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ORIGINAL ARTICLE

Suitability of day-old chicks as food for captive snakes

K. Arbuckle

84 Quebec Road, Bottesford, Scunthorpe, North Lincolnshire, DN17 2SW, UK

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Correspondence
Kevin Arbuckle, 84 Quebec Road, Bottesford, Scunthorpe, North Lincolnshire DN17 2SW, UK. Tel: +44 7766 945 385; E-mail: 0405118a@student.gla.ac.uk

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Summary

Snakes are increasingly kept by private hobbyists and their numbers in the pet trade are increasing. Since suitable diets are essential for the health, welfare and maintenance of captive animals, objective research is required to improve and evaluate current feeding practices. Unfortunately, the husbandry of reptiles is frequently led by tradition, resulting in methods which are not evidence based. One such occurrence is the widespread belief that day-old chicks (DOCs) are unsuitable as food for captive snakes. Since this assumption has not been systematically assessed, herein I review the evidence in order to provide a more informed basis from which to evaluate the suitability of chicks in relation to rodent prey. Commonly expressed nutritional, ecological and husbandry-related concerns are examined using compilations of previously published data, new data, prior experience and nutrient compositions obtained from the Zootrition™ database. Day-old chicks were compared with two rodent species (mice and rats) since these are the most commonly used alternative prey item. Rodents were clearly the better option only in their 'naturalness', in that mammalian prey species are more frequently represented in natural diets than birds. I conclude that DOCs are a suitable prey item for snakes in captive collections since the available data provide no firm evidence for their avoidance, contrary to popular belief. Many gaps in our knowledge remain that would assist further discussion of this issue, and these are highlighted within. It is pertinent that although these data indicate that DOCs are a viable alternative to rodent prey for captive snakes, they do not necessarily indicate its superiority. In most instances, rodents and DOCs may be regarded as practically equivalent and interchangeable. It is therefore the individual keeper's preference as to which to use, informed in particular circumstances by the information presented herein.

Introduction

The private sector of herpetoculture (the keeping and breeding of reptiles and amphibians) is a relatively recent branch of pet keeping. Furthermore, the reptile trade has increased considerably in the last 10–20 years, and continues to grow (Palazzolo, 1996; Mader and Mader-Weidner, 2006). Snakes have formed an important part of this trade, and some species such as *Pantherophis guttatus* (corn snake) are commonly kept in captivity. Dietary studies to allow evidence-based husbandry are important to promote good nutrition in captive animals. Since adequate nutrition is necessary for optimal growth, maintenance, health and reproduction (Oftedal and Allen, 1996), failure to provide suitable diets can negatively impact the husbandry, reproduction and welfare of captive animals. Research on the nutrition of exotic animals suffers from a taxonomic bias towards mammals (Arbuckle, 2009), a situation also found in other areas of biology (Bonnet et al., 2002; Anderson et al., 2008; Hosey et al., 2009). The most basic element of captive animal nutrition is the question of what to feed, and commercially available whole vertebrate prey (excluding fish) are limited to a very few species.

There has been a great deal of debate within the herpetocultural community regarding the suitability of day-old chicks (DOCs) as a staple dietary item for captive snakes. Many criticisms are often repeated concerning the practice of feeding DOCs as compared with rodent prey. These include a poor nutrient composition, that they represent a more 'unnatural' prey item, or that snakes get 'addicted' to DOCs and feeding other prey items subsequently becomes difficult. Of these, claims that DOCs have a low nutritional value are particularly common, and are frequently repeated in the literature (e.g. Bruins, 2006). There has been little previous research which can be used to test the hypothesis that DOCs are a poor staple food for snakes, and that which has been conducted focuses on the nutritional suitability, providing data for various prey items but not evaluated them against one another (e.g. Donoghue and Langenberg, 1994; Donoghue, 1998; Dierenfeld et al., 2002).

Various factors contribute to the suitability of a prey item for a predator, including nutrient composition, palatability, and ease of procurement and consumption. Furthermore, in captivity other factors such as the cost, availability, ease of storage and the similarity of the food item to the natural diet may be important (though the latter is likely a poorly justified concern of keepers rather than a real husbandry concern). Cooper (1990) summarized these factors, and also noted quality control (requirement for prey free of pathogens) and an acceptability factor (the likelihood that the animal will accept the prey, influenced by presentation and characteristics of the prey such as colour and scent) as important considerations. Consequently, this paper aims to evaluate and discuss the suitability of DOCs as a staple prey item for captive snakes, taking account of the concerns noted above.

Methods

The 'naturalness' of DOCs compared to rodents was assessed using dietary records from the literature. Diets were divided into higher-level taxa for analysis: mammals, birds, reptiles, amphibians, fish and invertebrates. This approach allows diverse diets from broad array of species to be compared, though it also imposes limitations since combining prey species into large groups can reduce the level of sensitivity for the detection of differences between snake species.

Since many reports of natural diets do not present quantitative data of the incidence of the various prey animals, the occurrence of mammals and birds in snake diets were measured in the qualitative literature. While this method is incapable of distinguishing between differences in the frequency or importance of a given prey item, it serves to highlight instances where a given prey item is not recorded in the diet.

Only a selection of the available data on natural prey items was analysed, partly because of the vast amount of information available (it would be unfeasible to provide a comprehensive review here) and also because comparatively few species of snake are frequently and widely kept in captivity. As a result, priority was given to those snake species most commonly kept in captive collections. For the purposes of this paper, captive collections are considered to be those of 'private hobbyists' or 'pet keepers', in contrast to organizations such as zoos and research facilities which regularly house a broader array of species.

For husbandry issues (e.g. DOCs resulting in reluctance of snakes to subsequently feed on other prey types), much of the discussion relies on the author's own husbandry experience with snakes, as well as observations of other keeper's practices. This is in lieu of relevant experimental data such as on habituation to prey types, which would assist in clarifying the situation. One aspect where data are easily collected is the question of cost. The price of mice, rats and DOCs was recorded from a sample of 20 retailers that provide prices for frozen vertebrate prey online. This sample included only those retailers providing prices in GBP (£) to facilitate comparison. Most retailers offered a lower cost per individual when buying in bulk so in order to incorporate this variation the highest and lowest price offered by a given retailer were noted separately and included as distinct groupings in the analysis.

Nutrient composition (proximates and minerals) of three prey items (DOCs, mice and rats) were taken from the software programme Zootrition™ and compared. In some cases, more than one entry was available for a given prey item, due to additional data from sources other than the original database. Since the entries were variable in the information they provided, selection was based on those that would allow the best comparison, such that the broadest overlap between all three prey items was obtained. However, this decision resulted in no data for energy values, which are of importance since energy is amongst the most common nutritional concerns in discussions of DOCs as food. Therefore, in order to allow an evaluation of energy content between DOCs, mice and rats, data were taken from Dierenfeld et al. (2002).

Mice and rats were used for comparison with DOCs as they are the most commonly fed rodents in captive snake diets. The nutritional quality of DOCs is not necessarily evaluated in absolute terms, but rather compared to commonly fed rodent prey. Given that rodents are generally accepted as providing adequate nutrition for captive snakes, and few diet-related health problems occur when feeding mice or rats in suitable quantities, this comparative approach was deemed appropriate. Because the composition of prey may show ontogenetic change, size classes of the prey items were chosen that would be a realistic alternative to DOCs. For example, fully grown rats were not used in favour of younger rats that could be fed to snakes capable of consuming DOCs.

All statistical tests were performed and all graphs were prepared using MINITAB™ Version 15.1.2. The nutrient comparisons presented herein are based on single values obtained from Zootrition™. Since the assays used to establish these values are conducted in triplicate, they are more robust than the single-number output would suggest. However, the individual data for each of the replicates are not provided on the database so statistical analysis of the nutrient data is not possible.

Results

Nutrient composition of DOCs, mice and rats is presented in Table 1. Comparison between these three species reveals a general similarity in their nutrient content. Furthermore, DOCs generally compare favourably with both rodents and recommended levels published in Allen and Oftedal (1994). Only for manganese content did DOCs fail to meet recommended levels.

Across snake species, mammals form approximately 50% of an average diet, but reptiles and birds also represented commonly eaten taxa (Table 2). Chi-square tests revealed significant variation between prey taxa in the quantity consumed ($X^2 = 4850.11$, $p < 0.0005$), and prey can be grouped into three frequency categories based on overlapping 95% confidence intervals (Fig. 1). These categories are (in decreasing frequency) Type I (mammals), Type II (birds and reptiles) and Type III (amphibians, fish and invertebrates). Interspecific variation in the natural diet is also evident (Table 2), highlighting the limitations of examining the diet of an 'average' snake. Analysis of the qualitative diet composition shows a trend for more species to include mammals in the diet than birds (Table 3), though this difference is not statistically significant ($X^2 = 0.94$, $p = 0.332$).

The mean cost of DOCs was cheaper than mice or rats in my sample by almost an order of magnitude

Nutrient	DOC	Mouse	Rat	Recommended minimum levels
% Water	77 (72–77)	71 (57–81)	70 (70–72)	
% Dry matter	23 (23–28)	29 (19–43)	30 (28–30)	
% Crude protein	68 (60–74)	61 (53–64)	58 (56–60)	30–50
% Crude fat	21 (17–28)	28 (17–47)	27 (26–28)	
% NDF	28	13	15	
Energy (kcal/g)	5.8	5.3	5.6	
% Ash	7 (6–8)	9 (8–12)	9 (9–15)	
% Ca	2.5 (0.8–2.5)	4.8 (1.2–4.8)	8.7 (1.0–8.7)	0.8–1.0
% Mg	0.2 (0.1–0.2)	0.4 (0.1–0.4)	0.4 (0.1–0.4)	0.04
% P	1.8 (0.5–1.8)	4.3 (1.2–4.3)	6.0 (0.8–6.0)	0.5–0.9
% K	1.7 (0.7–1.7)	2.9 (0.8–2.9)	2.9	0.4–0.6
% Na	1.9 (0.7–1.9)	1.2 (0.4–1.2)	1.3	0.2
% S	2.4	2.3	1.9	
Cu (mg/kg)	15 (3–15)	15 (6–19)	12 (9–12)	5–8
Fe (mg/kg)	155 (32–512)	168 (133–247)	179 (67–179)	60–80
Mn (mg/kg)	2 (0–10)	18 (0–18)	25 (9–25)	5
Zn (mg/kg)	58 (30–97)	80 (49–89)	94 (37–94)	50
Ca:P	1.4 (1.3–1.7)	1.1 (1.1–2.0)	1.5 (1.3–1.5)	1–2

Table 1 Nutrient composition of vertebrate prey. Main values are those obtained from the Zootrition™ database for this study. Values in parentheses, where available, are a range given by including data summarized in Nijboer et al. (2009) in order to give some indication of the variation possible. Recommended minimum levels are from Allen and Oftedal (1994)

Table 2 Composition of natural diets of some commonly kept snake species. Taxonomic categories include all life stages

	Taxonomic composition of diet						
Snake species	Mammals (%)	Birds (%)	Reptiles (%)	Amphibians (%)	Fish (%)	Invertebrates (%)	Reference
Aspidites melanocephalus	6	2	92				Shine and Slip (1990)
Aspidites ramsayi	48	4	48				Shine (1991)
Boa constrictor	25	40	35				Quick et al. (2005)
Bogertophis subocularis	78	17	5				Rodríguez-Robles (1999)
Boiga cyanea		86	14				Greene (1989)
Boiga dendrophila	32	25	41	2			Greene (1989)
Broghammerus reticulatus	91	9					Shine et al. (1999b)
Candoia aspera	17		78	5			Harlow and Shine (1992)
Charina bottae	69	8	22			1	Rodríguez-Robles et al. (1999)
Corallus caninus	91		9				Stafford and Henderson (1996)
Corallus hortulanus	59	38	3				Henderson (2002)
Elaphe quatuorlineata	65	28	7				Filippi et al. (2005)
Lampropeltis calligaster	81	5	14				Fitch (1999)
Lampropeltis getula	27	12	60	<1		<1	Rodríguez-Robles (1999)
Lampropeltis triangulum	23		77				Fitch and Fleet (1970)
Lampropeltis triangulum	47	16	26			11	Uhler et al. (1939)
Lampropeltis triangulum		26	74				Rodriguez and Drummond (2000)
Lampropeltis zonata	3	12	85				Rodríguez-Robles (1999)
Lampropeltis zonata	20	7	73				Greene and Rodríguez-Robles (2003)
Lamprophis fuliginosus	44	10	41	5			Akani et al. (2008)
Lamprophis lineatus	14	3	57	26			Akani et al. (2008)
Liasis children	36	5	26	33			Shine and Slip (1990)
Liasis maculosus	64	2	28	6			Shine (1991)
Morelia spilota	80	5	14	1			Shine (1991)
Morelia spilota mcdowelli	35	64	1				Fearn et al. (2001)
Morelia spilota spilota	86	9	5				Slip and Shine (1988)
Morelia spilota variegata	72	25	3				Shine and Fitzgerald (1996)
Morelia spilota variegata	72	9	17	2			Shine and Slip (1990)
Morelia viridis	44		56				Shine and Slip (1990)
Pantherophis guttatus	64	22	10	4			Rodríguez-Robles (1999)
Pantherophis obsoletus	73	20	3	4			Fitch (1963)
Pantherophis obsoletus	65	35	<1				Stickel et al. (1980)
Pantherophis obsoletus	50	43	3	2		2	Rodríguez-Robles (1999)
Pantherophis obsoletus	47	53					Barbour (1950)
Pituophis catenifer	81	15	4				Rodríguez-Robles (2002)
Pituophis catenifer	77	18	4	<1		<1	Rodríguez-Robles (1998)
Pituophis melanoleucus	53	21	26				Rodríguez-Robles (1999)
Python brongersmai	95	5					Shine et al. (1999a)
Python curtus	100						Shine et al. (1999a)
Python molurus bivittatus	70	28	2				Snow et al. (2007)
Python sebae	93		7				Luiselli et al. (2001)
Thamnophis sauritus				90	5	5	Carpenter (1952)
Thamnophis sirtalis	1			15	1	83	Carpenter (1952)
Average across species	51	17	25	5	<1	2	This study

(Fig. 2). The price of DOCs ranged from £0.04 to £0.25, which compares favourably to rats (£0.41–£1.80) and mice (£0.50–£1.50). These price ranges include the variation between retailers in addition to that produced as a result of bulk-buy offers. Note that even the most expensive DOCs are still cheaper than the lowest priced rodents.

Discussion

Nutritional considerations

Despite concerns over the nutritional value of DOCs as compared to rodent prey, Donoghue (1998) reported no clinical issues resulting from feeding DOCs. However, in other papers, Donoghue (2006;

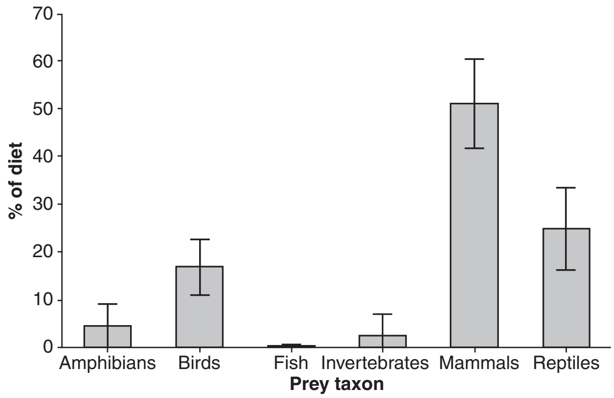

Fig. 1 Frequency of prey taxa in the diet of a generalized snake. Data from Table 2. Error bars are 95% confidence intervals.

Donoghue and Langenberg, 1994) stated a concern that they, along with other neonatal vertebrate prey such as 'pinkie' mice or rats, may contain low calcium levels and so lead to deficiency. Data presented here (Table 1) agree with previous findings of low calcium levels in DOCs in relation to rodents. Given this finding, concern may be warranted over the risk of calcium deficiency resulting from feeding DOCs as a staple food. However, although calcium requirements for most reptiles are unknown, Allen and Oftedal (1994) suggest (in part based on mammalian values) a minimum requirement of 0.8–1% dry matter (DM), which is met in DOCs (Table 1). Though calcium levels are relatively low in DOCs their calcium to phosphorus ratio (Ca:P) is comparable to rodents. This is due to the lower phosphorus levels in DOCs. Furthermore, the Ca:P (1.35:1) is suitable since a ratio of approximately 1–2:1 is adequate to allow sufficient absorption of calcium.

Although concerns regarding dietary calcium are the most commonly expressed in the literature, many private keepers regard DOCs as having a high water content or providing little energy, and these comments are frequently heard when discussing their nutritional value (K. Arbuckle, personal observation). Both these aspects, in addition to other nutrients, can be compared between DOCs and rodents, and an evaluation of their overall nutritional value can be made.

Proximate composition of DOCs compares favourably with rodents (Table 1), achieving either better or intermediate values as measured against mice and rats for crude protein, crude fat, and neutral detergent fibre (NDF). In terms of protein, it is noted that quality is at least as important as quantity. However, as protein quality is uniformly high between vertebrates (Klasing, 1998), no further discussion of this measure of carnivorous animal nutrition is given here. Ash content is lower than that of rodents, but not appreciably so. While it is true that DOCs contain a higher proportion of water there does not appear to be a major difference and so the observed variation is unlikely to represent grounds for avoidance of DOCs as a food item. In contrast to concerns expressed by many private keepers, energy values were actually higher in DOCs than either mice or rats, though the difference is small (Table 1). Carnivorous reptiles have been reported to assimilate approximately 90% of the energy present in vertebrate prey (Pough et al., 2004), and when this is taken into consideration the differences are further reduced (assimilated energy values for DOCs, mice and rats would be 5.22, 4.73 and 5.00 kcal/g respectively). Nevertheless, even if no statistical difference exists in energy content, DOCs still represent an equally good energy source as rodents.

Suitable data for comparison on the vitamin content of DOCs and rodents is lacking, but as hypovitaminoses are rarely reported in snakes, and the yolk of chicks contains high levels of carotenoids and presumably other vitamins and their precursors, they are unlikely to present a problem.

Excepting calcium and phosphorus (discussed above), little has been reported regarding comparison of mineral content between prey items. Some information was provided by Dierenfeld et al. (2002), but the authors did not indicate the age or size class of rats used, and chickens were listed either as adult or juvenile, and so DOCs do not seem to have been included in the relevant table. This may be particularly important as composition can change ontogenetically, and the presence of the yolk sac and nutrients contained therein may substantially alter the composition of DOCs over older stages. Table 1 shows higher levels of sodium and sulphur, intermediate levels of copper, and lower levels of magnesium, potassium, iron, manganese and zinc in DOCs as compared with mice and rats. It should be noted, however, that of the minerals present in lesser amounts in DOCs than rodents, only manganese is below the suggested minimum requirements (Allen and Oftedal, 1994).

Do the low manganese levels in DOCs represent a risk to the health of captive snakes? No cases or reports of manganese deficiency in snakes (or any other reptiles) appear to have been published. Furthermore, common symptoms of manganese deficiency such as reduced growth and skeletal abnormalities (McDowell, 2003) are also rarely reported. In addition, two American rat snakes (*Pantherophis*

Table 3 Presence of birds and mammals in the natural diets of some commonly kept snake species. When more than one reference gave the same information, the most recent was preferred for citation. This was deemed acceptable as the presence/absence of data is not additive, so duplication of data is not required. X = present, – = absent

Snake species	Mammals	Birds	Reference
Boa constrictor	X	X	Guyer and Donnelly (2005)
Bogertophis subocularis	X	X	Ernst and Ernst (2003)
Boiga dendrophila	X	X	Stuebing and Inger (1999)
Broghammerus reticulatus	X	X	Stuebing and Inger (1999)
Elaphe quatuorlineata	X	X	Arnold and Ovenden (2002)
Epicrates cenchria	X	X	Boos (2001)
Eryx colubrinus	X	X	Spawls et al. (2004)
Eryx jaculus	X	–	Rodríguez-Robles et al. (1999)
Eryx jaculus	X	X	Arnold and Ovenden (2002)
Heterodon nasicus	X	–	Russell and Bauer (2000)
Heterodon nasicus	X	X	Ernst and Ernst (2003)
Lampropeltis alterna	–	X	Tennant (2003)
Lampropeltis alterna	X	–	Ernst and Ernst (2003)
Lampropeltis calligaster	X	–	Linzey and Clifford (2002)
Lampropeltis calligaster	X	X	Ernst and Ernst (2003)
Lampropeltis getula	–	–	Hulse et al. (2001)
Lampropeltis getula	X	X	Ernst and Ernst (2003)
Lampropeltis triangulum	X	–	Werler and Dixon (2000)
Lampropeltis triangulum	X	X	Ernst and Ernst (2003)
Lamprophis fuliginosus	X	X	Spawls et al. (2004)
Natrix natrix	X	X	Arnold and Ovenden (2002)
Pantherophis emoryi	X	X	Ernst and Ernst (2003)
Pantherophis guttatus	X	–	Mount (1996)
Pantherophis guttatus	X	X	Ernst and Ernst (2003)
Pantherophis obsoletus	X	X	Ernst and Ernst (2003)
Pantherophis spiloides	X	X	Mount (1996)
Pituophis catenifer	X	X	Ernst and Ernst (2003)
Pituophis melanoleucus	X	X	Ernst and Ernst (2003)
Python regius	X	X	Spawls et al. (2004)
Python sebae	X	X	Spawls et al. (2004)
Rhinechis scalaris	X	X	Arnold and Ovenden (2002)
Thamnophis elegans	X	X	Ernst and Ernst (2003)
Thamnophis marcianus	X	–	Ernst and Ernst (2003)
Thamnophis radix	X	–	Tennant (2003)
Thamnophis radix	–	–	Harding (1997)
Thamnophis radix	X	X	Ernst and Ernst (2003)
Thamnophis sauritus	X	X	Harding (1997)
Thamnophis sauritus	–	–	Ernst and Ernst (2003)
Thamnophis sirtalis	X	–	Mount (1996)
Thamnophis sirtalis	X	X	Ernst and Ernst (2003)
Zamenis longissimus	X	X	Arnold and Ovenden (2002)
Zamenis situla	X	X	Arnold and Ovenden (2002)
Total	90%	71%	This study

obsoletus complex) maintained by the author almost solely on DOCs since the size of the snakes permitted their consumption both reached normal adult length and mass, exhibited normal growth rates, and have consistently shown good body condition.

It may be that the manganese values reported herein are abnormally low for DOCs, but it is perhaps more likely that established requirements for mammals are not representative for reptiles, with lower amounts needed in the latter. Certainly, Dierenfeld et al. (2002) gives mineral composition for two reptile species (both lizards) and the level of manganese is more similar to the value presented here for DOCs than rodents, though still slightly higher than the former. This is consistent with the idea that the requirements for reptiles are comparatively low. Further, the range of values in Table 1 indicates that manganese levels in DOCs may be higher than obtained for this study. As with many nutrients, manganese requirements (even for mammals) are based on studies of a handful of species, mostly domesticated animals of economic importance (such as farm animals or more traditional pets). As such, it is not overly surprising that even

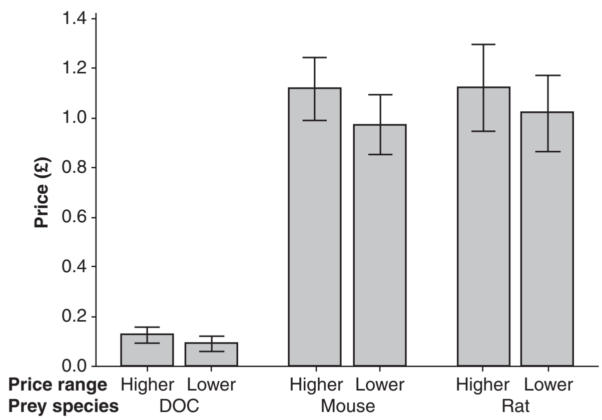

Fig. 2 Retail cost of vertebrate prey. Some retailers offer bulk-buy deals, so more than one price for a given prey species at one retailer is possible, the highest and lowest prices for each retailer are displayed. Error bars are 95% confidence intervals. See text for further details.

mammals such as exotic ruminants have shown no signs of manganese deficiency at lower dietary levels than requirements for cattle and sheep suggest (Arnhold et al., 2000). This finding further highlights the need for nutrient requirements to be determined for a greater number of species than that are presently available, particularly for trace minerals, which are frequently omitted from nutritional studies, especially of exotic species.

The data presented herein do not support nutritional concerns over the use of DOCs as a staple food for snakes. While the nutrient compositions given (Table 1) provide evidence to the contrary (i.e. that DOCs are a suitable prey item) for most nutrients, this is not the case for manganese (which fails to meet recommendations) and vitamins (as no data were available). Despite this, it is unlikely that these nutrients are deficient in captive snakes fed DOCs, as discussed above. Therefore, nutritionally there are no firm grounds for avoidance of DOCs as a prey item.

Ecological considerations

Kawata (2008) argues convincingly that it is not feasible to provide a truly natural diet to animals in captivity, and that even if this were a realistic objective it does not necessarily follow that it is the best feeding strategy to use. While many may disagree with the latter statement, the truth and accuracy of the word 'natural' when applied to captive diets for wild animals fails to stand up to scrutiny. Despite this, many keepers of captive snakes still believe that they are providing a natural diet for their animals, indeed many take pride in this assertion. One criticism of DOCs has used this idea to argue that rodents are a more natural prey than chicks. Despite this, no data have been compiled in a format conducive to making comparisons to test this contention.

Assuming a captive diet to be more natural if the broad taxonomic categories of prey are more similar to those consumed in the wild, Tables 2 and 3 present evidence that mammalian prey such as rodents are indeed more natural than birds. Table 2 shows that although much variation exists between species, when data from different species are combined birds are less often consumed than both mammals and reptiles, and the quantity is only a third that for mammals.

Using this categories of preferred foods described herein (Fig. 1), I found that despite the observation that birds are represented only 31% as frequently as mammals in this sample, they are in the second most commonly consumed category. Therefore, they cannot be discounted as an unimportant prey item in a generalized snake (using data for species commonly kept in captivity).

Since many reported diets do not include quantitative data, the occurrence (presence or absence of a prey type in the diet) can also be used to give an indication of the distribution of prey types in the diet. Although more species include mammals in the diet than birds, this difference was not statistically significant. However, this does not preclude the possibility that the result is biologically significant and the general trend of the data is towards more frequent occurrence of mammalian prey than birds. Similarly, in a summary of records from the literature, Mushinsky (1987) lists 8 of 14 commonly kept species with mammals as their primary prey, compared to five birds and one with both birds and mammals listed.

Regarding data on the taxonomic composition of diets, some caveats must be considered when it is evaluated. Habitat can impact on observed frequencies such that frequencies of certain items may vary with level of disturbance – a factor rarely reported in diet studies. For instance, frequency of birds consumed by *Hierophis viridiflavus* and *Zamenis longissimus* has been observed to decrease with increasing habitat alteration (Capizzi et al., 2008). Furthermore, although Luiselli et al. (2001) found no birds in the diet of *Python sebae* living in natural habitats, poultry formed 37.5% of their diet in suburban habitats. These data may suggest that snakes are opportunistic predators that will prey on birds where they are both abundant and relatively easy to capture, such as around human habitation.

The idea that birds are less common than mammals as prey of wild snakes may also be related to the relative difficulty of catching birds. Not only are birds more able to escape from snakes as a result of flight, but nests and roosting perches are not often as enclosed as a mammal burrow, within which the latter may be easily trapped. The use of chemosensory cues by many snakes while foraging may also bias prey encounters towards mammals, as their scent trails are more likely to be consistent and easily followed than those of birds, who may interrupt trails with flight. Finally, habitat segregation could also result in encounters with mammals being more frequent than with birds. Few of the species in Tables 2 and 3 exhibit a high level of arboreality, and therefore chance encounters with avian prey may be limited for terrestrial predators. It is notable that arboreal snakes such as those in the genus *Boiga* have proved to be extremely effective predators on birds (*Boiga irregularis*; Savidge, 1987), and may even have toxins in their venom specific to avian prey (Mackessy et al., 2006; Pawlak et al., 2006). The latter indicates a long evolutionary history of predation on birds.

Data on palatability of DOCs compared with rodents are lacking, but captive snakes are generally considered to readily accept the former. Combined with the inclusion of at least some avian prey in most wild snake diets so far studied, the available evidence suggests that palatability is unlikely to be an important issue. Furthermore, many reports exist of predation on domestic chickens by snakes that were found living in close proximity to humans (e.g. Fritts and McCoid, 1991; Luiselli et al., 2001).

Based on perceived 'naturalness' of prey, it could be argued that rodents should be preferred over chicks for most common captive species. Possible exceptions to this are *Boa constrictor*, *Boiga cyanea*, *Morelia spilota mcdowelli* and *P. obsoletus*, which consume more avian prey (Table 2). It is notable that all four of these taxa are arboreal. However, this conclusion is fraught with uncertainty both over the validity of the 'natural is better' belief and the degree to which studies of natural diet are influenced by encounter rate, and therefore the degree to which they reflect prey choice by the snake. As a result, there is no clear ecological justification for rejecting DOCs as a staple diet for captive snakes, despite mammals being more frequent than birds in wild diets.

Husbandry considerations

The only common criticism expressed in this category is that DOCs are 'addictive' in that when snakes are fed with chicks regularly, switching to other prey becomes difficult. As there is no reason to suspect true addiction (*sensu* Robinson and Berridge, 2003), it is perhaps more accurate to use the term stubbornness to describe this phenomenon. Data are not available to empirically test for strong habituation to DOCs in snakes or differences in habituation between prey species. Informal observations, however, do support the hypothesis that snakes fed on DOCs can stubbornly refuse to accept other prey. Therefore, the question that must be asked in this case is whether this represents a substantial disadvantage to captive husbandry.

A repetitious diet can result in a refusal to feed in captive lizards and tortoises, but this has not been reported in snakes (Funk, 2006). In fact, many keepers feed their snakes with one prey species only, except for when snakes are young and size constraints may require different, smaller prey species. Subsequently, providing the prey is nutritionally suitable there is often little or no need to switch between prey species. Since DOCs represent a nutritionally adequate prey species (see *Nutritional considerations*), it is unlikely that a stubbornness to switch diet would cause problems.

Indeed, DOCs appear to have a high acceptability factor in snakes (as defined in Cooper, 1990), possibly higher than rodents. Again, no data is available to confirm this, but few snakes seem to accept rodents and refuse DOCs in captivity. This potentially carries an advantage as a new captive may be more likely to begin feeding on DOCs than rodents if the former have a higher acceptability factor. This may have synergistic benefits with the stubbornness discussed above as it may be that snakes are easier both to start and maintain feeding if DOCs are used.

Although the issues discussed above are commonly used as criticisms against the use of DOCs as a staple food, there are other factors that are important in the selection of food for captive animals. These will also be discussed here to provide a broader overview of husbandry considerations of the choice of prey for captive snakes.

The first of these issues is cost. The average cost of DOCs was substantially cheaper than mice or rats (Fig. 2). Assuming the sample of stores providing prices online used in this study is representative of retailers more generally, rodent prey (mice and rats are similarly priced) are approximately 10 times more expensive than chicks (Fig. 2). This clearly shows the financial benefits conferred by using DOCs over rodents.

Storage is another general consideration, however, as all vertebrate prey are usually kept frozen and thawed when required there are no storage issues specific to DOCs. As regards availability, 18 of the retailers in the sample used above for price comparisons supplied all three of the prey species discussed in this paper. The remaining two retailers offered both mice and rats for sale, but not DOCs. As a result, the evidence indicates that availability to private keepers differs little between rodents and DOCs.

Quality control is important to ensure that prey is kept free from pathogens. Chicks have been recognized as frequently carrying certain salmonellae serotypes, some of which have been found in captive snakes (Onderka and Finlayson, 1985). It is important to understand that salmonellae are a normal part of the gut flora of most captive reptiles, and are by no means restricted to individuals fed chicks (Mitchell and Shane, 2001). Nevertheless, a few of these serotypes are pathogenic in snakes and may also carry a zoonotic risk. It should be stressed that reptile-associated salmonellosis in humans is still a relatively rare occurrence, despite the large number of people in direct or indirect contact with reptiles (Mitchell and Shane, 2001) and so the public health significance of this is minimal. In addition, most reports of reptile-associated salmonellosis in humans have been linked to turtles (Chiodini and Sundberg, 1981; Mitchell and Shane, 2001), with other reptiles such as snakes less commonly implicated. Fatal infections have also been reported in reptiles where the origin of the pathogen was mice (Hetzel et al., 2003).

Published reports of pathogens in whole prey items are few, though DOCs are more commonly considered to carry pathogenic organisms (to reptiles) than rodents. However, this could be a consequence of poultry also being a human food, and so more investigations may be targeted at pathogens from chickens than mice or rats. A comprehensive microbiological study of vertebrates commonly used as prey for captive animals is needed for proper evaluation of any risks. Until the results of such an investigation are available, we must consider that all meat, including whole prey, has the potential to carry pathogens that may infect the animals to which they are fed (Crissey et al., 2001).

Rodents do not appear to be superior to DOCs in any of the husbandry-related issues discussed above. Therefore, there is no basis for rejection of DOCs in favour of rodents in any of the aspects covered in this section.

Conclusions and general discussion

The results of this study are consistent with the hypothesis that DOCs represent a suitable staple diet for captive snakes. However, various points have been highlighted where further data are necessary for clarification. Day-old chicks appear to be a nutritionally adequate prey item and present no clear problems for the husbandry of snakes. Only one concern is supported in this paper: rodents are a more natural prey item for non-arboreal snake species than DOCs, at least using the crude method of comparing the broad taxonomic categories of mammals and birds in wild diets.

It should be noted that the results generally indicate an equivalency of the three prey species used here (with few exceptions), not a superiority of DOCs over rodents. This suggests that the best food to use for captive snakes is dependent on situation-specific factors such as keeper preference and species or individual preference of the snake in question. The variation observed between the prey species here, though mostly slight, may also inform choices for a given set of circumstances. Therefore, while some generalized statements can be made, each situation should be evaluated on its own merit using in part the data presented here. Further, the information and suggestions in this paper in part assume snakes of a size where they will consume few individual prey items per meal (the specific size will vary by species). This is an important consideration since the results are irrelevant to a snake too small to consume DOCs, and particularly large species such as *Python molurus bivittatus* (Burmese python) will reach a size where adult rats or rabbits are more suitable and may be more cost efficient than the large number of DOCs per meal that would be required.

The husbandry of exotic animals has a long history of doing things by tradition. Methods or supposed 'best practices' become established without proper evaluation, often justified simply because 'it has always been done that way' or for otherwise unknown or poorly substantiated reasons. This 'folklore husbandry' is prevalent in the reptile trade, and it is therefore important for research to evaluate such claims and provide an evidence-base for high quality husbandry. Future studies should focus on eliminating the gaps in our knowledge highlighted herein, in addition to evaluating other folklore husbandry claims.

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