The Growth Effect of a Commercial Diet versus Calcium-Dusted *Blaptica dubia* and *Carica papaya* on Juvenile *Correlophus ciliatus*

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Abstract.-

Background: Reptiles and amphibians are increasing in households across the United States. Pet owners are struggling to maintain their well-being due to lack of proper husbandry and nutrition, resulting in a poor quality of life and a reduced lifespan. This study was conducted to provide more information on nutrition to reptile owners, breeders, herpetologists, veterinary professionals and more. The goal is to provide dietary information for increased growth in *Correlophus ciliatus*, the crested gecko.

Materials and Methods: A food trial was conducted for 5 weeks with 60 juvenile crested geckos, 30 of which were fed a diet of calcium-dusted cockroaches and fresh papaya and the remaining 30 were fed Pangea © crested gecko diet. Their environments remained controlled and measurements were taken once a week, on their fourth feeding day. IACUC Approved: 19.006

Results: Before and after the food trial, the geckos had the same behavior, activity and appeared healthy, therefore their welfare was not compromised. Upon conducting a two-way repeated measures ANOVA and a paired t-test examining weight and length, the geckos of the insect/fruit diet group on average gained more weight and showed increased growth compared to the commercial diet group. The data analysis on length did not demonstrate any significant difference. Statistically, from Week 1 to 5, the insect/fruit diet and commercial diet groups had a total body percent increase of 24.13% and 13.07%, respectively.

Conclusions: Based on the study conducted, the juvenile crested geckos tested exhibited increased growth on a diet comprised of fruit and insect rather than a commercial diet.

Clinical relevance: With this data and analysis, crested gecko nutrition is better understood and statistically available for establishing better nutritional standards and procedures.

Key Words: Gecko; Dubia; Pangea; Papaya; Reptile

Introduction.-

Pets are a crucial part of society. Consequently, reptiles and amphibians are moving up the list of common household pets. According to the American Pet Product Manufacturers Association, more than 3.9 million households in the United States contained one or more pet reptiles or amphibians in 2000. This is a 44 percent increase since 1998. According to wildlife biologist and medical scientist Clifford Warwick, 75 percent of reptiles die during their first year in a domestic home environment [1]. Unfortunately, there is not a plethora of research supporting their biological needs, compared to canines for example. All reptile species demand a complete and balanced diet including calcium, vitamin D3, vitamin A and fiber. Yet it is known that a common factor of the high mortality rates in households is poor nutrition [2].

This study is conducted to help enhance the welfare for household reptiles. With the volume of food products in the market and brands that do not have research showing successful growth, development and lifespan with the feed, it is difficult as a pet-owner to decide what brand to feed their reptile or what type of diet to choose. To better understand reptile nutrition and development, we tested the effects of a commercial, Pangea© crested gecko diet, on juvenile crested geckos- *Correlophus ciliatus*- versus a fruit/insect diet consisting of calcium-dusted juvenile cockroaches and pureed papaya. These two options for feed were chosen specifically, as they are a reasonable replication of what is expected to a natural diet for the species in the wild [3]. This species is particularly prone to developing Metabolic Bone Disease (MBD) due to lacking minerals, such as calcium, in their diet. Vitamin D deficiency is a leading cause of MBD, as Vitamin D is the necessary agent for calcium absorption [4]. By having results of growth in groups treated with a homemade diet and a commercial diet, consumers of all backgrounds can

better understand the demands of a reptile and invest in feeding a diet that will prolong their lifespan and enhance their well-being. Prior to beginning the 5-week food trail, we hypothesized that the commercial diet fed group will have grown more than the insect/fruit diet fed group. We hypothesized that a commercial formula is more complex and contains more essential nutrients and minerals than a basic insect/fruit diet. For example, the commercial diet contains riboflavin, folic acid, vitamin B12, vitamin A, folic acid and sulfur, all considered essential in gecko nutrition [5]. Therefore, the commercially treated group will ideally show the best growth results.

Materials and Methods.-

The crested geckos used for this food trial experiment were obtained by the permission of one breeder and the experiment the use of the animals was approved by the Institutional Animal Care and Use Committee (19.006). The crested geckos used for this food trial experiment ranged from 3-4 months at the start of the food trial period. Exactly 60 geckos were used for this experiment, 30 in the insect/fruit diet fed group and 30 in the commercial diet fed group. The geckos were genetically related but were randomly categorized into the two groups for the experiment. Prior to beginning the trial, they were all on Pangea©. A humidifier was set in the room at all times, with humidity set to remain between 50-90%. The room remained between 70 and 73 Fahrenheit at all times. The humidity and temperature monitor brand was Govee Home©, purchased from Amazon©.

Each crested gecko resided individually in a labelled, hole-punched individual plastic container, measuring about 33 cm in length, 20 cm in width and 15 cm in height. The container brand was Rubbermaid© and they were purchased from WalMart© and Target©. Each container was furnished with a paper towel base, plastic green plant, egg carton piece, plastic food dish and plastic water dish. The paper towel brand was Bounty© and they were purchased from WalMart© and Target©. The plastic plants were purchased from Pangea© Reptile, manufactured by Zoo Med©. The egg cartons were obtained from Uline© and cut into 10 cm by 10 cm sections. The scale used for all measurements of feed weight and gecko weight was AC Pro-200 (200 g x 0.01 g) ©, purchased from Amazon©. The geckos were fed 4 times a week, therefore every other day and one consecutive day. Data was collected once a week, every Sunday. On feeding days, each gecko had a clean water dish replaced, a new paper towel and misting of its habitat and itself.

Prior to beginning the food trial, the three feed samples (cockroaches, papaya and Pangea©) were submitted to a nutrient analysis laboratory according to their sample size guidelines and shipping instructions. This tool was utilized to provide more information on the macronutrient content, testing for percent fat, protein, moisture, ash and fiber. The laboratory used was Cumberland Valley Analytical Services, Inc.

The commercial feed used was Pangea© Fruit Mix with Insects Complete Gecko Diet (as shown on the manufacturers website). The package itself calls it Pangea© Gecko Diet "With Insects." This was originally in powder formula, therefore each week a new paste was reconstituted with water, placed in a wide-mouth dispensing bottle and refrigerated. The paste was reconstituted following the instructions on the commercial diet "Directions" Label. A 1:2 ratio of paste to water, respectively, was stated, therefore we used 100 milliliters of paste and 200 milliliters of water. The mixture was added into the dispensing bottle immediately and shaken for 30 seconds. The geckos in this food group were given 2 grams paste, on an inverted clear plastic cup that measured 2 cm height and 2 cm diameter.

The insect/fruit group was fed a diet of roaches and papaya. The roaches used were juvenile cockroaches, *Blaptica dubia,* obtained from www.dubiaroaches.com. The roaches were gutloaded with Pangea© Superpig and Nature Zone© Total Bites. Approximately 2-3 roaches were fed to each gecko in the commercial diet group. The total weight of roaches fed to each gecko was 1 gram and sizes of each individual roach was decided based on size of the respective gecko. The protocol used was crude examination of the head of the gecko: roaches were given that were smaller than the size of the respective gecko head. The roaches were placed in a clear plastic cup (2 cm height and 2 cm diameter) and dusted with 0.1 gram of calcium powder. The calcium powder brand used was ReptiCalcium© with D3, manufactured by Zoo Med©. The

ingredients were precipitated calcium bicarbonate and cholecalciferol (source of vitamin D3). The papayas were purchased from Sprouts Market© and the peels and kernels were discarded with each use. The papaya used was blended and placed in a wide mouth dispensing bottle, then refrigerated. The papaya was used up within the week and replaced with new blended papaya at the end of the week for optimal freshness. Each gecko was given 1 gram of the papaya, placed on an inverted clear plastic cup (2 cm height and 2 cm diameter).

On data collection days, a protocol of minimal handling was set in place, to prevent gecko stress and loss of tail. The gecko was removed from its habitat, and first placed on a scale and weight in grams was measured. Following this, the gecko was placed on a laminated grid paper, parallel to the lines and a photo was taken directly above the gecko, 90 degrees to the table. The grid paper used had the following measurements: 5 squares=1 centimeter. This photo was then used to manually count and measure the total length of the gecko in centimeters.

At each data collection date, the geckos were physically evaluated for soundness and health. The following signs were looked out for as indications of poor health: jaundice (yellowing of eyes, mucous membranes or scales), dryness of scales, appearance of spine, loss of tail and reduced motility.

For data, the values used were body weight and total length. To test the variation in the data for the values collected, a t-test, paired t-test and a two-way repeated measures ANOVA were used.

Results.-

Upon physical examination from Week 1 to Week 5, there were no evident negative health differences in the geckos from both groups. No tails were lost and all geckos appeared healthy based on physical examination findings and lack of poor health signs stated above.

A two-way repeated measures ANOVA (one factor repetition) was conducted comparing live weight from week 1 to week 5. The data failed the normality test (ShapiroWilk) and equal variance test (Brown-Forsythe). There is a statistically significant interaction between diet and week ($P = <0.001$).

A two-way repeated measures ANOVA (one factor repetition) was conducted comparing live weight from week 2 to week 5. The data failed the normality test (ShapiroWilk) and passed the equal variance test (Brown-Forsythe). There is a statistically significant interaction between diet and week ($P = <0.001$).

An all pairwise multiple comparison procedures test (Bonferroni t-test) was conducted comparing insect/fruit diet versus commercial diet. By week 5, there was a significant weight gain ($P<0.050$) in the insect/fruit diet group compared to the commercial diet group.

A t-test conducted on change in weight and percent change in weight of the two groups by week 5 demonstrated a statistically significant difference ($P = 0.016$). A t-test conducted on change in live weight demonstrated statistical insignificance.

Time was a significant factor and showed growth over time in lengths. Figure 1 shows that the crested geckos started at approximately the same mean weight at Week 1 and at approximately Week 2-3, the commercial diet group plateaued while the insect/fruit diet group continued to increase. After Week 3, the commercial diet group resumed a steady growth pattern.

According to Table 3, by Week 5, there was growth exhibited in both groups, but the insect/fruit diet group averaged 4.055 grams and the commercial diet group averaged 3.684 grams. Table 2 demonstrates that the average weight gain in the insect/fruit diet group was 0.813 and in the commercial group the average weight gain was 0.4263. The percent increase for the insect/fruit diet group and the commercial diet group was 24.35% and 13.07%, respectively. Figure 2, comparing mean length of the groups from Week 1 to Week 5 demonstrated growth and change but no significant difference between the two groups.

Discussion.-

Based on the results from the t-test and the ANOVA, we can conclude that the ANOVA results are more significant and credible. The insect/fruit diet group had a significant increase in weight compared to the commercial diet group. We can reject our hypothesis and state that the insect/fruit diet group, over a five-week span, has shown greater average weight gain, therefore greater average growth, than the commercial diet treatment group.

Upon consideration of the nutrient content of each feed, it is evident as to why the insect/fruit diet group exhibited more growth and higher weights. The fat percentage of the cockroaches and papaya combined were 8.6%, compared to the commercial diet value of 4.6%, shown in Table 1. Furthermore, the protein percentages were 30.4% and 25.5% for the natural diet combination and the commercial diet, respectively. There is significance in considering dry matter, mineral content and prey size, as it alters digestibility per individual [6]. The roaches were dusted in calcium and were kept at a small size, possibly increasing the overall digestibility in the insect/fruit diet group.

The sex of the geckos was not determined during the study, as they cannot be distinguished until they have reached sexual maturity. For the nature of this experiment, the sex was deemed insignificant, considering the sample size was 30 per group and randomized.

The length of the geckos showed growth over time but they did not demonstrate a difference in groups, therefore it is not a significant factor when evaluating growth on a dietary basis. Measurement of body composition and width or girth to see what tissues are accounting for the increase in weight will also be a goal, to help understand the change in body composition and have more solid results.

A future direction would be for only one individual to conduct data collection and statistical analysis for less percent error and greater consistency.

For future studies, we would like to conduct the food trial for over 5 weeks. It would be ideal to monitor growth until the geckos were no longer juvenile and became sexually mature. This way the geckos can also be sexed and data can be collected comparing males and females as adults.

As part of the nutrient analysis, it would have been more complete to have specific mineral content percentages. For example, phosphorus, calcium and magnesium, as these are essential in any reptile diet to prevent Metabolic Bone Disease and to ensure healthy growth and development. For future studies, a micronutrient analysis will be conducted along with a macronutrient analysis.

Testing the fecal output to compare dry matter versus wet matter would also further conclude the data and provide stronger support. Another crucial part for any feed study would be recording the amount consumed quantified by deducting feed refusals. For example, we know that 2 grams of commercial diet was offered, but we did not quantify how much was consumed. For future projects, this is essential information to account in statistical analysis. It is possible that there is difference in taste of the diets and each gecko has difference in palatability which is a factor to consider [7].

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Figure Captions. –

Fig. 1. Average group weight per week from week 1 through week 5. The average weights of the insect/fruit diet and the commercial diet groups were approximately the same in the beginning of the study. At week 2 a deviation was seen, where the commercial diet group plateaued while the insect/fruit diet group continued weight gain. After week 3, the commercial diet group resumed growth and by week 5, the insect/fruit diet group exhibited increased weight gain compared to the commercial diet group.

Fig. 2. Average group length from week 1 through week 5. The insect/fruit diet group averaged with greater lengths throughout the food trial compared to the commercial diet group. The lengths gradually increased in the insect/fruit group. Whereas in the commercial group, between week 1 and week 2 a slight decrease in length was exhibited. The same pattern was seen from week 3 to week 4. There was no significant difference between the groups was exhibited by week 5.

Table 1:

Nutrient Analysis of *Blaptica dubia, Carica papaya* and Pangea© Diet					
Feed (Fresh)	Fat (%)	Moisture (%)	Protein (%)	Ash (%)	Fiber (%)
Blaptica dubia (as fed)	6.1	71.5	21.4	1.3	2.6
Carica papaya (as fed)	2.5	92.7	9.0	0.6	15.8
Pangea© (dry matter)	4.6	7.4	25.5	7.4	1.9

Table 2:

Comparison of Crested Geckos' Mean Starting Weight, Mean Weight Gain and Totally Body Percent Increase in Insect/Fruit Diet vs. Commercial Diet Groups				
Group	N	Mean Starting Weight (g)	Mean Weight Gain (g)	Total Body Percent Increase (%)
Insect/Fruit Diet	30	3.24	0.81	24.35
Commercial Diet	30	3.26	0.43	13.07

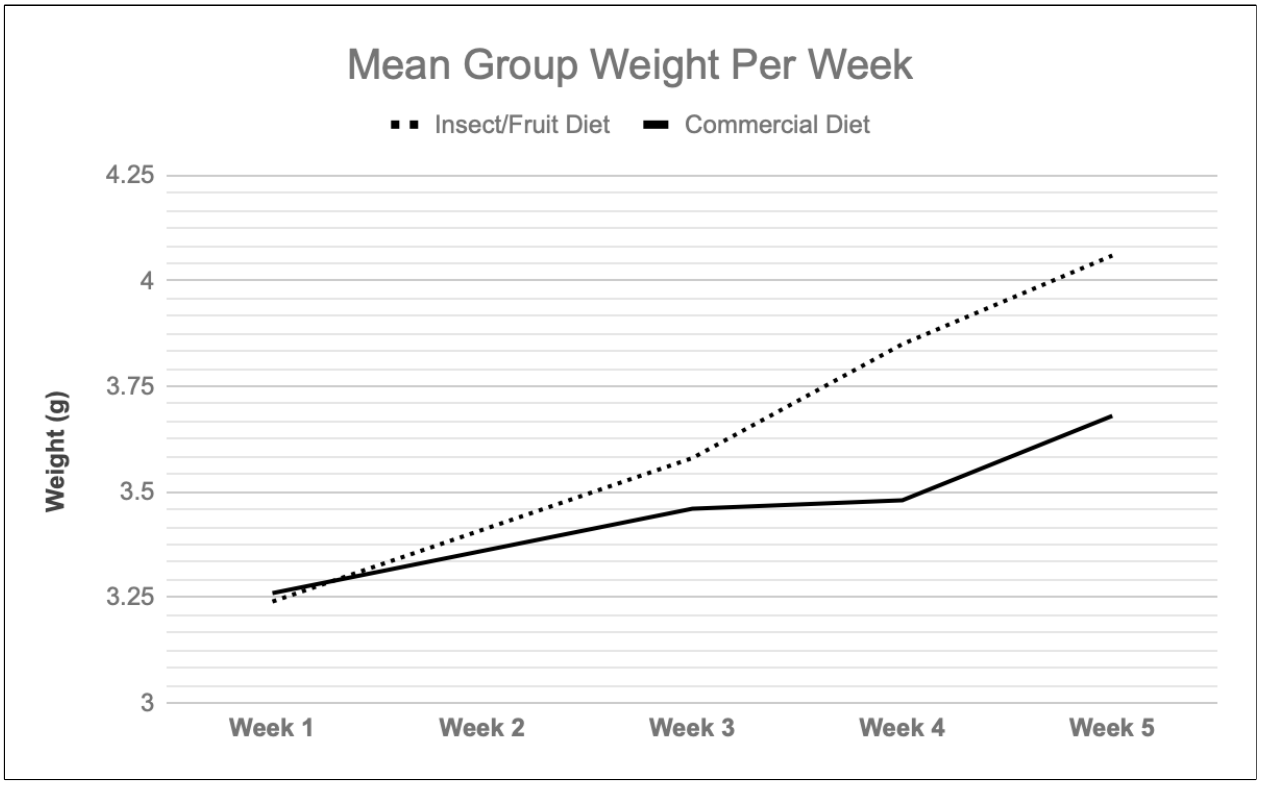
Table 3:

Comparison of Crested Geckos' Mean Group Weight per Week in Insect/Fruit vs. Commercial Diet Groups		
	Insect/Fruit Diet (g)	Commercial Diet (g)
Week 1	3.24	3.26
Week 2	3.41	3.36
Week 3	3.58	3.46
Week 4	3.85	3.48
Week 5	4.06	3.68

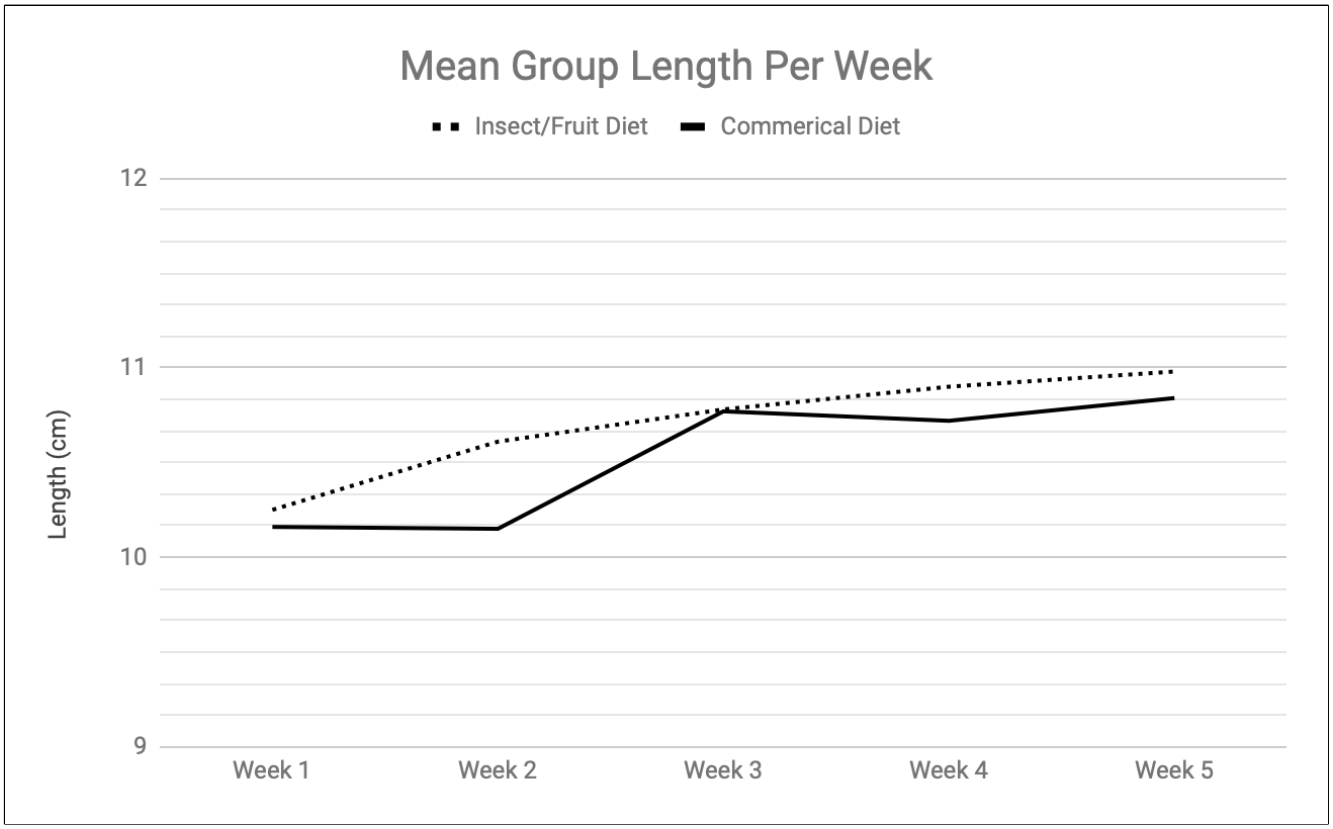
Table 4:

Comparison of Crested Geckos' Mean Group Length per Week in Insect/Fruit vs. Commercial Diet Groups		
	Insect/Fruit Diet (cm)	Commercial Diet (cm)
Week 1	10.25	10.16
Week 2	10.61	10.15
Week 3	10.78	10.77
Week 4	10.9	10.72
Week 5	10.98	10.84

Figure 1:



369 Figure 2:



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