Evaluation of a balanced fresh paste diet for maintenance of captive neotropical rattlesnakes used for venom production

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Objective—To evaluate efficacy of a balanced fresh paste diet for maintenance of captive neotropical rattlesnakes used for venom production.

Design—Controlled clinical trial.

Animals—40 healthy neotropical rattlesnakes.

Procedure—Rattlesnakes were force-fed once per week (10% of body weight) for 19 weeks; 20 control snakes received dead mice, whereas 20 test snakes received a balanced fresh paste diet. Ecdysis rates were calculated, and body weight was recorded weekly. After 19 weeks, venom was extracted and analyzed.

Results—Sickness or deaths were not observed; weight loss during ecdysis and weight gain overall were similar between groups. Snakes fed the balanced fresh paste diet had similar ecdysis frequency, venom potency, and protein concentration in venom as did snakes fed mice.

Conclusions and Clinical Relevance—Results suggest that a balanced fresh paste diet has sufficient nutritional value to avoid weight loss and death and does not adversely affect venom quality in captive neotropical rattlesnakes. (J Am Vet Med Assoc 2001;218:912-914)

One of the greatest difficulties in raising snakes in captivity is feeding them. The offered food must supply the snakes’ nutritional needs, be free of contamination by pathogenic microorganisms and parasites, and, ideally, be spontaneously accepted.

Refusal of food for long periods is commonly observed in snakes as they adjust to captivity; when they are sick or receiving treatment, when they are stressed (especially because of harvesting venom), and during pregnancy. During pregnancy, some snakes may refuse food for 2 to 9 months.\(^2\) In addition, several species of snakes have a well-defined seasonal or circadian pattern in appetite.\(^3,4\) Low food acceptance that does not cause medical problems for healthy snakes is observed in many neotropical species during the coldest period of the year, whereas snakes in captivity that have not accumulated sufficient fat deposits may need to be force-fed during these periods.

Some snakes fail to adapt to captivity and never begin to feed spontaneously.\(^5\) Moreover, some newborn snakes need to be hand-fed until they are able to feed by themselves.\(^5,10\) Lack of feeding will eventually cause generalized weakness, dehydration, and death at a rate dependent upon the age and previous nutritional status of the snake.

The maladaptation syndrome\(^1\) may be responsible for the death of 80% of snakes during the first 2 years of captivity,\(^6\) because this syndrome may lead to anorexia, long periods of food refusal, emaciation, tissue fragility, and infections by pathogenic or even commensal microorganisms.

Although snakes may survive up to 2 years under suboptimal conditions, depletion of body energy stores and essential nutrients causes increased susceptibility to secondary infections and nutritional diseases.\(^5,6,10\) Many will not adapt to captivity and will die if they are not force-fed.\(^11\)

Snakes from institutions where venom is collected every 28 days are generally fed only 7 days after collection, and food acceptance varies.\(^5\) Because the collection procedure can be stressful, a long period of food refusal may cause serious damage to the health of these snakes, because survival rates in captivity depend partially upon energy intake.

Crotalus durissus, the neotropical rattlesnake, is discontinuously distributed from Mexico to Argentina.\(^12,13\) In Brazil, C. durissus is observed in all states except Acre and Espírito Santo.\(^12\) It is commonly found in open areas of dry rocky regions. Brushy savannas (cerrados) and pastures are its preferred habitat. Crotalus durissus was responsible for 6.2% of snakebites from 1990 to 1993 in Brazil;\(^14\) therefore, this species has been widely raised for the production of antiserum.

The purpose of the study reported here was to evaluate efficacy of a balanced fresh paste diet for maintenance of captive neotropical rattlesnakes used for venom production.

Materials and Methods

Snakes and diets—Our study used 40 C. durissus that weighed from 57.6 to 245.3 g; all snakes were born at the Instituto de Biologia do Exército in 1998. Snakes were allocated into 2 equal groups on the basis of similar body weights and sex; the control group had 10 males and 10 females, and the test group had 9 males and 11 females.

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The experiment lasted for 19 weeks. Snakes were force-fed weekly with food that weighed 10% of each snake's body weight. This percentage was determined on the basis of results of field studies, which indicated that rattlesnakes consume 25% of their body weight in prey per month.4 Control snakes were force-fed dead suckling mice (Mus musculus), whereas test snakes were force-fed a balanced fresh paste diet administered with the aid of a lubricated gastric catheter.

The fresh paste diet was prepared by homogenizing beef, liver, eggs, glucose (50 g/kg of beef), and a vitamin-mineral supplement (10 g/kg of beef). Ratio of beef to liver content by weight was approximately 2:1, and eggs were added to the mixture as needed to produce a paste consistency (approx 12 eggs/kg of beef). Physicochemical analysis of the fresh paste diet revealed the following composition (mean values of 3 analyses): protein, 16.25%; total minerals, 1.79%; phosphorus, 190 mg/dl; calcium, 380 mg/dl; iron, 62.8 µg/g; cobalt, 1.81 µg/g; manganese, 1.18 µg/g; zinc, 18.53 µg/g; copper, 45.2 µg/g.

Snakes were housed in individual polypropylene boxes that were 30 cm long, 20 cm wide, and 18 cm deep. Each box had autoclaved pine scrap for bedding, a stone to aid in sloughing of the skin, and a plastic bowl that always contained water. The boxes were kept in a room with natural light, temperature of 28.0 ± 3.0 °C, and no humidity control.

**Ecdysis, body weight, and analysis of venom—**Ecdysis rates for each month were calculated by dividing the number of ecdysis events per month by the number of snakes in each group. Data regarding body weight and ecdysis were recorded weekly.

After diets were fed for 19 weeks, venom was extracted from all snakes in each group, pooled per group, and analyzed. Concentration of protein was measured by use of the Folin-Lowry method.5,6 Median lethal dose (LD₅₀) of venom was determined, using 5 dilutions of each venom pool inoculated IP in 5 mice (body weight, 18 to 22 g) for each dilution.7 Mice were observed for 48 hours, and the number of deaths was recorded.

**Statistical analyses—**Differences between diet groups for weight gain or loss were determined by use of ANCOVA,7 using days after start of experiment as a covariant and nesting the logarithmically transformed values of the weights of individual snakes within each group. A Student t-test was used to compare ecdysis rates between groups. Differences between groups for protein content of venom and LD₅₀ were determined. Differences between groups were considered significant at P < 0.05.

**Results**

**Ecdysis—**Mean frequency of shedding was similar in both groups (1.80 events/mo/snake in the control group and 1.76 in the test group). Difference between groups was not significant.

**Body weight—**All snakes lost body weight during the weeks when ecdysis occurred; mean ± SEM body weight loss in the test group was 5.5 ± 0.7% and in the control group was 4.6 ± 0.7%; these values were not significantly different. Snakes in both groups had similar overall linear weight gain during the trial. For the control group, initial and final body weights (mean ± SD) were 142.2 ± 47.29 g and 315.09 ± 103.97 g, respectively. For the test group, initial and final body weights were 144.38 ± 40.94 g and 292.09 ± 87.58 g, respectively. Statistical difference between diet groups was not detected.

**Venom—**Protein concentration in venom was 287 mg/ml in control snakes and 257 mg/ml in test snakes; these values were not significantly different. The LD₅₀ for venom of control snakes was 1.66 mg/ml and for test snakes was 1.55 mg/ml; these values were also not significantly different. Both results were within the range of toxicity cited for venom from *C. durissus*.8,9

**Discussion**

Force-feeding is often necessary because captive snakes may stop feeding because of age (some young snakes do not learn to eat by themselves), sickness, shedding period, low temperature, stress, pregnancy, mating season (adult males), recent introduction to captivity, and collection of venom. Although body stores of energy and nutrients may not be totally depleted, force-feeding of captive snakes may be of vital importance for survival, especially when 2 or more risk factors are evident (eg, when a thin pregnant female is captured during a cold season).

The use of a gastric tube to feed reptiles that have not adapted to captivity is beneficial.10 Although a mixture of eggs and commercially prepared baby food has been recommended,11 this diet may be economically unfeasible for a large group of snakes. The fresh paste diet we developed is low-cost, even compared with cat food, which has also been recommended for snakes that are not eating voluntarily.1

Force-feeding mice to debilitated snakes is not recommended, because additional stress may lead to regurgitation and dehydration or death.2 In our study, regurgitation or other problems were not seen in snakes fed mice or the fresh paste diet.

Changes in feeding behavior that are commonly associated with shedding have been widely described.3 Even when food was offered to a laboratory colony of snakes, a 6% reduction in food consumption developed during the weeks prior to shedding.4 This did not occur in our study, because both groups were force-fed. Even so, a substantial loss of weight was recorded during the week of ecdysis, probably because of the high amount of energy expended in cell proliferation and differentiation prior to shedding. Snakes invest a substantial amount of energy in the process of ecdysis, most of which is represented by the sloughed skin (21.1 kJ/g of skin for *Viperidae*).5

Dysecdysis was not observed during this experiment; dysecdysis may be attributed to poor nutrition,6,7 among other reasons. This suggests that our fresh diet contained sufficient basic nutrients to provide adequate nutrition for the snakes.

Shedding frequency is influenced by nutrition; well-fed snakes shed more frequently than snakes that have not fed for a considerable period.8 Although it has been reported that young snakes generally shed once every 5 or 6 weeks,9 results obtained in our study (mean frequency, 1.78 ecdysis events/mo/snake) may be considered normal for juvenile *C. durissus*; significant difference between the 2 groups was not detected for rate of ecdysis. Therefore, our fresh paste diet seemed to provide sufficient nutrients and energy not only for the snakes’ maintenance but also for the energy-demanding process of ecdysis.

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5. Komarek J. The use of a gastric tube to feed reptiles that have not adapted to captivity. Herpetologica 1957;13(2):143-145.
Significant differences were not detected between diet groups for potency or protein content of venom, which suggests that the fresh paste diet was adequate for maintenance of snakes used for venom production for at least 19 weeks.

Downregulation of intestinal activities that typically takes place between meals in Boa and Viperidae snakes is attributable to the high metabolic maintenance cost of intestinal function. It is necessary to feed captive snakes at regular intervals, because abnormally prolonged periods of nonfeeding cause intestinal villus atrophy that makes amino acid absorption impossible and causes protein catabolism and mineral and vitamin depletion, resulting in cachexia and muscular weakness. Results of the study reported here suggest that a balanced fresh paste diet may economically help avoid the negative consequences of prolonged nonfeeding in captive neotropical rattlesnakes.

References