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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 ground as a novel solution to food and nutrition insecurity especially in sub-tropical and tropical countries. Edible insects such as cockroaches have potential to mitigate nutritional deficiencies, alleviate erratic supply of protein in feeds and also be reared on locally available organic substrates. This study investigated growth performance and survival of *Blattella germanica* reared on locally available organic matter substrates as treatments-spent brewers grain (Treatment A), Treatment B consisting (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 but there was significant difference in mature weight, average daily weight gain, live weight and survival during the 42 days of rearing period. The highest mature weight, overall performance index, survival was 90.25 mg, 197.35, 96% recorded in treatment B. Based on this findings, a single feed as used in this study was inferior to the composite(treatment) in all parameters of growth performance and survival thus it could be suitable substrate for mass production of *B. germanica* for feed and food.

INTRODUCTION

The number of people who have embraced entomophagy has rapidly increased across all cultures and society in the last two decades. Harvesting of wild edible insects for feed and food is not sustainable as their natural habitat such as forests are already overstretched and diminishing due to human activities, urbanisation and negative effects of climate change[1-3]. Domestication and rearing of these edible insects will help meet their demand as entomophagy is becoming entrenched in human culture especially when processed into ingredient or favourite

dishes and animal feeds[4]. Industrial production of insects (at least 1 tonne/day) is necessary to meet the demand of edible insects for food and feed[5]. Development of sustainable industrial production of edible insects faces many challenges including inefficient technologies, inbreeding and few studies on nutrition and feeding strategies that optimise output[6,7].

Irrespective of sex, insects utilize carbohydrates as source of energy at all stages of growth while protein is essential for egg production in female. In case a diet does not provide sufficient energy, supplementary energy is derived from by conversion of lipids into simple sugars (monosaccharides) during metabolism. It is always a challenge to get one feed stuff that can satisfy all nutrients requirements of insects hence insects will feed on several organic matter to satisfy their daily nutrients requirement [8]. Insects such as crickets, Black soldier fly, American cockroach have successfully been reared by feeding them on formulated broilers mash, organic wastes and dog food respectively. It has been reported that even though the nutritional requirements of most insects are relatively similar, the optimal sources, types and proportions of nutrients widely vary among species and reproductive stages[9].

Although industrial rearing of *Blattella germanica* (german cockroach) has not been achieved, small quantities have successfully been reared on dog biscuits for laboratory research especially for digestive physiology, neurobiology and pesticide studies[10]. In a previous research, German cockroaches preferred finely-ground carbohydrate-rich feed such as potatoes and bananas as opposed to protein rich feeds such pork and cheese[11].

Blattela germanica is processed into a paste and consumed as an edible insect in Mexico. It has excellent nutritional value, for instance it has been reported to contain a crude protein of 78% on dry matter basis against an average crude protein of 57.03% in the order blattodea thus has a potential as an animal feed[7]. Besides, the crude protein is higher than conventional feed stuff used in animal feeding such as fish meal (55-60% CP). Although the growth performance of some edible insects such as crickets, housefly and black soldier fly when fed on organic matter has been documented, there is limited documentation on growth performance of *B. germanica* when reared in restricted conditions.

The aim of this study was to determine the effect of selected organic matter substrates on growth performance and survival of Blattella germanica cockroach.

MATERIALS AND METHODS

Study site: KALRO-Kakamega lies within Kakamega County lies at an altitude of 1585 m above sea level, latitude of 00016'N, longitude of 34045'E, The mean annual rainfall is 1883.96 mm, average mean temperature is 21.00 C, average maximum temperature is 27.00 C average minimum temperature is 14.00 C, average evaporation 120 mm and average day length 12 h. This area is classified as an agro ecological zone that is very ideal for livestock and crop production[12].

Optimization cockroach colony: New colonies of German cockroaches were trapped in a deserted building by baiting using an improved trap made of a plastic stacked with carton egg trays. The colony was transferred to a rearing room at Kenya Agricultural and Livestock Research Organisation in Kakamega County, Western Kenya region.

Within the rearing room, the floor was littered with wood shavings, the wall was painted in cream to reduce light reflection and completely sealed with allowances for sufficient ventilations. The colony was split into three groups of approximately sixty each and placed into an improvised rearing container.

Experimental design and treatment diets: Each Improvised Container (IC) was a 60 L capacity (diameter of 60 cm and height 80 cm) with wide-mouth plastic brown in colour covered with a tight-fitting lid. The lid had two rectangular provisions for ventilation, each ventilation measured 30 by 5 cm and was also screened with a mosquito net. Six inches from the top of IC, the inner surface of the container was coated with petroleum jelly to ensure the cockroaches were unable to climb out. Three carton egg trays were placed in each IC for hiding and anchorage. Environmental conditions within the room allowed for 24 h darkness at about 22-30ºC room temperature and 48-75% relative humidity.

Experimental procedures: The feed intake trial was set in a completely randomised design with four diets as treatments. The treatment diets consisted of Treatment A (dry spent brewer's grain) Treatment B (40% dry spent brewers grain: 40% wheat pollard: 20% *C. nilotica*), Treatment C (wheat pollard) and Treatment D (Freshwater shrimp-*C. nilotica* locally known as Ochong'a). Each treatment was replicated four times in the improved containers as described above. For each replicate, 25 nymphs aged 1-3 days were weighed before being put in each of the IC.

Clean water was provided at ad libitum by placing it on picnic trays with cotton wool to provide for anchorage. Fresh feed was added to feeding trays, after every seven days remnant feed-substrate was weighed, discarded and new feed added. Each IC was checked every day to identify and record any mortality. After 21 days, cockroaches were aspirated, group weighed and the average weight determined Each IC was also inspected daily to check presence of gravid females. Data collection was carried out for a period of 42 days.

Chemical analyses and calculations: The proximate components of Dry Matter (DM), ash, crude protein (CP), Crude Fibre (CF), Ether Extracts (EE) and Nitrogen Free Extracts (NFE) of the diets were analyzed according to the association of official analytical chemists[13] methods. The estimates of Metabolizable Energy was determined using the standard formulae[14]:

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

$$\text{Average daily feed intake} = \frac{\text{Final weight of substrate} - \text{Initial weight of substrate}}{\text{Total No. of days during the substrate intake}}$$

$$\text{Average growth rate} = \frac{\text{Final liveweight} - \text{Initial liveweight}}{\text{Total number of days}}$$

$$\text{Survival} = \frac{\text{Final Number of live cockrooaches} \times 100}{\text{Initial number of live cockroaches}}$$

$$\text{Overall performance index} = \text{Growth rate} \times \text{Survival}$$

$$\text{Feed conversion ratio} = \frac{\text{Total feed(Substrate)intake}}{\text{Total weight gain}}$$

Statistical data analyses: Data were analysed using R software version R 4.1.2 accessed under GPL. Data was subjected to one way analysis of variance with the different substrates as the treatment effect with an alpha of 0.05 was used to declare statistical significance. Means that were significantly different were separated by least significant difference.

RESULTS AND DISCUSSION

The dry matter, etabolizable energy and proximate composition of *B.germanica* feed-substrate are as recorded in Table 1 below. *A,* Spent Brewers grain; B, 40% SBG: 40% WB: 20% FS; C, Wheat Bran; D, Freshwater shrimp (FS) Treatment D had the highest level of Metabolizable energy and crude protein at 3031 Kcl kg^{-1} and 52.8%, respectively. Treatment B had a crude protein of 23% which is within recommended nutrient requirements of *B. germanica*. 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 $p \leq 0.05$

At the beginning of the experiments the german cockroaches weighed same but there was significant difference on weight at twenty-one days ($p<0.05$) as shown in Table 2. Treatment B recorded the highest mean weight at 44.25±0.48 mg but the least was for Treatment C which was 33.25±0.85 mg. Highest final mean weight at 42 days was recorded in Treatment B at 86.25±0.85 mg followed by treatment D and least for treatment C but the three means were significantly different ($p<0.05$). The difference in weight could be attributed to the nutritional composition of diets. Although Treatment D had the highest level of CP and ME as indicated in Table 1, it came second in terms weight gain compared to Treatment B which was second in terms of CP and ME. Although the mineral and amino acids profiles were not analyzed for the substrates, it is possible that the mix (treatment B) had a more balanced nutritional profile unlike the single ingredients.

The weight at 42 days was slightly consistent with those of Melampy and Maynard[15]. Who found mature weight at 42 days ranged between 77 and 80.2 mg. *Blattela germanica* also responded well to a mixture of wheat and skim milk than those of meat and cereals and were noted to be able to convert excess protein to lipids[15].

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 $p \leq 0.05$.

A significant difference ($p<0.05$) in average growth rate was recorded among all the treatment except 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 growth rate. The average feed intake was significantly different for all treatments during the whole period of study as indicated in Table 3. All the treatments were ground to less than 1 mm and thus all the cockroaches consumed to their maximum capacity. Based on texture, wheat barn is more course than brewer's waste and *C. nilotica* could be attributed to its high fibrous nature. In a study on intake and preference of nutrients in B. germanica, there was preference and higher intake reported for carbohydrates than protein. The most preferred feeds were potatoes, bananas and bread[9,11]. 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[16].

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. 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

Table 1: Nutrient and proximate composition of treatments diets

Treatment diet	Description	DM	ME (Kcl kg^{-1})	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	34.0	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	7.0	11.6	9.7

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)
A	4	35.00 ± 0.41^{c}	79.25 ± 0.95^{c}	75.00 ± 1.08^{c}
B	4	44.25 ± 0.48^{a}	90.25 ± 0.85^{a}	86.25 ± 0.85^{a}
C	4	33.25 ± 0.85^{c}	76.50 ± 0.29^{c}	72.50 ± 0.29^{c}
D	4	39.50 ± 0.87^{b}	84.75 ± 0.85^{b}	80.75 ± 0.85^{b}
		p = 0.0000	p = 0.0000	p = 0.0000

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

Treatments	Average growth rate (mg)	Average feed intake (mg)
A	1.79 ± 0.03^{c}	2.50 ± 0.25^{a}
B	2.06 ± 0.02^{a}	2.05 ± 0.24^{a}
C	1.73 ± 0.01^{c}	1.67 ± 0.29^{a}
D	1.92 ± 0.02^{b}	$2.02.75\pm0.34^{a}$
	p = 0.0000	p = 0.2765

Table 4: Percent mortality, survival and overall perfomance of blattela germanica reared on difference organic substrates

Treatments	Mortality (%)	Survival (%)	Overall performance index
A	15.50 ± 2.60^{ab}	84.50 ± 12.60^{ab}	150.68 ± 3.18^{c}
B	4.00 ± 1.63^{b}	96.00 ± 1.63^{a}	197.35 ± 4.91^{a}
C	17.05 ± 2.84^{a}	83.00 ± 3.24^{b}	143.17 ± 5.53^{c}
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

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 protein optimum growth and survival. 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%[8].

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 $p \leq 0.05$.

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 results, 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 imply that although single organic substrates can support life of cockroaches, the performance is not optimum. Mixing more than one organic substrate yield better survival and performance. In previous studies, it has been shown that availability of food and water affects the survival and development of cockroaches. In an earlier studies, reported a variation in growth, longevity, moulting and reproduction of *B. germanica*. It was also noted this varriation was pronounced in females than males cockroaches.

CONCLUSION

This study has shown that it is possible to rear *B. germanica* using improvised 60 L capacity containers with slight modification to allows 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 comparatively higher volume. There is need for more studies to find out an appropritae combination of organic substrates that can yield optimum productivity of *B. germanica*.

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