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Development of mass-rearing of African giant cricket (*Brachytrupes membranaceus* (Drury) (Orthoptera: Gryllidae)) based on plant material and by-product diets in the Republic of Benin

Corinne Mèdéou Anagonou,[1] Yêyinou Laura Estelle Loko,[1] Anicet G. Dassou,[1] Toffa Joelle,[1] Alexandre Dansi[2]

[1]Laboratory of Applied Zoology and Plant Health, National High School of Applied Biosciences and Biotechnologies, National University of Sciences, Technologies, Engineering and Mathematics, Dassa-Zoumé; [2]Laboratory of Genetics, Biotechnology and Applied Botany, National High School of Applied Biosciences and Biotechnologies, National University of Sciences, Technologies, Engineering and Mathematics, Dassa-Zoumé, Benin

Correspondence: Yêyinou Laura Estelle Loko, Laboratory of Applied Zoology and Plant Health, National High School of Applied Biosciences and Biotechnologies, National University of Sciences, Technologies, Engineering and Mathematics, Dassa-Zoumé, Benin.
E-mail: lokoestelle@yahoo.fr, loko.laura@unstim.bj

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Abstract

The African giant cricket (*Brachytrupes membranaceus*) is the most consumed species of cricket in Benin. Primarily collected in the wild during the rainy season, *B. membranaceus* is a seasonal source of animal protein for the population, whose availability and accessibility remain major challenges. This study aimed to determine the growth performance, survival rate, and feed preference of *B. membranaceus* fed with two different traditional diets. The diet was made up of cassava peelings, cassava stems, cowpea leaves, peanut shells, palm kernel cake, smoked fish waste, and eggshells. The measured parameters were growth, survival, and dietary data. The different diets induced significant variation ($p<0.001$) in the growth, mortality rate, and yield of the African giant cricket nymphs. The consumption of palm kernel cake, cassava stalks, fish waste, and cowpea leaves by *B. membranaceus* positively influenced ($p<0.001$) the crickets' weight and size gain. A significant reduction in the mortality rate ($p<0.001$) of African giant crickets was observed with the combination of foods such as cassava peel, cassava stem, fish waste, cowpea leaves, eggshells, and palm kernel cake in their diets. Cassava stems, palm kernel cake, red cowpea leaves, and fish waste could be promoted for the mass rearing of *B. membranaceus* in Benin.

Introduction

Crickets are the most consumed and farmed insect species worldwide (Van Huis *et al*., 2013; Grabowski *et al*., 2021). Crickets contribute to 31.6% of the global edible insect market. In developed countries, the most farmed cricket species for consumption are *Acheta domesticus* and *Gryllus bimaculatus* because they offer a shorter production cycle and higher yields (Costa-Neto & Dunkel, 2016). *G. bimaculatus* is mainly farmed in Asia, Africa, and Australia, while *A. domesticus* is farmed on all continents except Antarctica (Magara *et al*., 2021). Unlike other countries, the African giant cricket (*Brachytrupes membranaceus* (Drury) (Orthoptera: Gryllidae)) is an insect widely consumed by the entomophagous population in the Benin Republic. Beninese in rural areas have shifted their interest to the consumption of *B. membranaceus* because it offers an acceptable and delicious taste associated with its cultural value and richness in essential nutrients (Hongbété & Kindossi, 2017; Anagonou *et al*., 2023). Apart from its use as food in the human diet, *B. membranaceus* is also sold and used as an ingredient in poultry feed, for rituals, and therapeutic recipes in traditional medicine (Anagonou *et al*., 2023). For its various uses, *B. membranaceus* is often captured in the subsoil, mainly in natural ecosystems (Tchibozo *et al*., 2005; Riggi *et al*., 2013) during rainy periods. Indeed, the insect lives entirely underground (about 2 m deep), is nocturnal, and reproduces once a year between February and March. Adults die between February and April (Büttiker & Bünzli, 1958). This makes the African giant cricket a seasonal protein source whose availability and accessibility remain a major challenge for the population. Considering the culinary and cultural importance of the consumption of *B. membranaceus* among the entomophagous population, the various uses of *B. membranaceus*, and the consciousness of preserving biodiversity, it is crucial to develop an economical, environmentally friendly, and sustainable mass-rearing method of *B. membranaceus* to limit natural harvest and extinction of the species and ensure continued availability to consumers. However, there is little information on the local plants that *B. membranaceus* feeds on. Okweche *et al.* (2022) reported that the African giant cricket feeds on a variety of plant materials, including pumpkins, peanuts, sweet potatoes, leaves, and cashews. Adeyeye & Awokunmi (2010) and Büttiker & Bünzli (1958) noted that the African giant cricket in its natural habitat often feeds on succulent parts of young plants, roots, and leaves of crop plants such as maize, cowpea, cassava, and garden vegetables. Although promising, some of these feeds used for giant cricket farming are also consumed by local people. Therefore, could compete with their dietary needs and prove costly for mass production. Hence, it is necessary to find a low-cost and sustainable raw material. Studies have shown that the use of food waste for the rearing of edible insects for human and animal consumption seems a promising approach (Skrivervik, 2020; Van Huis, 2020), and some species of crickets already reared on food waste have shown encouraging results (Makkar *et al*., 2014). It would therefore be appropriate to explore the possibility of mass rearing of *B. membranaceus* with food waste commonly produced in Benin. Dried fish waste, cassava peelings, cassava stems, eggshells, palm kernel cake, and peanut shells are some food wastes whose nutritional profiles could contribute to the good growth of the African giant cricket. Using these food wastes as feed for *B. membranaceus* farming could be beneficial for the environment (Skrivervik, 2020) and reduce production costs (Zhang *et al*., 2009). In addition, these food wastes are plant and animal by-products, very rich in nutrients such as carbohydrates, lipids, essential amino acids, vitamins, and minerals essential for the proper development of crickets (Ortiz *et al*., 2013; Payne *et al*., 2016; Morales-Ramos *et al*., 2023). A good combination of these food wastes with some host plants that the African giant cricket feeds on could induce optimal growth in the African giant cricket. The study aims to: i) evaluate the growth performance, mortality rate, yield, and feed conversion ratio (FCR) of *B. membranaceus* fed with different diet formulations based on local plant materials and food waste; ii) determine the interaction between different formulated diets and the *B. membranaceus* growth parameters and mortality rate.

Materials and Methods

Collection of giant African crickets

B. membranaceus specimens were collected randomly from their burrows in the villages of Effèoutè (latitude 7°39'13" north and longitude 2°40'11") and Zouto (7°13'48" north and longitude 2°14'8"). The choice of these villages is based on endogenous knowledge of wild harvesting of edible insects by insect consumers (Anagonou *et al*., 2023). They identified African giant cricket collection areas using indicators such as the presence of certain tree species, such as mango trees, cashew trees, cola trees, intercropping fields (cowpea corn, peanut corn, cassava cowpea peanut, yam corn), and proximity to a river. 500 m^2 areas were demarcated around the identified areas (Ebenebe *et al*., 2024). The burrows were found somewhat hidden, covered by a mound of earth (Büttiker & Bünzli, 1958) and often under trees, at the foot of crop plants, or in somewhat untouched spaces along rivers. Burrows that the guides identified as containing crickets were carefully dug with shovels and hoes (Ebenebe *et al.*, 2024) up to the hiding place of the giant cricket, after removing the mounds and layers of earth. Only the nymphs of *B. membranaceus*, smaller than the adults, and having the same physical morphological characteristics, were captured from their gallery and placed in mesh plastic boxes. A total of 160 *B. membranaceus* nymphs, including 40 males and 120 females, were collected. Females were identified by the presence of their ovipositors, while males had two circuses at the end of their abdomen (Okweche *et al*., 2022). All *B. membranaceus* nymphs were brought back to the laboratory for rearing.

Formulation of experimental diets

Two experimental diets were formulated (Table 1). These traditional diets were designed based on food waste such as cassava peelings, dried fish waste, eggshells, palm kernel cake, peanut shells, soft stems of cassava leaves, and some local plants consumed by crickets (red cowpea leaves) available in the Republic of Benin. Cowpea leaves and cassava stems were harvested daily after sowing red cowpea seeds, and cassava stems in greenhouses located in the National School of Applied Biosciences and Biotechnologies (ENSBBA) at Dassa-Zoumè. Cassava peelings, palm kernel cake, and peanut shells were obtained from local processors of these products. Cassava peelings are food waste obtained during the local processing of cassava into "gari". Peanut shells are food waste from the shelling of peanuts to make "cakes" or peanut paste. Palm kernel cake comes from the processing of palm nuts into red oil. Smoked fish waste "dovevi" was purchased on the local market. Eggshells were collected from restaurateurs in the Dassa-Zoumè area.

Experimental design

B. membranaceus nymphs obtained after collection in the fields were brought back and raised in greenhouses installed by the Laboratory of Applied Zoology and Plant Health within the ENSBBA. To reduce the risk of mortality from cannibalism and provide enough space for the crickets (Das *et al*., 2022), four *B. mem-*

Table 1. Diet composition.

Diets	Composition
D1	25 g peanut shells + 25 g eggshells + 25 g palm kernel cake + 25 g cowpea leaf
D2	25 g cassava peelings + 25 g cassava stem + 25 g smoked fish waste + 25 g cowpea leaf

branaceus nymphs (1♂, 3♀), with a mean weight of 3.00±0.01 g and a mean size of 20.50±0.59 mm, were randomly selected and introduced into wooden boxes (length: 50 cm; width: 50 cm; height: 50 cm) with ventilation holes (5 cm in diameter) covered with a net (Sorjonen et al., 2019). Giant cricket nymphs were fed ad libitum with the two feed diets (D1, D2) provided separately in plastic Petri dishes for 12 weeks (Amadi *et al*., 2016; Okweche *et al*., 2022; Okweche *et al.*, 2024). Although they were diets, each ingredient was placed separately in small plastic Petri dishes within the cages according to the dietary composition of each diet, rather than on the same plate. To prevent the crickets from knocking the food over, a small pebble was placed in each Petri dish alongside the food. Each treatment was replicated 10 times in a randomized block design, resulting in a total of 20 experimental units; 10 were allocated to treatment D1 and 10 to treatment D2. Every 3 days, the old food given to the crickets the previous two days was weighed, discarded, and a new food was provided for each experimental unit. Since insects are not polite when they eat, food that has fallen out of the Petri dishes into the cage, such as leaf-based food, is returned to the Petri dishes before weighing the remaining food in each cage. Then, the weight of old food remaining in each cage was corrected for the effect of evaporation by comparing with uneaten food in control experimental units under the same conditions without insects (Gutiérrez *et al*., 2020). To provide hiding places and increase surface area, each experimental box was filled 1/3 full with 7000 g of wet sand. The wet cotton as a source of hydration kept the crickets healthy throughout the experimental period. Crickets were maintained at 28±1°C, with a relative humidity of 60±5% and a photoperiod of 12 light/12 dark (Clifford & Woodring, 1990).

Measured variables

The weight and size of giant cricket nymphs in each experimental unit were measured individually at the beginning of the experiment. After measuring a cricket's weight and size, its wings are marked with a colored marker to distinguish it from other crickets, before it is placed in the rearing cage. Once the experiment was set up, the weight and size of each live giant cricket nymph in each cage were recorded every 3 weeks until the end of the twelfth week. The crickets were counted by hand, one by one. They were weighed and measured individually in each plastic box. The weight of the crickets was measured using an analytical balance (AS 220.R2 PLUS, RADWAG, Radom, Poland; maximum capacity: 220 g; precision: 0.1 mg). The size of the crickets was measured with the electronic caliper 0-155 mm of the ELG TOOLS brand. After each measurement was completed, the crickets were returned to their respective boxes. Giant cricket mortality was recorded daily in each treatment, and all dead insects in each cage were recorded and removed. All dead specimens were carefully examined for signs of consumption, such as loss of antennae or limbs, and signs of cannibalization, and were classified as dead or cannibalized. No dead crickets were consumed or found with signs of consumption. Crickets that died naturally (no injuries or loss of body parts) were removed from the container without replacement. Giant crickets that died from cannibalization (separation of limbs or wings) in each experimental unit were immediately and completely removed and replaced by other live giant crickets of the same sex, similar weight and size (differences in weight and size more or less than one-thousandth) from a backup rearing, each containing 10 African giant crickets reared with the same experimental diets (D1, D2) as those they will replace (Runyambo *et al*., 2023). Various indices, such as weight gain, mortality rate, body mass index (BMI), FCR, and yield, were calculated to assess and compare feed intake and utilization in crickets.

The weight gain of the giant cricket was calculated using Eq. 1 (Sorjonen *et al.*, 2019):

Weight gain (g) = final body weight (g) –
average initial body weight (g) [Eq. 1]

The mortality rate was calculated using Eq. 2 (Das *et al.*, 2022):

Mortality percentage = Number of crickets dead recorded after the experiment period / Total number of crickets introduced for experiment × 100 [Eq. 2]

BMI of each African giant cricket was calculated as follows (Ganihar, 1997; Johnson & Strong, 2000) [Eq. 3]:

BMI = Weight of the individual (mg) /
Square of the individual length (mm) [Eq. 3]

The yield of the African giant cricket is the sum of the weight of crickets alive at the end of the experiment (Waldbauer 1968; Sorjonen *et al*., 2019) [Eq. 4]:

Yield (g) = ∑ Weight of crickets alive at the end of the experiment [Eq. 4]

The FCR on a fresh matter (Bawa *et al*., 2020; Mitchaothai *et al.*, 2022) [Eq. 5]:

FCR = Weight of feed ingested by crickets (g) /
Weight gain of crickets (g) [Eq. 5]

The weight of the feed ingested by the crickets was calculated for each cage. For each cage or experimental unit, the weight of feed ingested by the cricket group in that cage was obtained by subtracting the remaining feed weight from the introduced feed weight (Bawa *et al*., 2020). To determine the average amount of each feed or ingredient consumed by each cricket, the total weight of feed ingested by the cricket group in each experimental unit was divided by the number of live crickets in that unit.

Data analysis

Generalized linear models were used to compare the performance of African giant crickets fed with different experimental diet types. The model used the Poisson family for endpoint measurements, such as the size and weight of the African giant cricket. The binomial family model was used to measure the variation in mortality and relative growth rate of the African giant cricket in response to different diets. The student test was used to reveal significant differences in group mean values. Linear mixed models were used to determine the effects of the constituents in each formulated diet on *B. membranaceus*' growth parameters (size and weight) and mortality rate. These models incorporate fixed effects representing diet constituents and their interactions, while random effects account for the hierarchical structure of the data (*e.g*., repeated measures or experimental blocks). This method enabled precise estimation of the influence of individual ingredients and their combinations on growth, while considering natural variability and experimental design factors. This framework allowed for rigorous evaluation of how diet composition and ingredient interactions affect mortality risk in *B. membranaceus*. The data were transformed by arcsin to homogenize variances before performing the multivariate analysis. R software (R Development Core Team 2022) was utilized for all statistical analyses. Differences in $p<0.05$ were considered significant.

Results

Growth performance of *Brachytrupes membranaceus*

Weight and size of *Brachytrupes membranaceus*

The African giant cricket nymphs' average weight (D1: 4.59±0.22 g; D2: 4.51±0.17 g) did not differ significantly (df=1; p=0.878) at the beginning of the experiment. There was also no significant difference (df=1; p=0.940) in the size (D1: 37.37±0.70 mm; D2: 37.27±0.54 mm) of *B. membranaceus* nymphs at the start of the experiment (Table 2). At the end of the experiment, the weight of African giant crickets fed with the two experimental diets significantly varied (df=1; p<0.001) according to diet. The highest final weight was observed in giant crickets fed with diet D2 (8.22±0.22 g). However, the diets did not induce any significant difference (df=1; p=0.658) in the size of the crickets at the end of the experiment. On the other hand, the final size (D1: 42.84±0.61 mm; D2: 42.04±0.49 mm) of the crickets was the same in both treatments (Table 2).

The weight gain of *B. membranaceus* was significantly influenced (df=7; p<0.001) by the different feeding periods. At week 3, the weight gained of *B. membranaceus* in treatments D1 and D2 was similar (p>0.05). Significant variation (p<0.001) in weight gain was observed between giant crickets fed treatments D1 and D2, 6, 9, and 12 weeks after feeding. Treatment D2 was found to increase *B. membranaceus* growth, resulting in the greatest body weight gain compared with treatment D1 (Table 3).

Body mass index

The BMI of giant crickets significantly varied in response to different experimental diets (df=1; p<0.001). Giant crickets fed with diet D2 had the highest BMI (4.43±0.035), while those fed with diet D1 (3.48±0.03) had the lowest BMI (Table 4). Sex also had a significant impact on the BMI of crickets (df=1; F-value=406.17; p<0.001). Male African giant crickets (4.14±0.05 g) were significantly (p<0.001) heavier than females of African giant crickets (3.98±0.037 g) in both treatments. In addition, BMI significantly influenced the mortality rate of *B. membranaceus* (df=1; p<0.001). A negative correlation was observed between BMI and the mortality rate (r=-0.006; p>0.05) of *B. membranaceus*.

Yield and feed conversion ratio

The feed conversion ratio (df=1; p>0.05) of *B. membranaceus* did not show any significant difference between the two treatments. However, the yield (df=1; p<0.05) of *B. membranaceus* rearing significantly varied between the two experimental diets. The highest yield was observed in African giant crickets fed with experimental diet D2 (23.84±1.77) (Table 4).

Influence of diet D1 composition on growth performance of *Brachytrupes membranaceus*

Only Palm kernel cake (estimated at 0.255, t=3.201) of diet D1 have significant positive effect on the mean weight of *B. membranaceus* regarding fixed effects (*Supplementary Table 1*). The effects of other individual ingredients, such as peanut shells, eggshells, and cowpea leaves, were not significant, which indicates no clear impact within this model. Regarding interactions between ingredients, none were statistically significant.

Regarding the impact of diet D1 on the size of *B. membranaceus*, only the palm kernel cake (estimated at 0.582, t=1.986) and cowpea leaves (estimated at 1.398, t=2.949) have a significant

Table 2. Average weight and average size (± standard error) of *Brachytrupes membranaceus* at the beginning and end of the experiment.

Period of experimentation	Diets	Weight (g)	Size (mm)
Start (ns)			
	D1	4.59±0.22	37.37±0.70
	D2	4.51±0.17	37.27±0.54
	p	0.878	0.940
End	D1	6.48±0.27a	42.84±0.61a
	D2	8.22±0.22b	42.04±0.49a
	p	<0.001	0.658

Means with the same superscript letter within a column are not significantly different (p<0.05); ns, no significant difference.

Table 3. Average weight gain (g) (± standard error) of *Brachytrupes membranaceus* on different diets.

Diets	3 WOF	6 WOF	9 WOF	12 WOF
D1	1.17±0.18^{a}	1.63±0.22^{a}	1.81±0.25^{a}	1.89±0.27^{a}
D2	1.55±0.20^{a}	3.15±0.18^{b}	3.50±0.20^{b}	3.64±0.30^{b}
p	0.115	<0.001	<0.001	<0.001

Means with the same superscript letter within a column are not significantly different (p<0.05); WOF, weeks of feeding.

Table 4. Body mass index, feed conversion ratio, and yield (± standard error) of *Brachytrupes membranaceus* fed on different diets.

Diets	Body mass index	Feed conversion rate	Yield (g)
D1	3.48±2.79^{a}	3.93±0.38^{a}	18.02±0.3^{a}
D2	4. 43±0.03^{b}	3.57±0.36^{a}	23.84±1.77^{b}
p	<0.001	0.499	<0.05

Means with the same superscript letter within a column are not significantly different (p<0.05).

effect. Regarding fixed effects, the marginal R^2 indicated that fixed effects (ingredients) explained only 11.6% of the variance in insect size. The conditional R^2 (R^2 conditional = 0.248) showed that 24.8% of the variance is explained by the full model. None of the main effects or interactions between diet ingredients was statistically significant (*Supplementary Table 2*).

Influence of diet D2 composition on growth performance of *Brachytrupes membranaceus*

The diet D2 ingredients, such as cassava stem, smoked fish waste, and cowpea leaves, have a significant and positive effect on the weight of giant crickets (*Supplementary Table 3*). Regarding interactions between diet ingredients, consumption of smoked fish waste and cowpea leaves by crickets showed a strong positive influence on cricket weight.

Giant crickets showed a significant and positive response to the inclusion of diet D2 ingredients such as cassava stem and smoked fish waste (*Supplementary Table 4*). Regarding interactions between diet D2 ingredients, the consumption of smoked fish waste combined with cowpea leaves by crickets was found to have a strong positive influence on their size.

Mortality rate

The mortality percentage (df=7; p<0.001) of *B. membranaceus* at different feeding intervals significantly varied among diets (Table 5). At 3 and 12 weeks after feeding, the mortality of crickets on experimental diet D1 was higher than that of giant crickets on diet D2. The mortality rate of giant crickets fed diets D1 and D2 was similar at the sixth and ninth weeks after feeding. At the end of the trial, giant crickets fed the diet D1 had the highest mortality rate, up to 32.53%.

Certain ingredients in diet D1, notably palm kernel cake, significantly reduce the insect mortality rate (*Supplementary Table 5*). However, the combined effects of treatments are more complex: for example, the combination of palm kernel cake and cowpea leaves or eggshell and cowpea leaves strongly decreases mortality.

The β mixed model analysis revealed that the ingredients of diet D2 significantly influenced the insect mortality rate. With the exception of smoked fish waste and cowpea leaves, none of the diet D2 ingredients significantly increased the mortality of giant African crickets when taken in isolation. (*Supplementary Table 6*). On the other hand, most of the ingredients combined significantly reduced *B. membranaceus* mortality in the diet D2, with the exception of cassava stem and cowpea leaves.

Discussion

This study found that *B. membranaceus* fed with two different diets (D1, D2) had significant differences in weight, size, BMI, mortality rate, and yield. Indeed, African giant crickets raised on different diets exhibit different growth rates and developmental trajectories (Tawes, 2014). Diet D2 mainly consisted of cassava peel, cassava stem, and fish waste. Diet D1consisted of groundnut shell, palm kernel cake, and eggshells. Cassava peels contained 81.9-93.9% organic matter; 4.1 to 6.5% protein (Kongkiattikajorn & Sornvorawea, 2011) and minerals such as zinc, phosphorus, manganese, and sodium, phosphorus (Adelekan & Bamgboye, 2009; Otache *et al*., 2017). Cassava stems contain amino acids (1.4%), carbohydrates (36.3%), fiber (1.8%), water (59.7%), vitamins (A, β-carotene, B1, B2, B3, B5, B6, B7, B9, C), and mineral elements (Na, K, Ca, Mg, P, Fe, Cu, Zn, In, Mn, Cr, Se) (Aro *et al*., 2010). Fish waste contains about 60-65% protein (Mujinga *et al*., 2009). Chicken eggshell is a natural bio mineral composed of 95% calcium carbonate (as calcite), 1.7% organic matter (proteoglycans and polysaccharides), 1.8% protein (arginine and glycine), and 1.5% water. It also contains vitamins and minerals (Schaafsma *et al*., 2000; Nakano *et al*., 2003). The main components of peanut shells are cellulose (37.0%), lignin (28.8%), protein (8.2%), and carbohydrate (2.5%). They also contain lipid, vitamins, and mineral salts (Bobet *et al*., 2020). Palm kernel meal contains 14-18% amino acids, 12-20% fiber, 3-9% fatty acids, and different amounts of vitamins and minerals (Azizi *et al*., 2021). Diet D2, therefore, represents a diet highly rich in carbohydrate and protein, thus promoting optimal growth and survival in *B. membranaceus*, unlike diet D1, which is mainly rich in lipid, thus causing reduced growth and high mortality in *B. membranaceus*. Previous studies have shown that diets rich in carbohydrates and proteins produce high-weight insects with good development (Megido *et al*., 2016), unlike diets low or high in lipids that slow down development and reduce insect weight (Lemoine *et al*., 2016). The observed negative correlation between BMI and the mortality rate of *B. membranaceus* shows that when the BMI of crickets increases, their mortality rate decreases. This is not surprising, as it has been shown that the lifespan of insects can be influenced by their individual body mass (Honěk, 1993). Thus, insects with a higher "body condition index" survived better than those in poorer conditions (Reid & Purcell, 2011).

The results of this study also showed that the constituent elements (cassava stem, fish waste, palm kernel cake, and cowpea leaves) of the two experimental diets, taken in isolation, significantly influenced the weight, size, and mortality rate of *B. membranaceus*. The positive or negative impact of this or that ingredient in diets is a scientific fact. Indeed, previous research has shown that abiotic factors such as temperature, rain, relative humidity, food quality in terms of physical presentation (shape, color, odor, hardness, and allelochemical compounds) influenced the development, survival (Caglar, 2016), and the ability of insects to consume and digest food substrates. Although African giant crickets were reared under similar conditions, it is therefore not surprising that some feeds, such as peanut shells and cassava peeling, were more or less preferred and consumed or poorly digested than other feeds, thus causing poor growth and mortality of *B. membranaceus*.

Conclusions

This study aimed to determine the feeding preferences of *B. membranaceus* fed two locally designed diets with plant and animal

Table 5. Mortality percentage (± standard error) of *Brachytrupes membranaceus* according to the diets.

Diets	3 WOF	6 WOF	9 WOF	12 WOF
D1	6.85±1.58[a]	15.91±2.67[a]	22.18±2.21[a]	32.53±2.51[a]
D2	1.87±1.05[b]	12.49±2.25[a]	20.16± 3.22[a]	22.98±4.02[b]
p	0.009	0.329	0.612	<0.001

Means with the same superscript letter within a column are not significantly different (p<0.05); WOF, weeks of feeding.

products and by-products available in the Benin Republic. The results showed better growth performance and reduced mortality rates in African giant crickets fed with the experimental diet D2. However, consumption of cassava stems, palm kernel cake, red cowpea leaves, and fish waste by giant crickets was more closely associated with their performance than other plant products and by-products in their diet. Therefore, Cassava stems, palm kernel cake, red cowpea leaves, and fish waste could be promoted for mass farming of *B. membranaceus* in the Republic of Benin.

References

ADELEKAN B.A., BAMGBOYE A.I., 2009 - Comparison of biogas productivity of cassava peels mixed in selected ratios with major livestock waste types. - Afr. J. Agric. Res. 4: 571-577.

ADEYEYE E.I., AWOKUNMI E.E., 2010 - Chemical composition of female and male giant African crickets, Brachytrypes membranaceus L. - Int. J. Pharma Bio Sci. 1: 125-136.

ANAGONOU C.M., LOKO L.E.Y., DASSOU A.G., TOFFA J., DJEGBE I., SALIOU M., DANSI A., 2023 - Entomophagy practices, use patterns, and factors influencing perception and consumption frequency of edible insects in the Republic of Benin. - J. Ethnobiol. Ethnomed. 19: 54.

ARO S.O., ALETOR V.A., TEWE O.O., AGBEDE J.O., 2010 - Nutritional potentials of cassava tuber wastes: a case study of a cassava starch processing factory in south-western Nigeria. - Livest. Res. Rural Dev. 22: 42-47.

AZIZI M.N., LOH T.C., FOO H.L., TEIK CHUNG E.L., 2021- Is palm kernel cake a suitable alternative feed ingredient for poultry? - Animals 11: 338.

BAWA M., SONGSERMPONG S., KAEWTAPEE C., CHANPUT W., 2020 - Effect of diet on the growth performance, feed conversion, and nutrient content of the house cricket. - J. Insect Sci. 20: 10.

BOBET, O., NASSIO, S., SEYNOU, M., REMY, B., ZERBO, L., SANOU, I., SAWADOGO, M., MILLOGO, Y., GILLES, E., 2020 - Characterization of peanut shells for their valorization in earth brick. - JMMCE 8:301-315.

BÜTTIKER W.W., BUNZLI G.H., 1958 - Biological notes on the tobacco cricket, Brachytrupes membranaceus (Dru.)(Orthop; Gryllidae) South Africa. - Bull. Entomol. Res. 48: 49-57.

CLIFFORD C.W., WOODRING J.P., 1990 - Methods for rearing the house cricket, Acheta domesticus (L.), along with baseline values for feeding rates, growth rates, development times, and blood composition. - J. Appl. Entomol. 109: 1-14.

COSTA-NETO E.M., DUNKEL F.V., 2016 - Insects as food: history, culture, and modern use around the world. In: Dossey A.T., Morales-ramos J.A.,Rojas M.G. (eds.). Insects as sustainable food ingredients. - Academic Press, London: 29-60 pp.

DAS A., GHOSH D., MANNA B., DOLAI A., PATI A., MANDAL S., MUKHERJEE K., 2022 - Does space matter? Estimation and evaluation of required space for commercial mass culture of grasshoppers (Acridoidea: Orthoptera). - PLoS One 17: e0265664.

EBENEBE C.I., OKONKWO M.N., EZENYILIMBA B.N., EZEANO C.I., 2024 - Ecological, Behavioural and Morphometric Characteristics of the Giant Cricket (Brachytrupes membranaceus L.) in Oji River LGA, Enugu State, South East, Nigeria: a prelude to semi-intensive rearing technique. - e-Proceedings of the Faculty of Agriculture International Conference: 251-261 pp.

GANIHAR S.R., 1997 - Biomass estimates of terrestrial arthropods based on body length. - J. Biosci. 22: 219-224.

GRABOWSKI N.T., CHHAY T., KEO S., LERTPATARAKOMOL R., KAJAYSRI J., KANG K., MITCHAOTHAI J., 2021 - Proximate composition of Thai and Cambodian ready-to-eat insects. - J. Food Qual. 2021: 9731464.

GUTIÉRREZ Y., FRESCH M., OTT D., BROCKMEYER J., SCHERBER C., 2020 - Diet composition and social environment determine food consumption, phenotype and fecundity in an omnivorous insect. - R. Soc. Open Sci. 7: 200100.

HONGBÉTÉ F., KINDOSSI J., 2017 - Diversity and traditional consumption of edible insects in North Benin. - J. Sci. Res. Rep. 14: 1-11.

HONĚK A., 1993 - Intraspecific variation in body size and fecundity in insects: a general relationship. - Oikos 66: 483-492.

JOHNSON M.D., STRONG A.M., 2000 - Length-weight relationships of Jamaican arthropods. - Entomological News 270-281.

KONGKIATTIKAJORN J., SORNVORAWEAT B., 2011 - Comparative study of bioethanol production from cassava peels by monoculture and co-culture of yeast. - Agric. Nat. Resour. 45: 268-274.

LEMOINE N.P., SHANTZ A.A., 2016 - Increased temperature causes protein limitation by reducing the efficiency of nitrogen digestion in the ectothermic herbivore *Spodoptera exigua*. - Physiol. Entomol. 41: 143-151.

MAKKAR H.P., TRAN G., HEUZÉ V., ANKERS P., 2014 - State-of-the-art on use of insects as animal feed. - Anim. Feed Sci. Technol. 197: 1-33.

MAGARA H.J.O., NIASSY S., AYIEKO M.A., MUKUNDAMAGO M., EGONYU J.P., TANGA C.M., KIMATHI E.K., ONGERE J.O., FIABOE K.K.M., HUGEL S., ORINDA M.A., ROOS N., EKESI S., 2021 - Edible crickets (Orthoptera) around the world: distribution, nutritional value, and other benefits—a review. - Front. Nutr. 7:537915.

MEGIDO R.C., GIERTS C., BLECKER C., BROSTAUX Y., HAUBRUGE É., ALABI T., FRANCIS F., 2016 - Consumer acceptance of insect-based alternative meat products in Western countries. Food Qual. Pref. 52: 237-243.

MITCHAOTHAI J., GRABOWSKI N.T., LERTPATARAKOMOL R., TRAIRATAPIWAN T., CHHAY T., KEO S., LUKKANANUKOOL A., 2022 - Production performance and nutrient conversion efficiency of field cricket (Gryllus bimaculatus) in mass-rearing conditions. - J. Anim. 12: 2263.

MORALES-RAMOS J.A., ROJAS M.G., DOSSEY A.T., BERHOW M., 2020 - Self-selection of food ingredients and agricultural by-products by the house cricket, Acheta domesticus (Orthoptera: Gryllidae): a holistic approach to develop optimized diets. - PLoS One 15: e0227400.

MUJINGA W., LWAMBA J., MUTALA S., HÜSKEN S.M.C., 2009 - Inventaire des espèces de poisson disponibles sur les marchés urbains de Lubumbashi, République Démocratique du Congo. The WorldFish Center, Malaysia: 33 pp.

NAKANO T., IKAWA N.I., OZIMEK L., 2003 - Chemical composition of chicken eggshell and shell membranes. - Poult. Sci. 82: 510-514.

OKWECHE S.I., EYO K.I., EFFA E.B., 2022 - Food preference and nutrient composition of African cricket Brachytrupes membranaceus L.(Dury) in Cross River State, Nigeria. - J. Insects Food Feed 8: 1501-1510.

OKWECHE S.I., UGWU Q.O., NWAOGU C., 2024 - Nutritional composition of cricket, Brachytrupes membranaceus (Drury, 1770), and selected animal source foods in Cross River State, Nigeria. - Int. J. Trop. Insect Sci. 44:1271-1278.

ORTIZ J.C., RUIZ A.T., MORALES-RAMOS J.A., THOMAS M., ROJAS M.G., TOMBERLIN J.K., JULLIEN R.L., 2016 - Insect mass production technologies. In: Dossey A.T., Morales-Ramos

J.A., Rojas M.G. (eds.). Insects as sustainable food ingredients. Academic Press, San Diego: 153-201 pp.

OTACHE M.A., UBWA S.T., GODWIN A.K., 2017 - Proximate analysis and mineral composition of peels of three sweet cassava cultivars. - Asian J. Phys. Chem. Sci. 3: 1-10.

PAYNE C.L.R., SCARBOROUGH P., RAYNER M., NONAKA K., 2016 - A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values. - Trends Food Sci. Technol. 47: 69-77.

RIGGI L., VERONESI M., VERSPOOR R., MACFARLANE C., TCHIBOZO S., 2013 - Exploring entomophagy in northern benin-practices, perceptions and possibilities. - International Conference Insects to Feed the World Ede The Netherlands 14-17 May 2014. 802-823 pp.

REID M.L., PURCELL J.R.C., 2011 - Condition-dependent tolerance of monoterpenes in an insect herbivore. - Arthropod-Plant Interact. 5: 331-337.

RUNYAMBO I., ANDIKA D., WATAKO A., MWONGA S., MWERESA C., 2023 - Feeding preferences of the field cricket Scapsipedus icipe (Orthoptera: Gryllidae) for different species of Commelina. - Eur. J. Entomol. 120 :115-127.

SCHAAFSMA A., PAKAN I., HOFSTEDE G.J.H., MUSKIET F.A., VAN DER VEER E., DE VRIES P.J.F., 2000 - Mineral, amino acid, and hormonal composition of chicken eggshell powder and the evaluation of its use in human nutrition. - Poult. Sci. 79: 1833-1838.

SKRIVERVIK E., 2020 – Insects' contribution to the bioeconomy and the reduction of food waste. - Heliyon 6:e03934.

SORJONEN J.M., VALTONEN A., HIRVISALO E., KARHAPÄÄ M., LEHTOVAARA V.J., LINDGREN J., ROININEN H., 2019 - The plant-based by-product diets for the mass-rearing of Acheta domesticus and Gryllus bimaculatus. - PLos One 14: e0218830.

TAWES B., 2014 - The effect of changing juvenile nutritional conditions and compensatory growth on life history traits in a field cricket, *Gryllus texensis*. Graduate theses and dissertations. - Iowa State University, Paper 13800.

TCHIBOZO S., VAN HUIS A., PAOLETTI M.G., 2005 - Notes on edible insects of South Benin: a source of protein. In: Paoletti M.G. (ed.). Ecological implications of minilivestock (role of rodents, frogs, snails, and insects for sustainable development). Science Publishers: 245-251 pp.

VAN HUIS A., 2013 - Potential of insects as food and feed in assuring food security. - Annu. Rev. Entomol. 58: 563-583.

VAN HUIS A., 2020 - Edible crickets, but which species? - J. Insects Food Feed 6: 91-94.

WALDBAUER G.P., 1968 - The consumption and utilization of food by insects. - Adv. Insect Physiol. 5: 229-288.

ZHANG X., TANG H., CHEN G., QIAO L., LI J., LIU B., LIU Z., LI M., LIU X., 2019 - Growth performance and nutritional profile of mealworms reared on corn stover, soybean meal, and distillers' grains. - Eur. Food Res. Technol. 245: 2631-2640.

Online supplementary material:

Supplementary Table 1. Effects of diet D1 on the weight of Brachytrupes membranaceus.

Supplementary Table 2. Effects of diet D1 on the size of Brachytrupes membranaceus.

Supplementary Table 3. Effects of different ingredients of diet D2 and their interactions on the mean weight of Brachytrupes membranaceus.

Supplementary Table 4. Effects of diet D2 on the size of Brachytrupes membranaceus.

Supplementary Table 5. Effects of diet D1 on the mortality rate of Brachytrupes membranaceus.

Supplementary Table 6. Effects of different ingredients of diet D2 and their interactions on the mortality rate of Brachytrupes membranaceus.