Evaluation of Various Calcium-fortified High Moisture Commercial Products for Improving the Calcium Content of Crickets, *Acheta domesticus*

Mark D. Finke[1], PhD, Shari U. Dunham[2], PhD, John S. Cole III[2]

1. Mark D Finke Inc., 6811 E Horned Owl Trail, Scottsdale, AZ 85262 USA
2. Colby College, 5762 Mayflower Hill, Waterville, ME 04901, USA

ABSTRACT: Crickets, *Acheta domesticus*, are commonly fed special diets to alter their nutrient content (especially with regards to calcium) to make them a more complete diet for insectivorous birds, reptiles, and amphibians. Typically calcium-fortified dry diets are used to increase the insects' calcium content. In this experiment we compare the moisture, calcium and phosphorus content of crickets offered a typical dry calcium-fortified gut loading diet and distilled water, with those fed several commercial products (two commercial "calcium-fortified cricket waters" and a calcium-fortified high moisture diet designed to provide both food and water). An unfortified dry diet served as a negative control. Crickets fed the calcium-fortified dry diet contained significantly more calcium than those fed the other treatments. Cricket phosphorus content was not affected by diet. In summary the commercial products tested were ineffective in increasing the calcium content of crickets fed these products. For that reason the use of a calcium-fortified dry diet is recommended for supplementing crickets with sufficient calcium to meet the needs of insectivorous reptiles and amphibians to which they are fed.

KEYWORDS: calcium, gut loading, crickets.

INTRODUCTION

Crickets, *Acheta domesticus*, are an important food source for many insectivorous reptiles and amphibians kept by zoos and pet owners but unless treated, contain inadequate levels of calcium to meet the animal's requirement (Allen and Oftedal 1989, Barker, *et al*, 1998, Finke 2002). Three methods have been used to enhance the calcium content of crickets. The first method is referred to as "dusting" and involves using a powder (usually calcium carbonate) to coat the cricket prior to being fed to the animal. While effective, this method can provide variable results since the amount that adheres to the insect depends on the characteristics of the powder (particle size, electrostatic properties), the size of the cricket, and the ability of the cricket to groom itself and remove the calcium (Trusk and Crissey, 1987).

A second method, "dipping", has recently been evaluated where insects are immersed in a solution containing calcium gluconate as a means to enhance their calcium content (Winn, *et al,* 2003).

A third more common method is "gut loading" where the cricket is fed a high calcium diet so that the calcium contained in the crickets' gastrointestinal tract provides sufficient calcium for the reptile (Allen and Oftedal, 1989, Ferguson *et al*, 1996, Allen, 1997, Anderson 2000, Hunt, *et al,* 2001, Finke 2003). These diets are usually fed 24 to 72 hr prior to the use of the cricket as food since these high calcium diets are not suitable for growth and reproduction of the cricket.

Hydrated polyacrylamide gels containing 98% or more water are now commercially available to provide water for crickets without the risk of crickets drowning as they often do when free water is provided. Recently, calcium-fortified versions of these "cricket waters" have appeared and are being marketed as a means to provide additional calcium to reptiles and amphibians. A calcium-fortified high moisture food providing both food and water in one dose has also recently been introduced. Since the effectiveness of these products is unknown the purpose of this experiment was to test the effects of these new calcium-fortified high moisture commercial products on the calcium content of crickets compared to those fed a more traditional calcium-fortified dry diet.

MATERIALS AND METHODS

Treatments – The experiment consisted of five treatments (Table 1). Treatment 1 has previously been shown to result in crickets which contained sufficient calcium and thus served as a positive control, while treatment 2 served as a negative control (Finke, 2003). Treatments 3 and 4 were tests of two commercial calcium-fortified cricket waters and treatment 5 was a test of a commercial calcium-fortified high moisture food designed to provide crickets with both food and water.

Animals – Cricket nymphs, *Acheta domesticus*, were obtained from Timberline Industries (Timberline Industries Inc, Marion, IL) and used as received.

Table 1. Description of the food and moisture sources used in the experiments.

Treatment	1	2	3	4	5
Food Source	Timberline Cricket Food + 15% added $CaCO_3$	Timberline Cricket Food	Timberline Cricket Food	Timberline Cricket Food	Fluker's Orange Cube™ Complete Cricket Diet
Water Source	Distilled Water	Distilled Water	Fluker's® Calcium Fortified Cricket Quencher	Jurassi•Quench™ Calcium and Vitamin C	Fluker's Orange Cube™ Complete Cricket Diet

Food and Water Sources – The diet for treatment 1 was Timberline Cricket Power Food mixed with 15% calcium carbonate (FMC Corporation, Chicago, IL) to achieve an estimated 65 g Ca/kg diet (Finke, 2003). The diet for treatments 2, 3 and 4 was Timberline Cricket Power Food (a diet designed for cricket growth and reproduction) without any additional supplementation. The water source for treatments 1 and 2 was distilled water. The water sources for treatments 3 and 4 were Fluker's® Calcium Fortified Cricket Quencher (Fluker Laboratories, Baton Rouge, LA) and Jurassi•Quench™ Calcium & Vitamin C – Enriched Water Source for Insects (JurassiPet™, Stone Mountain, GA) respectively. The diet and water source for treatment 5 was a single product, Fluker's Orange Cube™ (Fluker Laboratories, Baton Rouge, LA). The Timberline cricket food was provided by Timberline Fisheries Inc. All other food and water sources were purchased at retail or through the Internet.

Feeding experiments – All experiments were carried out at a temperature of 28° – 29°C (82 – 84°F) with a photoperiod of 12:12 (light:dark). Eighty to one hundred cricket nymphs (weight 127 ± 3 mg; mean ± SEM) were placed in each of ten (two containers/treatment) plastic rectangular containers (26.5 x 15.9 x 17.1 cm [length x width x height]) with ventilated plastic tops (Kritter Keeper, Lee's Pet Products, San Marcos, CA). Cardboard egg cartons were stacked in each container to increase surface area and to provide cover. Food and water were provided in small dishes (6.1 x 1.2 cm [diameter x height]). For treatments 1 and 2, where distilled water was provided, small pieces of paper towel were placed in the dishes to prevent the crickets from drowning. Dishes were cleaned and food and water replaced at 22 and 42 hr. All insects were fed the diets for 48 hr after which the insects were frozen. A time period of 48 hr was used as it has been previously shown to be sufficient time to maximize calcium content of crickets when they are fed a calcium-fortified diet (Allen & Oftedal, 1989, Anderson, 2000).

Chemical Analysis – Diets and insects were kept frozen until analyzed for moisture, calcium and phosphorus. Moisture was determined by adapting AOAC method 925.09 with oven drying at 80°C (176°F) for several days until the dry sample weight was constant (AOAC 1990). For calcium and phosphorus analysis, dry samples (0.5 g or approximately 10 crickets) were digested in 15 ml of concentrated nitric acid (trace metal grade) using a Microwave Sample Preparation System (MDS-2000, CEM Corporation). Digested samples were diluted and analyzed for calcium (at 393.66 nm with background correction) and phosphorus (at 213.618 nm) on a Leeman Labs PS1000 Inductively-Coupled Plasma Atomic Emission Spectrometer using a modification of AOAC method 984.27 (AOAC 1990).

Statistical Analysis – Insect moisture, calcium and phosphorus concentrations were analyzed using an ANOVA and between treatment differences detected with Tukey's Studentized Range Test. Statistical analysis was performed using Statgraphics Plus for Windows 5.0 software (Statistical Graphics Corp, Rockeville, MD).

Results

The calcium content of the food and water sources used in the five treatments is shown in table two. The calcium fortified diet contained 65.9 g Ca/kg diet while the base diet contained 12.06 g Ca/kg diet. The distilled water contained almost no calcium (0.017 g/kg) while the two commercial cricket waters contained somewhat more calcium (0.37 and 0.24 g/kg). The high moisture commercial diet contained only 1.07 g Ca/kg diet.

The effect of the five treatments on cricket moisture, calcium and phosphorus content are shown in table three. Cricket moisture content was significantly affected by diet ($F=3.88$; $p=0.027$) although the only significant differences were between treatments 3 and 5. There were significant differences between treatments for the calcium content of crickets

Table 2. Calcium content (g/kg) of the diet and moisture sources used in the experiment. All data reported on an "as is" basis. Values are means ± SEM and sample sizes are shown in parenthesis.

Treatment	1	2	3	4	5
Food Source	65.9 ± 2.4 (4)	12.06 ± 0.48 (4)	12.06 ± 0.48 (4)	12.06 ± 0.48 (4)	1.07 ± 0.08 (2)
Water Source	0.017 ± 0.001 (2)		0.37 ± 0.05 (2)	0.24 ± 0.05 (2)	1.07 ± 0.08 (2)

Table 3. Moisture, calcium and phosphorus content of the crickets after fed the various food and water sources for 48 hr. Moisture data is reported on an "as is" basis. Calcium and phosphorus is reported on a dry weight basis. Values are means ± SEM and sample sizes are shown in parenthesis. Treatments with different superscripts denote significant differences $p < 0.05$.

Treatment	1	2	3	4	5
Moisture (g/kg)	762 ± 4^{ab} (6)	765 ± 6^{ab} (3)	767 ± 5^{a} (3)	753 ± 3^{ab} (3)	740 ± 3^{b} (3)
Calcium (g/kg)	10.6 ± 1.6^{a} (6)	2.9 ± 0.1^{b} (3)	2.8 ± 0.3^{b} (3)	2.8 ± 0.2^{b} (3)	2.3 ± 0.1^{b} (3)
Phosphorus (g/kg)	8.4 ± 0.3 (3)	8.4 ± 0.1 (3)	8.9 ± 0.1 (3)	8.7 ± 0.1 (3)	8.8 ± 0.2 (3)
Ca:P	1.26:1.0	0.34:1.0	0.31:1.0	0.32:1.0	0.26:1.0

($F=10.35$, $p=0.0005$). Crickets fed the calcium-fortified dry diet with distilled water (treatment 1) contained significantly more ($p < 0.01$) calcium than crickets fed the other four treatments. There were no significant differences ($p > 0.10$) in the calcium content between crickets fed an unfortified dry diet and distilled water (treatment 2) and those fed the three calcium-fortified high moisture commercial products (treatments 3,4 and 5). Cricket phosphorus content was unaffected by diet ($F=1.59$; $p=0.251$). Only crickets on treatment 1 had a calcium:phosphorus ratio greater than one.

Discussion

A palatable dry diet containing 50 – 80 g Ca/kg diet has been shown to be suitable for "gut loading" crickets (Allen and Oftedal, 1989, Hunt, *et al*, 2001, Finke, 2003). In this experiment a dry diet containing 65.9 g Ca/kg diet resulted in crickets containing 10.6 g Ca/kg dry matter which is consistent with the results of a previous study (Finke, 2003) and the estimated minimum dietary calcium requirement (6.1 to 8.5 g Ca/kg diet dry matter basis) of leopard geckos (Allen, 1997). In contrast to the results obtained for treatment 1, the three calcium-fortified high moisture commercial products tested resulted in crickets containing no more calcium than those fed an unfortified diet and provided with distilled water.

Since gut loading results in an increase in cricket calcium content due to the food retained in the crickets' gastrointestinal tract (Allen and Oftedal, 1989), it is not surprising that commercial "calcium-fortified cricket waters" containing only 0.37 and 0.24 g/kg Ca would have no significant effect on cricket calcium content. Both products however are marketed as an important source of calcium for reptiles. Claims include "it offers a source of calcium" and "the calcium fortification helps to shift the calcium:phosphorus ratio of insects closer to the ideal of 2:1."

Whereas the calcium-fortified high moisture commercial cricket food makes no specific claims relative to calcium it directs the user to "offer the food to crickets for at least 24 hr in order to provide the most complete nutritional prey for your pet reptile or amphibian". While the crickets in these experiments were only analyzed for moisture, calcium and phosphorus and not other nutrients, it is clear that crickets fed this product would be calcium deficient for most insectivorous reptiles and amphibians. Since the general recommendation is for gut loading diets to contain 50 to 80 g calcium/kg diet, usually from calcium carbonate (400 g calcium/kg by weight), this means these diets should be supplemented with 125 to 200 g calcium carbonate/kg diet in order to be effective. For that reason it is not surprising that "calcium-fortified cricket waters" (guaranteed maximum moisture content of 974.9 g/kg and 986.5 g/kg) or high moisture diets (guaranteed maximum moisture content of 920 g/kg) are ineffective in significantly increasing the calcium content of crickets. Other common calcium supplements contain even less calcium by weight (calcium chloride – 361 g Ca/kg; calcium lactate – 184 g Ca/kg; calcium gluconate – 93 g Ca/kg; calcium phosphate tribasic – 388 g Ca/kg (Merck Index, 1989)) making it physically impossible to supply sufficient calcium in diets or moisture sources containing more than 875 g water/kg diet or moisture source.

For cricket moisture the only statistically significant differences were between crickets in treatment 3 and treatment 5. Crickets in treatment 5 contained the least moisture, although the significance of these results is unclear. While no attempt was made to quantify cricket survival, casual observations suggest no obvious differences between the five treatments.

In summary these data suggest that, while commercial cricket waters are an effective means of supplying moisture to feeder insects, neither of the "calcium-fortified cricket waters" nor the calcium-fortified high moisture commercial cricket food are suitable for gut loading crickets with sufficient calcium to meet the needs of insectivorous reptiles and amphibians. For this reason the use of palatable dry diets containing 50 – 80 g Ca/kg diet is recommended, as they should supply sufficient calcium to meet the requirement of most insectivorous reptiles and amphibians.

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