1	18.1	16.6±0.21*	9.3	3.0±0.32*	3.4	1.9±0.23*	8.0	7.3±0.14*	71.2
B2	14.8	20.5±0.24*	13.3	4.9±0.29*	4.8	3.3±0.08*	6.3	5.5±0.16*	65.8
C1	14.0	14.2±0.08	20.0	21.5±0.52*	2.0	2.6±0.24*	14.0	13.2±0.35*	48.2
C2	12.5	10.9±0.12*	22.0	24.9±0.48*	2.5	1.9±0.18*	8.5	9.6±*0.25	52.7
D	9.0	13.8±0.22*	26.0	19.8±0.59*	2.0	2.5±0.28*	10.0	7.7±*0.12	56.2
E1	9.0	12.2±0.16*	22.0	24.5±0.65*	0.5	2.2±0.32*	10.0	7.8±*0.04	53.3

Capital letters indicate the different manufacturing companies. A = Nutrin-Aquarium Tortoise Sticks; B1 = Sera Raffy Vital Herbivor; B2 = Sera Reptil Herbivor, C1= JBL Herbil; C2 = JBL Agivert; D = Exo Terra European Tortoise Adult; E1 = Tetra Tortoise. CP = crude protein, CF = crude fibre, EE = ether extract, CA = crude ash, NFE = nitrogen-free extract, [1]label information; [2]own analysis; NA = not available; *significant difference (p<0.05)

Table 2: Nutrient content of the turtle pellets and feeds on dry matter basis

Feed	CP % label[1]	CP % own[2]	CF % label	CF % own	EE % label	EE% own	CA % label	CA % own	NFE % own
C3	40.0	36.8±2.51*	0.5	2.4±0.28*	7.00	6.9±0.22	8.0	7.6±0.16	46.4
C4	NA	38.5±3.04	NA	3.2±0.22	NA	5.8±0.24	NA	8.1±0.05	44.4
C5	NA	30.2±1.67	NA	1.6±0.23	NA	3.9±0.15	NA	6.9±0.08	57.4
E2	39.0	36.2±3.25*	2.0	0.5±0.18	4.5	2.7±0.07*	NA	11.6±0.17	49.0
E3	47.0	55.9±2.34*	4.0	0.05±0.04	7.0	5.8±0.18*	15.0	11.7±0.22*	26.5
E4	45.0	46.9±3.58*	2.0	0.05±0.05	8.0	5.5±0.04*	NA	11.6±0.1	35.9
F	25.0	27.3±1.28*	2.0	0.9±0.18	1.50	0.4±0.12*	7.0	3.1±0.04*	68.3
LBF	NA	64.7±3.64	NA	NA	NA	10.0±0.31	NA	10.3±0.26	NA
Shrimp	NA	70.7±0.15	NA	NA	NA	2.3±0.12	NA	17.3±0.28	NA
Gammarus	NA	49.4±0.14	NA	NA	NA	5.2±0.24	NA	19.2±0.24	NA
Fish**	NA	67.7±0.16	NA	NA	NA	12.9±0.28	NA	16.2±0.14	NA

Capital letters indicate the different manufacturing the companies. C3 = JBL Agil; C4 = JBL Tortil; JBL = Rugil; E2 = Tetra ReptoMin Sticks; E3 = Tetra ReptoMin Energy; E4 = Tetra ReptoMin Baby, F = Panzi. NA = not available; [1]label information; [2]own analysis; LBF = lyophilised beef heart, *significant difference (p<0.05), ** whole frozen fish, European smelt (*Osmerus eperlanus*); CP = crude protein, CF = crude fibre, EE = ether extract, CA = crude ash, DM = dry matter

Table 3: Calcium and phosphorus content of complete tortoise pellets on dry matter basis

Feed	Ca % label[1]	Ca % own[2]	P % label	P % own	Ca:P own
A	NA	1.3±0.06	NA	0.4±0.02	3.2:1
B1	1.5	2.3±0.01*	0.6	0.5±0.01*	4.6:1
B2	2.5	1.2±0.04*	0.7	0.3±0.02*	4:1
C1	2.1	1.3±0.03*	0.6	0.4±0.02*	3.2:1
C2	NA	1.1±0.02	NA	0.4±0.01	2.7:1
D	NA	1.2±0.05	NA	0.4±0.02	3:1
E1	NA	1.0±0.02	NA	0.2±0.01	2:1

Capital letters indicate the different manufacturing companies. A = Nutrin-Aquarium Tortoise Sticks; B1 = Sera Raffy Vital Herbivor; B2 = Sera Reptil Herbivor, C1= JBL Herbil; C2 = JBL Agivert; D = Exo Terra European Tortoise Adult; E1 = Tetra Tortoise. [1]label information; [2]own analysis; NA = not available; *significant difference (p < 0.05)

Table 4: Calcium and phosphorus content of turtle pellets and feeds on dry matter basis

Feed	Ca % label[1]	Ca % own[2]	P % label	P % own	Ca:P own
C3	NA	1.5±0.04	NA	1.1±0.01	1.4:1
C4	NA	1.6±0.04	NA	0.9±0.02	1.8:1
C5	NA	1.5±0.03	NA	1.0±0.02	1.5:1
E2	3.3	3.6±0.06	1.2	1.4±0.01	2.6:1
E3	NA	2.4±0.05	NA	1.3±0.01	1.8:1
E4	3.2	3.6±0.04	1.3	1.5±0.01	2.4:1
F	NA	0.3±0.01	NA	0.4±0.00	0.7:1
LBF	NA	2.5±0.05	NA	2.0±0.02	1.2:1
Shrimp	NA	3.9±0.03	NA	1.3±0.01	3:1
Gammarus	NA	5.0±0.02	NA	1.5±0.02	3.3:1
Fish*	NA	5.1±0.02	NA	3.3±0.01	1.5:1

Capital letters indicate the different manufacturing companies. C3 = JBL Agil; C4 = JBL Tortil; JBL = Rugil; E2 = Tetra ReptoMin Sticks; E3 = Tetra ReptoMin Energy; E4 = Tetra ReptoMin Baby, F = Panzi. NA = not available; [1]label information; [2]own analysis; LBF = lyophilised beef heart; *whole frozen fish, European smelt (*Osmerus eperlanus*)

In the case of the turtle pellets our own data differed significantly (p<0.05) from the label information on several occasions. The labelling of products was also very poor, lacking the declaration of nutritive value and mineral content in 2 pellets and 3 other commercial feeds. The CP was significantly lower in two pellets (C3 and E2) and higher in three pellets (E3, E4 and F) than the label information. The CP content of lyophilised beef heart, shrimp, Gammarus and fish was the highest. The CF levels were significantly lower than the declared values with one exception (C3). The EE was approximately the same as the label data for one pellet (C3) but significantly lower in the case of the others. The EE content of lyophilised beef heart and fish was much higher than that of the other feeds. The CA was significantly lower than the declared value in two pellets (E3 and F). The NFE contents varied between 26.5–68.3%. Three pellets with >45% NFE contained cereal grains as the main ingredient (C3, C5, F). In two pellets (E2 and E3) cereal grains were not mentioned but it was not specified what 'ingredient of plant origin' meant. Pellet E2 had 49% NFE content which presumably means cereal grain content. Pellets C4 and E4 also listed cereal grains but not as a main ingredient.

The Ca and P contents were not declared in 4 pellets and 4 other commercial feeds. Both of the remaining 2 pellets had higher Ca and P concentrations than indicated on the label. Shrimp, Gammarus and whole fish had much higher Ca content than the other feeds. The P level of dried invertebrates was similar to that of the pellets while lyophilised beef heart and fish contained more P. The Ca:P ratio showed bigger differences than that of the tortoise pellets. One pellet (F) had a very disadvantageous ratio (0.7:1) which can be explained by the extremely low (0.3±0.01%) Ca content. The Ca:P ratio of lyophilised beef heart and fish was similar to that of the pellets with one exception (F), while shrimp and Gammarus had much higher Ca:P ratios.

Discussion

The diet for captive chelonians should resemble their wild diet. Herbivorous reptiles cover their energy requirement mainly by carbohydrates (50–75% DM), of this 15–40% is the CF. Protein represents 15–35% and fat is less than 10% (14).

This composition highly depends on the tortoise species. For captive tortoises it is better to reduce the protein intake and increase the fibre in order to reduce the growth rate. This diet may include garden weeds (e.g. dandelion, chickweed), dark leafy greens (e.g. mustard green, turnip top, kale, rugula, corn salad) and a small amount of vegetables (19). Tortoises fed with a diet containing less than 80% grasses and weeds in the summer tend to develop pyramidal growth syndrome (20). Fruits should be avoided or reduced to a minimum (<5%) because of their high carbohydrate content (14, 19). Some species may receive higher amount of fruits which fits their natural diet (e.g. red-footed tortoise [*Chelonoidis carbonaria*]; 21).

The natural diet of herbivorous chelonians is low in CP (approx. 15% DM; 13); however, they occasionally ingest protein of animal origin (8, 12, 22). Excess protein intake leads to accelerated growth rate, renal failure, gout and it is also associated with pyramidal growth syndrome (1, 15, 23, 24, 25). Captive chelonians may have even lower protein intake to reduce their growth rate. Five pellets met the CP requirement while one (B1) had a slightly higher level. The 20.5% CP content of pellet B2 seems to be too high for pet chelonians and thus it is not recommended.

Little is known about the fat requirement of tortoises, but it should be around 3% DM (23). The EE contents were generally lower than indicated on the label, but they probably cover the requirement. However, it is not known whether the 1.4% EE content of pellet A is sufficient if the pellet is used as the only feed.

The carbohydrate content should be around 45.5–52.3% (23). Most feeds met this requirement with three exceptions. Pellets A and B2 had approximately 10% higher NFE content while B2 had a much higher NFE concentration than optimal. Carbohydrate overload also accelerates the growth rate. It is also important to mention that some species such as the steppe tortoise (*Testudo horsfieldi*) have very low activity and spend very little time foraging (<15 min per day; 27). Thus, these chelonians can satisfy their energy requirement with a modest feeding effort.

In nature, herbivorous tortoises consume a wide range of plant species (10, 12, 13, 23, 27, 28, 29). These are typically high in CF (15–40% DM) and calcium. The high CF content of diets for captive reptiles is important for reducing the feed intake and thus the growth rate (28, 30, 31, 32). Captive

reptiles grow much faster than free-ranging ones (2, 3, 15, 25, 33, 34). In the diet of Galapagos giant tortoises (*Geochelone nigra*), CF may reach 30–40% on DM basis which might be the case in other herbivorous chelonians as well (29). In the diet of captive desert tortoise *(Gopherus agassizii)* the CF level can be 25–30% (35). Some species (e.g. the Bolson tortoise [*Gopherus flavomarginatus*]) feed on droppings of rabbits which are high (30% DM) in undigested fibre (36) and can serve as a source of trace elements as well. Herbivorous chelonians rely on gut microbes to ferment dietary fibre and produce volatile fatty acids (14, 37, 38). It seems that they can digest cellulose and hemicellulose as efficiently as herbivorous mammals (32, 39). Pellets A, B1 and B2 did not contain an adequate amount of CF. Four pellets (C1, C2, D and E1) reached the recommended minimum level but pellet D contained much less CF than the declared value (19.8 vs. 26% DM).

The natural diet is rich in Ca and tortoises feed on soil, bones, or faeces of carnivores to fulfil their Ca requirement (12, 36, 40, 41, 42). Tortoises have high Ca tolerance which can be explained by the fact that these animals grow until death (43). Higher Ca intake also leads to enhanced Ca digestibility (44, 45). In 6 pellets (A, B2, C1, C2, D and E1) the Ca concentration was around 1% which seems to be too low.

The optimal Ca:P ratio of tortoise diets is much higher (3.1–5.8:1 or even higher; 46) than the general recommendations for mammals (Ca:P = 2:1). According to experimental data this ratio may reach 6:1 without causing adverse effects (1.29% Ca on a dry matter basis; 44). In the diet of wild juvenile and adult desert tortoises the Ca:P ratio of needlegrasses (*Achantherum* spp.) is 22:1 and 13:1, respectively, while desert dandelion (*Malacothrix* spp.) forbs have a ratio of 9:1 and 14:1, respectively (9). In some plant species the Ca:P ratio may reach 32.4:1 (*Cardus australis;* 13). Five pellets reached or exceeded the minimum recommendation for Ca:P and two pellets (C2 and E1) were below that.

Carnivorous aquatic chelonians have much higher protein and fat requirements than herbivores while their fibre and carbohydrate requirements are much lower (12, 47). Whole frozen fish can be a reference feed which is available in pet shops. Freezing has the advantage that it eliminates parasites. It is advised to feed a variety of fish species to avoid the possible long-term negative effects of the exclusive feeding of one species. For example, smelt may have high thiaminase activity and can induce thiamine deficiency (48). Whole fish should be fed frequently to most freshwater turtles and should be the main feed for piscivorous species (14, 47, 48 49, 50, 51). Besides that, other whole vertebrates and invertebrates such as shrimp or Gammarus can be offered. Carnivorous reptiles mainly cover their energy requirements from protein (25–60%) and fats (30–60%), which highlights the importance of these nutrients. Carbohydrates have the lowest importance with less than 10% DM (12). Many of the freshwater turtles are opportunistic carnivores or omnivores, as they undergo an ontogenetic shift in their diet as they mature (6, 11, 14, 51, 52, 53, 54, 55, 56, 57, 58). This dietary shift can be explained by the hypothesis that larger turtle species are less able to meet their metabolic requirements on a carnivore diet, have greater capacity to store fats and can cover their energy requirements on a plant diet as well. Diet change is also linked to changes in physiological needs and specific requirements (51, 59, 60). Specialities can be mentioned as adult pond sliders (*Trachemys scripta*) become predominately herbivorous; the animal to plant matter ratio in their diet is 77:23 (54). Carbohydrates are more important for omnivorous reptiles (20–75% DM), while fats represent 5–40% and protein is between 15–40% (14).

The CP levels of pellets were much lower than those of fish or dried invertebrates. The recommended protein level for Chinese softshell turtle (*Pelodiscus sinensis*) is 39.0–47.7% DM (61, 62, 63, 64, 65, 66, 67, 68). In red-eared terrapins (*Trachemys scripta elegans)* a growth rate equal to the natural one was obtained with 25–40% CP (50). When turtles are kept as pets and not as farmed animals the protein concentrations may be lowered to prevent fast growth rate (69), but exact recommendations are missing. Sudden overfeeding with protein may lead to dysbiosis and diarrhoea while prolonged overfeeding results in obesity (49). This is why overfeeding with whole fish should be avoided by applying adequate feeding frequency. Juveniles and breeding females have much higher protein requirements (53, 66, 68), the latter may reach 61–66% (69). Too low (<30%) protein intake of growing turtles may lead to reduced growth rate (50, 64, 70). The animal:plant protein ratio of the diet should be around 3:1 (61). With one

exception (F), these commercial pellets may cover the requirements of slow-growing adults as these turtles may be fed moderate CP levels of around 26%. Pellets C5 and E4 were dedicated to young growing animals. Product E4 with its 46.9% CP content may cover the requirement but product C5 with 30.2% seems to be inadequate.

Because of packaging and storage, it is better to have pellets with lower EE content, but this macronutrient is important in the energy supply of carnivorous and omnivorous turtles (14). As Table 2 shows, the EE levels of pellets were much lower than that of the frozen fish (12.9% DM). The recommended EE level for Chinese softshell turtle in commercial farms is around 4.2–8.8% (74, 64, 65, 66, 67, 68, 70, 71, 72). High-fat diets (13.9% EE) should be avoided as they lead to the accumulation of lipids in the liver and liver injury (65). The optimal EE intake for pet turtles is not known but presumably it may be lower. Accordingly, it seems that most of the pellets can cover the EE requirements. Pellet F with 0.4% EE content is an exception. Although it is called a 'complete feed', it does not cover the requirement of the animals. Based on the EE content of whole fish, especially the European smelt, moderate and not exclusive feeding is recommended as part of a balanced diet.

The NFE requirement of turtles may vary according to their specific requirements. If we calculate with 39–46% CP, 9% EE and 4% CF for carnivorous turtles, then the NFE is approximately 41–46%. This seems to be adequate for carnivores (61, 64) and the optimal starch content for farmed juvenile soft-shelled turtle is around 30% (71). Opportunistic carnivores may have higher NFE requirements.

Little is known about the CF requirements of carnivorous or opportunistic carnivorous chelonians. Feeds of animal origin do not contain CF, thus it may only be important for opportunistic carnivores. On the other hand, fibre has a satiating effect which helps to avoid overfeeding and may have a beneficial effect on the gut microbiota of pet turtles. For juvenile soft-shelled turtles 2–8% CF seems to be adequate (71).

The Ca and P contents of the pellets and lyophilised beef heart were much lower than those of Gammarus and whole fish. Imbalanced diets having low Ca content lead to metabolic bone disease of nutritional origin in aquatic turtles as well (73). However, excess Ca intake (2.24% DM) may have a negative impact on the growth rate of aquatic turtles (74). On the other hand, the optimal Ca and P intake for Chinese softshell turtle is 5.7% and 3.0%, respectively (75). These data are very similar to the Ca and P levels of European smelt. Metabolic bone disease of nutritional origin can be prevented by providing 1.16–2.95% Ca and 0.92–2.56% P in the diet (74). Shrimp, Gammarus and whole fish are good Ca sources. As aquatic turtles feed underwater, dusting the feed with dietary minerals and vitamin supplements does little to cover the requirements. Therefore, the diet should have optimal Ca and P content.

According to studies on Chinese softshell turtle, the Ca:P ratio should be approximately 2:1. This can be reached with 5.7% Ca and 3.0% P (60). The lower Ca:P ratio may lead to shell malformations or lower growth rates. This recommended ratio was reached only in pellets E2 and E4. The Ca:P ratio of European smelt is lower than 2:1 but close to the 1.9:1 ratio recommended for Chinese softshell turtle (75). Shrimp and Gammarus have much higher Ca:P ratio than the minimum requirements; thus, they can be fed in combination with whole fish to increase the Ca:P ratio.

Conclusion

As a general recommendation, we suggest not to buy any commercial feed that does not have detailed nutritional values. For herbivorous tortoises a good-quality pellet should be low in protein (10–15%), high in crude fibre (18–20%) and its Ca:P ratio should be >3:1. Avoid feeds containing proteins of animal origin. According to the nutritional values determined by our own analysis, products C2 and E1 can be accepted but their Ca:P ratios were far from the requirements. Thus, none of the commercial feeds is recommended for use as main feed. The nutrient content of the pellets should be checked very carefully, as label information is not necessarily precise. For carnivorous turtles the nutrient content of artificial feeds should be close to the nutritive value of whole fish or the recommendations. This means 25–50% protein (for young growing animals >30%), 4–8% EE and a Ca:P ratio of >2:1. Based on their CP and EE levels, four pellets (C3, C4, E3 and E4) can be accepted, but because of the inadequate Ca:P ratio only pellet E4 can be recommended.

Based on the nutritive value of the pellets it is not advised to use them as the only or main feedstuff. Different chelonian species may have widely varying requirements, and thus a diet universally suitable for all of them cannot be formulated. Greater emphasis should be put on the proper labelling of products.

Acknowledgments

References

1. McArthur S. Problem solving approach to com-mon diseases of terrestrial and semi-aquatic chelonians. In: McArthur S, Wilkinson R, Meyer J, Innis JC, Her-nandez-Divers S, eds. Medicine and surgery of tortoises and turtles. Oxford : Blackwell Publishing, 2004: 309–77.

2. Ritz J, Griebeler EM, Huner R, Clauss M. Body size development of captive and free-ranging African spurred tortoise (Geochelone sulcata): high plasticity in reptilian growth rates. Herpetol J 2010; 20: 213–16.

3. Ritz J, Hammer C, Clauss M. Body size develop-ment of captive and free-ranging Leopard tortoise (Geo-chelone pardalis). Zoo Biol 2010; 29: 517–25. doi:10.5167/uzh-36147.

4. Mans C, Braun J. Update on common nutritional disorders of captive reptiles, Vet Clin North Am Exot Anim Pract 2014; 17: 369–95. doi: 10.1016/j.cvex.2014.05.002.

5. Boyer TH, Scott PW. Nutritional diseases. In: Di-vers S, Stahl S, eds. Mader's reptile and amphibian med-icine and surgery. 3rd ed. St. Louis : Saunders Elsevier, 2019: 932–50.

6. Dreslik MJ. Dietary notes on the red-eared slider (Trachemys scripta) and River Cooter (Pseudemys concinna) from Southern Illinois. Trans Ill State Acad Sci 1999; 92: 233–41.

7. El Mouden EH, Slimani T, Kaddour KB, Lagarde F, Ouhammou A, Bonnet X. Testudo graeca graeca feeding ecology in an arid and over-grazed zone in Morocco. J Arid Environ 2006; 64: 422–35. doi:10.1016/j.jaridenv.2005.06.010.

8. Rouag R, Ferrah C, Luiselli L, Tiar G, Ben-yacoub S, Ziane N, El Mouden E. Food choice of an Algerian population of the spur-thighed tortoise, Testudo graeca. Afr J Herpetol 2008; 57: 103–13. doi: 10.1080/21564574.2008.9635573.

9. Hazard LC, Shemanski DR, Nagy KA. Nutritional quality of natural foods of juvenile and adult Desert tortoises (Gopherus agassizii): calcium, phosphorus, and magnesium digestibility. J Herpetol 2010 44: 135–47. doi:10.1670/08-134.1.

10. Del Vecchio, S, Burke R.L, Rugiero L, Capula M, Luiselli L. Seasonal changes in the diet of Testudo her-manni hermanni in central Italy. Herpetologica 2011; 67: 236–49. doi:10.1655/HERPETOLOGICA-D-10-00064.1.

11. Çiçek K, Ayaz D. Food composition of the Eu-ropean pond turtle (Emysorbicularis) in Lake Sülüklü (Western Anatolia, Turkey). J Freshw Ecol 2011; 26: 571–8. doi: 10.1080/02705060.2011.580536.

12. Iftime A, Iftime O. Long term observations on the alimentation of wild Eastern Greek tortoises Testudo graeca ibera (Reptilia: Testudines: Testudinidae) in Dobrogea, Romania. Acta Herpetol 2012; 7: 105–10. Doi: 10.13128/Acta_Herpetol-9800.

13. Shelley JR, Kaufman L. Report on the analysis of the wild diet of Testudo werneri. http://www.nature-conservation.org.il/. Nature conservation. 2012.

14. Boyer TH, Scott PW. Nutrition. In: Divers S, Stahl S, eds. Mader's reptile and amphibian medicine and surgery. 3rd ed. St. Louis : Saunders Elsevier, 2019: 201–23.

15. Furrer SC, Hatt J-M, Snell H, Marquez C, Hon-egger RE, Rübel A. Comparative study on the growth of juvenile Galapagos giant tortoises (Geochelone nigra) at the Charles Darwin Research Station (Galapagos Islands, Ecuador) and Zoo Zurich (Zurich, Switzerland). Zoo Biol 2004; 23: 177–83. doi:10.1002/zoo.10130.

16. Mader DR, Divers S. Reptile medicine and sur-gery. 2nd ed. St. Louis : Saunders Elsevier, 2006: 1241 pp.

17. Kik MJL, Dorrestein GM, Beynen AC. Evalua-tion of 15 commercial diets and their possible relation to metabolic bone diseases in different species of reptiles. In: Proc. 41. Internationalen Symposiums über die Erkrankungen der Zoo- und Wildtiere, Rome, Italy, 2003: 87–90.

18. AOAC. Official methods of analysis of the AOAC. 15th ed. Arlington : Association of official ana-lytical chemists, 1990.

19. McArthur S, Barrows M. Nutrition. In: McArthur S, Wilkinson, R, Meyer J, Innis JC, Hernandez-Divers S, eds. Medicine and surgery of tortoises and turtles. Ox-ford : Blackwell Publishing, 2004: 73–86.

20. Bauer T, Reese S, Koelle P: Nutrition and hus-bandry conditions of Palearctic tortoises (Testudo spp.) in captivity. J Appl Anim Welf Sci 2019; 22: 1–12. doi: 10.1080/10888705.2018.1453814.

21. Wang E, Donatti CI, Ferreira VL, Raizer J, Himmelstein J. Food habits and notes on the biology of Chelonoidis carbonaria (Spix 1824) (Testudinidae, Chelonia) in the Southern Pantanal, Brazil. South Am J Herpetol 2011; 6: 11–9. doi: 10.2994/057.006.0102.

22. Buskirk JR, Keller C, Andreu AC. Testudo graeca Linnaeus, 1758 – Maurische Landschildkroten. In: Fritz, U, ed. Schildkroten (Testudines) I, Handbuch der Reptili-en und Amphibien Europas. Wiebelsheim : Aula Ver-lag, 2001: 126–78.

23. Johnson JD, Averill-Murray RC, Jarchow JL. Captive care of the desert tortoise, Gopherus agassizii. J Herp Med Surg 2001; 11: 8–11. doi: doi.org/10.5818/1529-9651.11.3.8.

24. Wiesner CS, Iben C. Influence of environmental humidity and dietary protein on pyramidal growth of carapaces in African spurred tortoises (Geochelone sulcata). J Anim Physiol Anim Nutr 2003; 87: 66–74. doi:10.1046/j.1439-0396.2003.00411.x.

25. Lapid RH, Nir I, Robinzon B. Growth and body composition in captive Testudo graeca terrestris fed with a high-energy diet. Appl Herpetol 2005; 2: 201–9. doi: 10.1163/1570754043492090

26. Hazard LC, Shemanski DR, Nagy KA. Nutrition-al quality of natural foods of juvenile desert tortoises (Gopherus agassizii): energy, nitrogen, and fiber digestibil-ity. J Herpetol 2009; 43: 38–48. doi: 10.1670/07-160R1.1.

27. Lagarde F, Bonnet X, Corbin J. Naulleau G. For-aging behaviour and diet of an ectothermic herbivore: Testudo horsfieldi. Ecography 2013; 26: 236-242. doi: 10.1034/j.1600-0587.2003.03365.x.

28. Hansen RM, Johnson MK, Van Devender TR. Foods of the desert tortoise Gopherus aga-zzissi in Arizona and Utah. Herpetologica 1976; 32: 247-51.

29. Hatt JM, Clauss M, Gisler R, Liesegang A Wan-ner M. Fiber digestibility in juvenile Galapa-gos tortoises (Geochelone nigra) and implications for the development of captive animals. Zoo Biol 2005; 24: 185–191. doi: 10.1002/zoo.20039.

30. Barboza PS. Digesta passage and functional anat-omy of the digestive tract in the desert tortoise (Xerobates agassizii). J Comp Physiol B 1995; 165: 193-202. doi: 0.1007/BF00260810.

31. McMaster M.K., Downs CT. Digestive parame-ters and water turnover of Leopard tortoises. Comp Biochem Physiol 2008; 151: 114–25. doi: 10.1016/j.cbpa.2008.06.007.

32. Franz R, Hummel J, Müller DWH, Bauert M, Hatt JM, Clauss M. Herbivorous reptiles and body mass: effects on food intake, digesta retention, digestibility and gut capacity, and a comparison with mammals. Comp Biochem Physiol A 2011; 158: 94–101. doi: 10.1016/j.cbpa.2010.09.007.

33. Lambert MR: Studies on the growth, structure and abundance of the Mediterranean spur-thighed tor-toise, Tesudo graeca in field populations. J Zool 1982; 196: 165–89. doi: 10.1111/j.1469-7998.1982.tb03499.x.

34. Ritz J, Clauss, M, Streich WJ, Hatt JM. Variation in growth and potentially associated health status in Hermann's and spur-thighed tortoises (Testudo hermanni and Testudo graeca). Zoo Biol 2012; 31: 705–17. doi: 10.1002/zoo.21002.

35. Oftedal OT. Nutritional ecology of the desert tortoise in the Mojave and Sonoran deserts. In: Van Denever TR, ed. The Somoran desert tortoise natural history, biology and conservation. Tucson : University of Arizona Press, 2002: 194–41.

36. García-Feria LM, Ureńa-Aranda CA. Non-specific coprophagy of a free-ranging neonate Gopherus flavomar-ginatus Legler, 1959. Herpetozoa 2018; 30: 209–11. doi: 10.2305/iucn.uk.2007.rlts.t9402a12983328.en.

37. Bjorndal KA. Digestive efficiency in a temperate herbivorous reptile, Gopherus polyphemus. Copeia 1987; 3: 714–20.

38. Yuan ML, Dean SH, Longo A, Rothermel BB, Tuberville TD, Zamudio KR. Kinship, inbreeding and fine-scale spatial structure influence gut microbiota in a hindgut-fermenting tortoise. Mol Ecol 2015; 24: 2521–36. doi: 10.1111/mec.13169.

39. Bjorndal KA, Bolten AB, Moore JE. Digestive fermentation in herbivores: effect of food particle. Physiol Zool 1990; 63: 710–21. doi: 10.1086/physzool.63.4.30158172.

40. Soler J, Martínez-Silvestre A. Coprofagia de Tes-tudo hermanni sobre excrementos de tejón (Me-

les meles). Bola Asoc Herpetol. Esp 2011; 22: 57–8.

41. Moore JA, Dornburg A. Ingestion of fossil sea-shells, stones and small mammal bones by gravid gopher tortoises (Gopherus polyphemus) in South Florida. Bull Pea-body Mus Nat Hist New Haven 2014; 55: 55–63. doi: 10.3374/014.055.0105.

42. Suliva BK, Cahill TM. Seasonal timing of con-sumption of calcium-rich caliche in the Sonoran desert tortoise (Gopherus morafkai) in Central Arizona. Chelonian Conserv Biol 2019; 18: 98–101. doi: 10.2744/CCB-1339.1.

43. Fledelius B, Jorgensen GW, Jensen HE, Brimer L. Influence of the calcium content of the diet offered to Leopard tortoises (Geochelone pardalis). Vet Rec 2005; 156: 831–35. doi: 10.1136/vr.156.26.831.

44. Liesegang A, Hatt JM., Nijboer J, Forrer R, Wan-ner M, Isenbügel E. Influence of different dietary calci-um levels on the digestibility of Ca, Mg, and P in cap-tive-born juvenile Galapagos giant tortoises (Geochelone nigra). Zoo Biol 2001; 20: 367–74. doi: 10.1002/zoo.1035.

45. Liesegang A, Hatt JM, Wanner M. Influence of different dietary calcium levels on the digestibility of Ca, Mg, and P in Hermann's tortoises (Testudo hermanni). J Anim Phisiol Anim Nutr 2007; 91: 459–64. doi: 10.1111/j.1439-0396.2007.00676.x.

46. Jarchow JL. Veterinary management of the desert tortoise, GopherliS agassizii at the Arizona Sonora Desert Museum: a rational approach to diet. In: Proceedings of Desert Tortoise Council Symposium, 1984: 83–94.

47. Rawski M, Józefiak D. Body condition scoring and obesity in captive African side-neck turtles (Pelome-dusidae). Ann Anim Sci 2014; 14: 573–84. doi: 10.2478/aoas-2014-0037

48. Wappel SM, Schulte MS. Turtle care and hus-bandry. Vet Clin North Am Exot Anim Pract 2004; 7: 447–72. doi: 10.1016/j.cvex.2004.03.002.

49. Zwart P. Nutrition of tortoises and terra-pins. In: Proceedings of the first International Congress of. Che-lonian Pathology. Gonfaron, Var, France, 1992: 156–63.

50. Avery HW, Spotila R, Congdon JD, Fischer RU, Standora EA, Avery SB. Roles of diet protein and tem-perature in the growth and nutritional energetics of ju-venile slider turtles, Trachemys scripta. Physiol Biochem Zool 1993; 66: 902–25. doi: 10.1086/physzool.66.6.30163746.

51. Eisemberg CC, Stephen J. Reynoldsa, Keith A. Christiana, Richard C. Vogt: Diet of Amazon river tur-tles (Podocnemididae): a review of the effects of body size, phylogeny, season and habitat. Zoology 2017; 120: 92–100. doi: 10.1016/j.zool.2016.07.003.

52. De La Ossa J, Vogt RC, Santos-Júnior LB: Feed-ing of Peltocephalus dulmerilianus (Testudines: Podocnemididae) in a natural environ-ment. Actu Biol 2011; 33: 85–92.

53. Bouchard SS, Bjordnal K: Ontogenetic Diet Shifts and Digestive Constraints in the Omnivorous Freshwater Turtle Trachemys scrip-ta. Physiol Biochem Zool 2006; 79:150–8. doi: 10.1086/498190.

54. Gibbson JW: Editor. Life history and ecology of the slider turtle. Washington D.C., USA, Smithsonian Institution Press, 1990. 368 pp. doi: 10.1126/science.250.4984.1164.

55. Luiselli L, Akani GC, Ebere N, Rugiero L, Vi-gnoli L, Angelivi FM: Eniang EA, Behangana N: Food habits of a pelomedusid turtle, Pelom-edusa subrufa, in trop-ical Africa (Nigeria): The effects of sex, body size, sea-son, and site. Chelonian Conserv Bi 2011; 10: 138–44. doi: 10.2744/CCB-0843.1.

56. Ottonello D, Salvidio S, Rosecchi E: Feed-ing habits of the European pond terrapin Emys orbicularis in Camargue (Rhône delta, South-ern France). Amphib-Reptil. 2005; 26: 562. doi: 10.1163/156853805774806241.

57. Rhodin A, Ibarrondo B, Kuchling G: Chelo-dina mccordi Rhodin 1994 – Roti Island snake-necked turtle, McCord's snake-necked turtle, kura-kura rote. Chelonian Conserv Bi 2008; 5: 001–8. doi: 10.3854/crm.5.008.mccordi.vl.

58. Spencer RJ, Thompson MB, Hume ID: The diet and digestive energetics of an Austra-lian short-necked turtle, Emydura macquarii. Comp Biochem Phys A 1998; 121: 341–49. doi: 10.1016/s1095-6433(98)10132-0.

59. Bjorndal KA: Diet mixing: nonadditive in-terac-tions of diet items in an omnivorous fresh-water turtle. Ecology 1991; 72: 1234-–41. doi: 10.2307/1941097.

60. Bjorndal KA, Bolten AB: Digestive efficien-cies in herbivorous and omnivorous freshwater turtles on plant diets: do herbivores have a nu-tritional advantage? Phys-iol Biochem Zool 1993; 66: 384–95. 10.1086/physzool.66.3.30163699.

61. Jia Y, Yang Z, Hoa Y, Gao Y: Effects of animal–plant protein ratio in extruded and ex-

panded diets on nitrogen and energy budgets of juvenile Chinese soft-shelled turtle (Pelodiscus sinensis Wiegmann). Aquacul Res 2005; 36: 61−8. doi: 10.1111/j.1365-2109.2004.01184.x.

62. Nuangseang B, Boonyaratapalin M: Protein re-quirement of juvenile soft-shelled turtle Trionyx sinensis Wiegmann. Aquacult Res 2001; 32: 106−11. doi: 10.1046/j.1355-557x.2001.00049.x.

63. Zhou F, Ding XY, Feng H, Xu YB, Xue HL, Zhang JR, Ng WK: The dietary protein requirement of a new Japanese strain of juvenile Chinese soft shell turtle, Pelodiscus sinensis. Aquaculture 2013 412: 74–80. doi: 10.1016/j. aquaculture.2013.07.018.

64. Xie QS, Yang ZC, Li JW, Li YJ: Effect of protein restriction with subsequent re–alimentation on compensatory growth of juvenile soft–shelled turtles (Pelodiscus sinensis). Aquac Int 2012; 20: 19–27. https://doi.org/10.1007/s10499-011-9438-8.

65. Zhong Y, Pan Y, Liu L, Li H, Li Y, Jiang J, Xiang J, Zhang J, Chu W: Effects of high fat diet on lipid ac-cumulation, oxidative stress and autophagyin the liver of Chinese softshell turtle (Pelodiscus sinensis). Comp Bio-chem Physiol B 2020; 240. doi:10.1016/j.cbpb.2019.110331.

66. Sun C–X, Xu W–N, Li X–F, Zhang D–D, Qi-an Y, Jiang G–Z, Liu W–B: Effects of fish meal re-placement with animal protein blend on growth perfor-mance, nutrient digestibility and body composition of juvenile Chinese soft–shelled turtle Pelodiscus sinensis. Aquac Nutr 2016; 22: 315−25. https://doi.org/10.1111/anu.12247.

67. Sun C-X, Xu W-N, Zhang D-D, Li X-F, Li P-F, Jiang G-Z, Liu W-B: Different preference is modulated by the feeding stimulant supplementation in different Chinese soft-shelled turtle (Pelodiscus sinensis) basic diets. Aquac Nutr 2018; 24:195−203. doi:10.1111/anu.12547.

68. Zhou F, Wang YQ, Ding XY, Ng WK, He F, Xue HL: Partial Replacement of Fish Meal by Soy Pro-tein Concentrates in Diets for a New Japanese Strain of Juvenile Soft-Shelled Turtle, Pel-

odiscus sinensis. Aquac Res 2016; 47: 875−86. http://dx.doi.org/10.1111/are.12548

69. Meers, M. B., K. L. Robinson, D. Smith, A. Scordino, and L. Fisher: Effect of diet on growth in captive Podocnemis unifilis: assessing optimal diets for turtles in head-starting programs. Bull Fla Mus Nat His 2016; 54(4):58–68.

70. Wang J, Qi Z, Yang Z: Effects of Dietary Pro-tein Level on Nitrogen and Energy Budget of Juvenile Chinese Soft-shelled Turtle, Pelodiscus sinensis, Wiegmann. J World Aquac Soc 2016; 47: 450−8 doi: 10.1111/jwas.12280.

71. Kou H, Miao Y, Pan X, Yan LX, Wang AN, Lin L: Impact of dietary cornstarch levels on growth per-formance, body composition and digestive enzyme ac-tivities of juvenile soft-shelled turtle (Pelodiscus sinensis). Ann Anim Resour Sci 2018; 18: 1029−43. doi: 10.2478/aoas-2018-0040.

72. Lin WY, Huang CH: Fatty acid composi-tion and lipid peroxidation of soft-shelled turtle, Pelodiscus sinensis, fed different dietary lip-id sources. Comp Biochem Phys C 2007; 144: 327−33. doi: 10.1016/j.cbpc.2006.10.006.

73. McWilliams D: Nutrition research on cal-cium homeostasis. II. Freshwater turtles (with recommenda-tions). Int Zoo Yearbook, 2005; 39: 77−85. doi: 10.1111/j.1748-1090.2005. tb00007.x

74. Stancel CF, Dierenfeld ES, Schoknecht PA: Cal-cium and phosphorus supplementation decreases growth, but does not induce pyra-miding, in young red-eared sliders, Trachemys scripta elegans. Zoo Biol 1998; 17: 17–24. doi: 10.1002/(SICI)1098-2361(1998)17:1<17::AID-ZOO2>3.0.CO;2-D.

75. Huang CH, Lin WY, Wu SM: Effect of di-etary calcium and phosphorus supplementa-tion in fish meal-based diets on the growth of soft-shelled turtle Pelodiscus sinensis (Wieg-mann). Aquacult Res 2003; 34: 843−8. doi: 10.1046/j.1365-2109.2003.00891.x

VREDNOTENJE KOMERCIALNIH ŽELV IN KRME ZA ŽELVE

N. Hetényi, E. Andrásofszky

Izvleček: Želve v ujetništvu je potrebno hraniti z naravno krmo, da dosežejo podobno stopnjo rasti kot živali v prosti reji. Na voljo je širok izbor komercialno pripravljene hrane za želve. Prednost hranjenja želv s komercialno hrano je priročnost, vendar podatki o prehranskih potrebah za posamezne vrste želv še niso na voljo. Namen te raziskave je bil analizirati in ovrednotiti komercialne pelete in krmo za želve. V trgovinah za živali smo od 6 podjetij kupili komercialne pelete ($n_{\text{peleti za vodne želve}} = 7$, $n_{\text{peleti za kopenkse želve}} = 7$) za mesojede vodne in rastlinojede kopenske želve ter drugo krmo za vodne želve (liofilizirano goveje srce, posušene vodne nevretenčarje in zamrznjene cele ribe). Zamrznjene cele ribe smo uporabili kot referenčno krmo za mesojede vodne želve. Določili smo kemično sestavo in vsebnost kalcija (Ca) ter fosforja (P). Za ničelno hipotezo smo uporabili T-test enega vzorca s podatki na etiketi in rezultate lastne paralelne analize za surove beljakovine (an gl. *crude proteins, CP*), ekstrakt etra (angl. *ether extract, EE*), surovo vlaknino (angl. *crude fibre, CF*), Ca in P. Oznake nekaterih peletov so bile pomanjkljive, saj so manjkali podatki o hranilnih vrednostih, Ca in P ($n_{\text{peleti za kopenske želve}} = 4$ od 7, $n_{\text{peleti za vodne želve}} = 5$ od 7). Podatki na etiketi so se bistveno razlikovali ($p < 0{,}05$) od rezultatov naše analize pri 13 od 14 vrst peletov. Nobeni peleti za kopenske želve niso v celoti izpolnjevali potreb živali. Zaradi neustreznega razmerja Ca : P smo kot ustrezno določili le eno izmed 7 vrst peletov za vodne želve, zaradi česar nobenih od komercialnih peletov nismo določili kot priporočljivih za glavno ali edino krmo za želve.

Ključne besede: prehrana; peleti; presnovna bolezen kosti; želve