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# Effects of Organic Substrates on Development and Survival of *Blattela germanica* for Food and Feed in Kenya

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## Abstract

Entomophagy has gained popularity as a novel approach to addressing food and nutrition insecurity, particularly in sub-tropical and tropical countries. Cockroaches, for example, have the potential to alleviate nutritional deficiencies, as well as the erratic supply of protein in feeds. They can also be reared on locally available organic substrates. This study investigated growth performance and survival of german cockroach (*Blattella germanica)* reared on locally available organic matter substrates as treatments; spent brewers' grain (Treatment A), Treatment B consisting of (40%: wheat bran: 40% spent brewers' grain: 20% *Caridina nilotica*), wheat bran (Treatment C), and *C. nilotica* (Treatment D) and in a completely randomised design (CRD). Each treatment was replicated four times, while in each replicate 20 - 30 nymphs were reared for forty-two days. Feed intake for all the treatments was not significantly different. There was a significant difference ($P < 0.05$) in mature weight, average daily weight gain, live weight, and survival during rearing period. Cockroach performed well on treatment B and recorded highest mature weight, overall performance index, survival was 90.25 mg, 197.35, 96%. The least perfomance was reported in Treatment C; 1.78, 83, 143.17 and 72.5 for average growth rate, survival, overall perfomance and mature weight respectively. B. Based on these findings, a single feed as used in this study was inferior to the composite (Treatment B) in all parameters of growth performance and survival. The composite diet (Treatment B) could be suitable substrate for mass production of *B. germanica* for feed and food.

## Keywords

Cockroach, Feed Intake, Growth Rate

## 1. Introduction

In the last two decades, the number of people who practice entomophagy has grown rapidly across all cultures and societies. Wild edible insect harvesting for feed and food is not sustainable because their natural habitat, such as forests, is already overstressed and diminishing due to human activities, urbanization, and the negative effects of climate change [1] [2] [3]. Domestication and rearing of these edible insects will aid in meeting demand as entomophagy becomes more entrenched in human culture, particularly when processed into ingredients or favourite dishes and animal feeds [4]. To meet the demand for edible insects for food and feed, industrial production of insects (at least 1 tonne/day) is required [5] [6]. Many challenges face the development of sustainable industrial production of edible insects, including inefficient technologies, inbreeding and a lack of research on nutrition and feeding strategies that maximize output [7] [8].

Insects, regardless of sex, use carbohydrates as a source of energy at all stages of development, whereas protein is required for egg production. If a diet does not provide enough energy, supplemental energy is obtained during metabolism by converting lipids into simple sugars (monosaccharides). It is always difficult to find a single feedstuff that can satisfy all of an insect's nutrient requirements, so insects will feed on a variety of organic matter to meet their daily nutrient requirements [9]. Crickets, Black soldier flies, and American cockroaches have all been successfully reared by feeding them formulated chicken mash, organic waste, and dog food, respectively. Brewers waste, wheat bran, and wheat pollard are examples of common organic wastes. Although the nutritional requirements of most insects are relatively similar, the optimal sources, types, and proportions of nutrients vary greatly between species and reproductive stages [10].

For centuries, *B. germanica* has been consumed in many Asian and American countries. In Mexico, for example, it is ground into a paste and consumed as food by family members. This could be attributed to its high nutritional value, which has been documented in previous articles. According to one study, it has a crude protein content of 78 percent on a dry matter basis, which is higher than the order blattodea's average crude protein content of 57.03 percent [8]. According to documented crude protein values in *B. germanica*, crude protein is higher than conventional feedstuffs used in animal feeding, such as fishmeal. It is prudent to consider mass production of *B. germanica* for livestock feeding, particularly poultry.

Although industrial rearing of *Blattella germanica* (german cockroach) has not been accomplished, small quantities have been successfully reared on dog biscuits for laboratory research, particularly in the areas of digestive physiology, neurobiology, and pesticide studies [11]. In China, American cockroaches have been reared on a large scale on dog food and chicken feed, but this is quite wasteful because cockroaches can utilize other less useful organic wastes. In a previous study, german cockroaches preferred finely ground carbohydrate-rich feed like potatoes and bananas to protein-rich feed like pork and cheese [12].

The difficulty in using the latter is competition for its use as human food. Some edible insects, such as crickets, houseflies, and black soldier flies, have been successfully reared on industrially organic wastes such as brewer's wastes, slaughter slab wastes, poultry wastes, and kitchen waste. The potential for mass production of *B. germanica* on locally available organic wastes from industrial, cereal, and aquaculture wastes was investigated in this study. The growth performance and survival of the *B. germanica* cockroach were also documented.

## 2. Materials and Methods

### 2.1. Study Site

The study location was KALRO-Kakamega, which is located within Kakamega County at an elevation of 1585 m above sea level, latitude of 00016'N, longitude of 34045'E. The average annual rainfall is 1883.96 mm, the average mean temperature is 21˚C, the average maximum temperature is 27˚C, the average minimum temperature is 14˚C, the average evaporation is 120 mm, and the average day length is 12 hours. This area is designated as an agro-ecological zone, making it ideal for livestock and crop production [13].

### 2.2. Optimization of Cockroach Colony

#### 2.2.1. Study Site

New colonies of German cockroaches were trapped in a deserted building using a baited trap made of plastic stacked with carton egg trays. The colony was relocated to a rearing facility at the Kenya Agricultural and Livestock Research Organization in Kakamega County, Western Kenya.

#### 2.2.2. Rearing Unit

The floor in the rearing room was littered with wood shavings, the walls were painted cream to reduce light reflection, and the room was completely sealed with allowances for adequate ventilations. The colony was divided into three groups of about sixty individuals each and placed in an improvised rearing container.

### 2.3. Experimental Design and Treatment Diets

Each improvised container (IC) had a capacity of 60 litres (diameter 60 cm, height 80 cm), a wide-mouth brown plastic color, and a tight-fitting lid. The lid had two rectangular ventilation provisions, each measuring 30 cm by 5 cm, and was screened with a mosquito net. The inner surface of the container was coated with petroleum jelly six inches from the top to prevent the cockroaches from climbing out. Each IC was outfitted with three carton egg trays for concealment and anchorage. The room's environmental conditions allowed for 24-hour darkness at about 22˚C - 30˚C room temperature and 48 - 75 percent relative humidity.

### 2.4. Experimental Procedures

The feed intake trial used a completely randomised design with four different dietary treatments. Treatment A consisted of (dry spent brewer's grain), Treatment B (40 percent dry spent brewer's grain: 40 percent wheat pollard: 20 percent *C. nilotica*), Treatment C (wheat pollard), and Treatment D (freshwater shrimp, *C. nilotica* locally known as *Ochong'a*) each replicated four times. Twenty-five nymphs aged 1 - 3 days were weighed before being placed in each of the IC for each replicate.

Clean water was made available ad libitum by placing it on picnic trays with cotton wool for anchorage. Every seven days, remnant feed-substrate was weighed, discarded, and fresh feed was provided onto the feeding trays. Every IC was checked daily to identify and record mortality. After 21 days, the cockroaches were aspirated, weighed in groups, and the average weight measured. Each IC was also inspected daily for the presence of gravid females. The data was collected over the course of 42 days.

## 2.5. Chemical Analyses and Calculations

Dietary proximate components for dry matter (DM), ash, crude protein (CP), crude fiber (CF), and ether extracts (EE) and nitrogen free extracts (NFE) were analyzed using the Association of Official Analytical Chemists [14] methods. The Metabolizable Energy estimates were calculated using standard formulae; [15].

$$\text{ME}\left(\frac{\text{Kcal}}{\text{Kg}}\right) = (\text{g of crude protein} * 4) + (\text{g of crude fat} * 9) + (\text{g of nitrogen free extract} * 4)$$

1) $$\text{Average Daily Feed Intake} = \frac{\text{Final weight of Substrate} - \text{Initial Weight of Substrate}}{\text{Total Number of Days during the Substrate intake}}$$

2) $$\text{Average Growth Rate} = \frac{\text{Final liveweight} - \text{Initial Liveweight}}{\text{Total Number of Days}}$$

3) $$\text{Survival} = \frac{\text{Final Number of live cockrooaches} * 100}{\text{Initial Number of Live Cockroaches}}$$

4) $$\text{Overall Performance Index} = \text{Growth Rate} * \text{Survival}$$

5) $$\text{Feed Conversion Ratio} = \frac{\text{Total Feed (Substrate) intake}}{\text{Total Weight Gain}}$$

## 2.6. Statistical Data Analyses

Data were analyzed using R software version R 4.1.2, which was obtained under the GPL. To determine statistical significance, the data was subjected to a one-way analysis of variance with the different substrates as the treatment effect, with an alpha of 0.05. Means that differed significantly were separated by the least significant difference.

# 3. Results and Discussion

The dry matter, metabolizable energy and proximate composition of *B. germanica* feed-substrate are as recorded in Table 1 below.

Treatment D had the highest level of metabolizable energy and crude protein at 3031 Kcal/Kg and 52.8% respectively. Treatment B had a crude protein of 23% which is within recommended nutrient requirements for *B. germanica.*

Initial cockroach live weight was similar (4 mg) across the dietary treatments, but there was a significant difference in weight after twenty-one days ($P < 0.05$) of feeding, as shown in Table 2. Treatment B had the highest mean weight at 44.25 ± 0.48 mg, while Treatment C had the lowest at 33.25 ± 0.85 mg. Treatment B had the highest final mean weight at 42 days of feeding (86.25 ± 0.85 mg), followed by Treatment D, and the lowest weights were in Treatment C. Cockroach weights were significantly different ($P < 0.05$) after 42 days of feeding. The weight difference could be attributed to the nutritional composition of diets, particularly micronutrients.

Although Treatment D had the highest level of crude protein and metabolizable energy, as shown in Table 1, cockroach performance was second in terms of weight gain. But even though the mineral and amino acid profiles of the substrates were not examined, the mix (treatment B) may have had a more balanced

**Table 1.** Nutrient and proximate composition of treatments diets.

| Treatment Diet | Dietary Contents | DM | ME (Kcal/Kg) | CP (%) | EE (%) | CF (%) | ASH (%) | NFE (%) |
|---|---|---|---|---|---|---|---|---|
| A | Spent Brewers grain | 90.5 | 1883 | 17.5 | 5.5 | 46.5 | 3.8 | 17.2 |
| B | 40% SBG: 40% WB: 20% FS | 89 | 2327 | 23 | 7.5 | 34 | 6.2 | 18.3 |
| C | Wheat Bran | 88 | 1114.2 | 11.7 | 4.9 | 13.7 | 6.4 | 51.3 |
| D | Freshwater Shrimp (FS) (*Caridina niloticus)* | 87 | 3031 | 52.8 | 5.9 | 7 | 11.6 | 9.7 |

A, Spent Brewers grain; B, 40% SBG: 40% WB: 20% FS; C, Wheat Bran; D, Freshwater shrimp (FS)

**Table 2.** Mean live weight change of *B. germanica* at days 3, 21, and 42 grown of different organic substrates.

| Treatments | Average Weight at 3 day (mg) | Weight at 21 days(mg) | Weight at 42 days(mg) | Total Weight Gain(mg) |
|---|---|---|---|---|
| Treatment A | 4 | $35.00 \pm 0.41^c$ | $79.25 \pm 0.95^c$ | $75.00 \pm 1.08^c$ |
| Treatment B | 4 | $44.25 \pm 0.48^a$ | $90.25 \pm 0.85^a$ | $86.25 \pm 0.85^a$ |
| Treatment C | 4 | $33.25 \pm 0.85^c$ | $76.50 \pm 0.29^c$ | $72.50 \pm 0.29^c$ |
| Treatment D | 4 | $39.50 \pm 0.87^b$ | $84.75 \pm 0.85^b$ | $80.75 \pm 0.85^b$ |
| | | P = 0.0000 | P = 0.0000 | P = 0.0000 |

A, Spent Brewers grain; B, 40% SBG: 40% WB: 20% FS; C, Wheat Bran; D, Freshwater shrimp (FS) *Means within the same column with same superscript letter are not significantly different* $P \leq 0.05$.

nutritional profile than diets with single ingredients.

The mature cockoraoch weight at 42 days ranged between 77 - 80.2 mg, which was consistent with the findings of [16]. In the same study, *Blattela germanica* responded positively to a mixture of wheat and skimmed milk compared to that of meat and cereals. Most insects are capable of converting excess protein to lipids, particularly during starvation [16].

Significant difference (P < 0.05) in average growth rate was recorded among all the treatment. However, there is a similarity in average growth rate for treatment A and C as shown in **Table 3**. Treatment B recorded the highest daily growth rate (2.06 ± 0.02 mg) whereas Treatment C produced the least average growth rate. The average feed intake was significantly different for all treatments during the whole period of study as indicated in **Table 3**. During the feed processing, all the treatments were ground to recommended particle size of less than 1 mm, and thus all the cockroaches consumed to their maximum capacity. Numerical variation in average daily feed intake could be attributed to feed texture, wheat bran is more course than brewer's waste and *C. nilotica.* In a previous study that evaluated feed intake and preference in among a population of *B. germanica*, it was demonstrated that there a preference and higher intake reported for carbohydrates than protein. The most preferred feeds were potatoes, bananas and bread [12]. Cockroaches are also selective in nutritients composition, for instance, *B. germanica* are averse to both D-glucose and any substance containing it, but attracted to a carbohydrate with a higher level fructose [17].

Other factors that have documented to affect feed intake in insects include; size of feed particles, size and stage of growth of insects, environmental changes and physiological state of insects. [18] studied effect of feed particle size on intake and growth of *B. gernanica* and recorded significant difference in daily weight gain when particle sizes were varied. For instance, when the particle size was ground to 0.7 - 4.0 mm, insects fed on smaller particle sizes (0.7 mm) gained weight faster than those on larger particles (4.0 mm). It can be deduced that smaller particles of approximately 1mm are preferred by cockroaches.

It has been suggested that a good diet for *B. germanica* should have a bulk of fructose-glucose dominated carbohydrates and considerable amount of quality

**Table 3.** Growth parameter indices of *B. germanica* reared on different organic substrates.

| Treatments | Average Growth Rate (mg) | Average Feed Intake (mg) |
|---|---|---|
| Treatment A | $1.79 \pm 0.03^{c}$ | $2.50 \pm 0.25^{a}$ |
| Treatment B | $2.06 \pm 0.02^{a}$ | $2.05 \pm 0.24^{a}$ |
| Treatment C | $1.73 \pm 0.01^{c}$ | $1.67 \pm 0.29^{a}$ |
| Treatment D | $1.92 \pm 0.02^{b}$ | $2.02.75 \pm 0.34^{a}$ |
| | P = 0.0000 | P = 0.2765 |

A, Spent Brewers grain; B, 40% SBG: 40% WB: 20% FS; C, Wheat Bran; D, Freshwater shrimp (FS). *Means within the same column with same superscript letter are not significantly different P* ≤ 0.05.

protein optimum growth and survival [18]. Crickets which are close associates of cockroaches have successfully been reared on poultry feeds with a crude protein content of 20% with a survival rate of up to 80% [19].

The survival rate of *B. germanica* was significantly different (P < 0.05) among the different substrates as indicated in **Table 4**. Treatment B supported the highest percent survival whereas highest mortality was recorded in Treatment A. In treatments that had lower mortality, survival was higher, this could be attributed to ability of feed nutrients to nourish and support life of cockroaches.

Overall performance index is a parameter used to indicate how good the rearing conditions were able to support multiplication of insects reared and controlled conditions. In **Table 4**, the overall performance index of *B. germanica* was significantly different (P < 0.05). Treatment B had the highest overall performance index of 197.35 ± 4.91, followed by Treatment D and the least was recorded in Treatment C. From this result, we can deduce that the treatment B (composite diet) gave the best results in terms of overall performance of *B. germanica* compared to single ingredient diets. It also implies that although single organic substrates can support life of cockroaches, the perfomance is not optimum. Mix more than one organic substrate yield better survival and perfomance. In previous studies, it has been shown that availability of food and water affects the survival and development of cockroaches. In an earlier studies, [18] reported a variation in growth, longevity, moulting and reproduction of *B. germanica*. It was also noted this variation was pronounced in female than male cockroaches.

**Table 4.** Percent mortality, survival and overall perfomance of *Blattela germanica* reared on difference organic substrates.

| Treatments | Percent Mortality (%) | Survival (%) | Overall Perfomance Index |
|---|---|---|---|
| Treatment A | 15.50 ± 2.60$^{ab}$ | 84.50 ± 12.60$^{ab}$ | 150.68 ± 3.18$^{c}$ |
| Treatment B | 4.00 ± 1.63$^{b}$ | 96.00 ± 1.63$^{a}$ | 197.35 ± 4.91$^{a}$ |
| Treatment C | 17.05 ± 2.84$^{a}$ | 83.00 ± 3.24$^{b}$ | 143.17 ± 5.53$^{c}$ |
| Treatment D | 9.50 ± 3.28$^{ab}$ | 90.50 ± 3.28$^{ab}$ | 173.93 ± 6.04$^{b}$ |
| | P = 0.01478 | P = 0.02407 | P = 0.0000 |

*A,* Spent Brewers grain; B, 40% SBG: 40% WB: 20% FS; C, Wheat Bran; D, Freshwater shrimp (FS), *Means within the same column with same superscript letter are not significantly different* $P \leq 0.05$.

## 4. Conclusion

This study has shown that it is possible to rear *B. germanica* using improvised containers with slight modification to allow for ventilation in normal room conditions in Kenya. Although organic substrates such as brewers waste, wheat pollard and ochong'a (*C. nilotica*) can support mass production of *B. germanica*, a composite of 40% spent brewers waste; 40% wheat pollard and 20% *C. nilotica* will yield a comparatively higher volume. Based on the highest percent survival and perfomance index of 96 and 197 respectively recorded in treatment B, the composite can be used in mass production of german cockroach. Further research can be done to find out an appropriate combination of organic substrates that can yield optimum productivity of *B. germanica*.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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