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EVALUATION OF FOUR DIETS IN AN EDIBLE CRICKET (*Acheta domesticus*) PRODUCTION SYSTEM IN THE ANDEAN FOOTHILLS OF ECUADOR

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Abstract: The current demand for food implies greater pressure on ecosystems, so it is necessary to find alternatives for animal production that require less use of natural resources. Insects are a viable alternative in this path. In Ecuador there is research on the production of *Acheta domesticus*, however, there is no information regarding diets that compare biomass gain with local resources. In this study, four diets (squash, cassava leaves, chicken feed, and a mixture of squash and cassava leaves) are evaluated in a completely randomized block design with 4 treatments and 3 repetitions to determine the increase in biomass, mortality, days to maturity, and crickets' length in the shortest time possible. Exclusive feeding with cassava leaves extended the life cycle by 26% compared to chicken feed. The chicken feed and the combination of cassava leaves and pumpkin, on average, showed the lowest mortality rates: 6.97%, 5.15%, respectively, as well as 27% more length. Demonstrating the possibility of obtaining better returns with local resources.
Keywords: Gryllidae, entomophagy, bioeconomy, food alternative.

INTRODUCTION

In recent years, demographic growth and urbanization are gaining momentum and with it the extension of the agricultural and livestock frontier, which increases the demand for food and greater pressure on ecosystems, contributing to climate change (SATTERTHWAITE et al, 2010), leading to negative ecological effects and increasing food insecurity (VAN BERKUM, 2023). Therefore, it is necessary to find new alternatives for the production of animal species that require less space, that meet protein needs and that in turn promote the appropriate and sustainable use of water, soil and air resources (ARROYAVE et al, 2020).

The consumption of insects can contribute to food security, mainly due to their nutritional benefits, and is also useful in animal nutrition (AVENDAÑO et al, 2020). *Acheta domesticus* (Linnaeus, 1758) is presented as an alternative with several management experiences already in the region (APOLO; LANNACONE, 2016); despite still requiring details about its production methods because there is contrasting information on its toxicological profile (FERNANDEZ-CASSI, 2018; VERVERIS, 2022). That may vary based on enclosure, and cricket cages can be made with materials such as cardboard, plastic, wood, and glass; to provide protection and create a suitable space for crickets (APOLO & LANNACONE, 2015). Being important to provide a large number of hiding places in their breeding, the commonly used materials are egg trays and toilet paper rolls (ORINDA et al, 2021). The boxes need proper ventilation (HANBOONSONG & DURST, 2020).

A. domesticus has the potential to be used in food formulations, and in the enrichment of products derived from cereals, but it is dependent on factors such as the physiological state of the crickets, their diet, as well as their rearing methods (PILCO, 2021).

In the research on diets for the production of domestic cricket to obtain flour, it is stated that the flour that was obtained based on animal feed reached a high level of protein, notably surpassing other treatments derived from food scraps, fruits (apple, papaya, guava), and vegetables (cabbage, broccoli, spinach) (VACA, 2020). These insects reproduce quickly, have high growth and feed conversion rates, and have a reduced environmental impact during their life cycle. They can be raised by taking advantage of various flows of food waste (ARELLANO & VELÁSQUEZ, 2017). The cricket, being an omnivorous animal, can efficiently take advantage of many types of food even with their nutritional variations (NAKAGAKI,1991; FAO, 2013) so it can adjust to diets that come from local materials that facilitate its breeding, and contribute to the use of local resources.

In Ecuador, the production of *A. domesticus* is a recent activity. Several investigations have been carried out, however, there is no timely information regarding a low-cost diet suitable for production in each geographical area. Therefore, this study focuses on collecting information on local foods that improve the breeding of *A. domesticus* in rural areas of the country.

METHODOLOGY

LOCATION

The study was carried out in the Selva Alegre parish, located 80 km from the Otavalo Canton, Imbabura Province, Ecuador, with its coordinates 0°16' 0" N and 78°34' 60" W (Figure 1). It is located at 1,800 meters above sea level, forming part of the montane evergreen shrub ecosystems of the northern Andes and the lower montane evergreen forest of the Western Cordillera of the Andes (MAE, 2013).

MANAGEMENT AND EXPERIMENTAL DESIGN

In the experiment, four types of foods were handled that constituted the treatments under study: Pumpkin fruit - *Cucurbita moschata* (Duchesne ex Lam.) Duschesne ex Poir., 1818 (T1), cassava leaves - *Manihot esculenta* Crantz, 1766 (T2), chicken feed (T3) as a control diet according to the research by Arroyave et al. (2020), and a combination of cassava leaves and pumpkin fruit (T4). *A. domesticus* comes from the Crickets Farm in the Plaza Gutiérrez parish. The breeding stock was obtained in the egg state.

Plastic boxes with metal mesh for the cover, and vertical cardboard egg trays were used as breeding chambers to provide individual hiding places to avoid contact of the cricket with its own excrement. In addition, drinkers with absorbent fabric and soil to prevent the nymphs from drowning were also provided (Figure 2).

The research area was 5 m^2, it consisted of 12 experimental units of 7425 cm^3 that contained 110 microcrickets at the beginning of the study and a total of 1320 individuals. Based on this number of individuals, mortality, biological cycle length, length, and weight were estimated. The final values were averaged for each experimental unit, and statistical analyses were performed with them.

An Analysis of Variance (ANOVA) was performed for all the variables evaluated.

In the ANOVA, the treatments were considered as fixed factors, while the blocks (replications) were random. When there were significant differences ($p \leq 0.05$) between treatments, the Tukey test was applied to separate means, using the emmeans package (LENTH, et al. 2023). As a complement to the ANOVA, a possible relationship between diet and the biomass achieved by adults was determined. Statistical analyses were done using R studio software (TEAM C.R.M., 2014). ggpubr (KASSAMBARA, 2023) was used for the graphics.

DIET COST

To determine the cost of the diets, the price of inputs in the main agricultural stores in the parish was investigated. With this price base and the nutritional proportion, during the fourteen weeks per treatment, the following calculation was carried out in which the total price was obtained.

Quantity (g) * Unit price (USD) = Total USD

Cassava leaves did not represent any cost since it is a residue of the crops and is collected as food for crickets.

Before feeding the food, 50 g of each diet was weighed fresh, except for the chicken feed, which was 25 g. Afterward, a dehydration process was carried out in a gas lamp at 30ºC. The dehydration time for pumpkin was 2 hours for 3 days, cassava leaves 2 hours for 2 days, chicken feed 1 hour in 1 day, and for the pumpkin + cassava leaves mix 2 hours in 1 day. A difference was made between the wet weight and the dry weight of each of the foods to determine the exact amount of water in g. The amount initially planned for all diets was 100 g in half-liter tubs. Consequently, the water supply for each diet, considering the diet input, was as follows: pumpkin 143 g, cassava leaves 128 g, chicken feed 103 g, squash + cassava leaves mix 137 g. Food and water were provided every three and seven days respectively. Cleaning was carried out every three days, completely replacing the food provided.

RESULTS AND DISCUSSION

Acheta spp. has three phases during its life cycle: egg, nymph, and adult. The time required to complete each stage varies slightly depending on the species. Crickets have incomplete metamorphosis development and therefore do not enter a pupal stage, but instead hatch from the egg into a nymph that resembles the adult (HANBOONSONG & DURST, 2020).

Patton (1967) mentions that the protein content of the diets influences maturity or development since he applied a holistic diet that contained 25% protein and this favored the days to collection being an average of 56 days. With a richer, more varied diet and with high temperatures (26 - 32ºC), crickets will grow faster (PROTEINSECTA, 2018).

Our study confirms these findings, given that raw diets with higher protein value such as the combination of pumpkin with 4.4 to 14.5% (MAYNARD, 2002), cassava leaves with 6.05% (GIL, 2015), and the chicken feed with 19% protein (CASTILLO et al., 2021), influenced the total duration of the biological cycle in days (Figure 3). There were no differences between T3 (80.0±6.24), T4 (88.7 ±6.03), and T1 (85±13.58), while T2 (108±2.65) extended the insect cycle ($F(3,12) = 6.1$, $p < 0.05$). These results are directly impacted by the temperature values of the study area, which ranged between 14 and 25ºC, with lower values further prolonging the biological cycle.

The mortality percentage was higher in T2 (23.64±2.65) and T1 (17.27±13.58), while T3(6.97±6.24) and T4 (5.15±6.03) obtained a larger population at the end of the experiment ($F(3,12) = 6.1$, $p < 0.05$). Crickets fed with minimally processed diets or food scraps may have a greater mortality rate (LUNDY & PARRELLA, 2015). According to Collavo (2005) the mortality of the population is affected by the quality of the food. In this work, low mortality percentages were obtained in treatments with unprocessed diets, except for balanced diets.

The greatest length was obtained in T4 (27.49±1.20), followed by T3 (27.70±0.68), these being statistically greater than T1 and T2 ($F(3,12) = 8.7$, $p < 0.05$). *A. domesticus* obtained a greater weight with the combination of cassava leaves plus pumpkin (0.97±0.06) tending to be greater than the other treatments, without having significant differences among their means ($F(3,12) = 3.7$, $p = 0.08$). In the relationship between weight and length, treatments T3 and T4 had the best effects, while T2 was the worst regarding the weight reached by the insects. Results found by Patton (1978) showed that the average weight of 3 individuals was 0.91g with a holidic diet containing 25% protein; this value is similar to those achieved in this study. In T3 a fresh weight of 0.90 g was obtained. with a diet based on chicken feed, with 19% protein, and in T4, 0.97 g of fresh weight with a mixed diet of pumpkin and cassava leaves, with a protein content of 14.5% and 6.05%, respectively. For its part, Vaca (2020) obtained an average weight of 0.94 g using a diet based on fish feed with 42% protein. In short, there is a similarity in the weight obtained in comparison to the high percentage of protein in the aforementioned works.

Regarding the length, there is a coincidence with the work of Vaca (2020), which reports lengths between 2-2.5 cm for sacrifice, very similar to those obtained in this work (2.4 to 2.8 cm).

TOTAL DIET COSTS

It is evident that the unit prices for each 50 grams of food were low cost for a feeding time of 14 weeks, however, the lowest price considering its yield was the pumpkin fruit + cassava leaves with a total expense of 0.56 USD ; while, the food with the highest price was the chicken feed with 3.78 USD throughout the experiment, due to the fact that, being a food that easily rots, it was changed three times a week, therefore, it is considered that the Treatment 4 (pumpkin and cassava leaves) is the most accessible for the production of *A. domesticus* in this area.

Portillo (2017) indicates that, when using fish feed, potatoes, and cabbage to feed crickets, an average food expense of 4.12 USD was incurred in a period of a month and a half, while the food that was used in this trial had an average cost of 2.94 USD over 14 weeks for each treatment. Being the accumulated cost of the balanced chicken, pumpkin, and cassava leaves, 8.82 USD.

CONCLUSIONS

The diet selection criteria for rearing *A. domesticus* was made based on including foods that were produced in the Selva Alegre parish and that have nutritional value for the sustenance of the crickets. The duration of the biological cycle was between 80 to 88 days with the exception of the treatment based on cassava leaves alone, which extended the life cycle up to 108 days, this diet being the one with the lowest protein intake.

The effect on insect mortality was low in the treatments that reached the best biomass values (6.97% and 5.15%). The combination of pumpkin plus cassava leaves, and chicken feed obtained the best weight and length, so it is recommended to use them as a diet in the production of *A. domesticus* in the Selva Alegre parish, Province of Imbabura. The mixture of pumpkin and cassava leaves must be prioritized as an alternative source of protein because they are locally produced and low-cost products.

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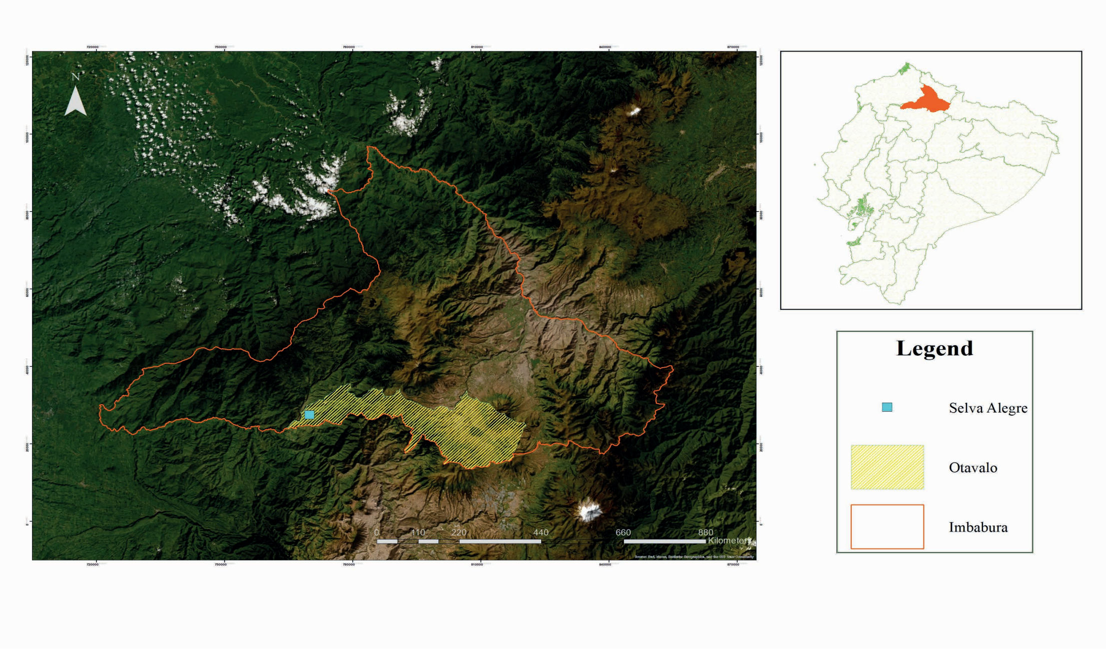

Figure 1. Location map of the Selva Alegre parish where the breeding of *Acheta domesticus* took place

Figure 2. Experimental units

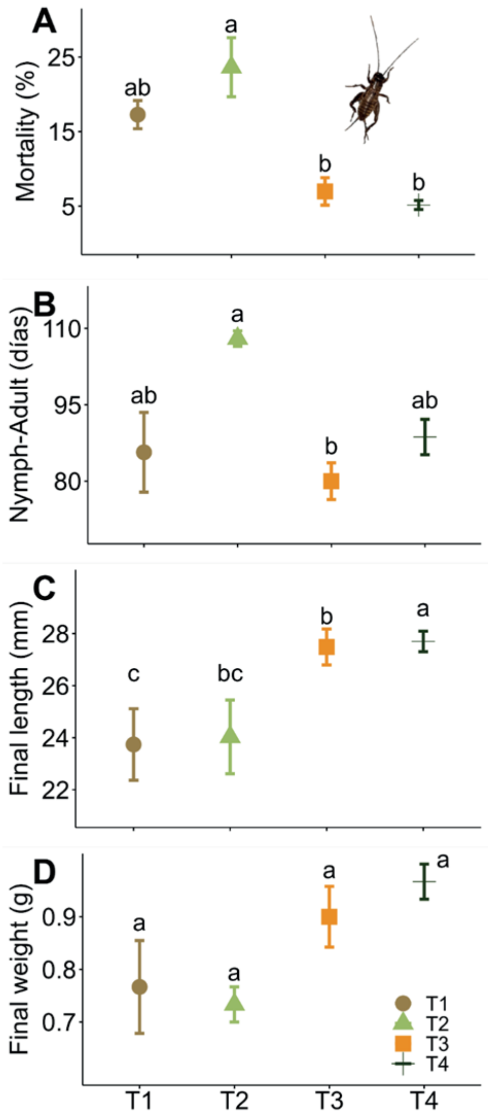

Figure 3. Average values of *Acheta domesticus* at fourteen weeks of study, referring to its mortality (A), days to adulthood (B), length at the end of the trial (C), and final weight (D). T1 = pumpkin, T2 = Cassava leaves, T3 = Chicken feed, T4 = Pumpkin + Cassava leaves