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COMPARATIVE ASSESSMENT OF THE NUTRITIONAL PROFILE OF *HERMETIA ILLUCENS* REARED ON BRAN-BASED RESIDUES AND ORGANIC WASTES

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ABSTRACT

Hermetia illucens (black soldier fly) is a promising alternative protein source due to its high nutritional value, rapid growth, and capacity to utilize organic wastes. This study evaluated the nutritional composition of larvae on five substrates; corn bran, millet bran, tigernut bran, wheat bran, and poultry mash (control) all reared under controlled laboratory conditions (28 ± 0.5 °C; 70 ± 0.5% RH). Proximate analysis revealed significant substrate-dependent variations. Larvae fed corn bran recorded the highest crude protein (47.75%) and fat (64.79%), followed by tigernut bran (44.43% protein; 54.70% fat). Moisture content ranged from 36.16% to 82.84%, while crude fiber (1.26–3.97%) and carbohydrate (3.47–7.26%) showed minimal variation. Mineral analysis indicated higher calcium levels in larvae reared on corn and tigernut bran, with negligible heavy metal accumulation. Overall, corn and tigernut bran produced nutritionally superior larvae, demonstrating their potential as cost-effective substrates for sustainable insect farming and improved feed security.

Keywords: Waste, biodegradation, proximate composition, by-products, black soldier fly larvae

INTRODUCTION

Interest in insect-based nutrition has grown as a result of the global need for sustainable and eco-friendly protein sources (Nirmal *et al*., 2025). Among the various insect species investigated, the black soldier fly (*Hermetia illucens*) has emerged as a highly promising alternative protein source. This is largely due to its rich nutritional profile, rapid growth cycle, and ability to thrive on a wide range of organic waste materials (Amrul *et al*., 2022). Notably, black soldier flies have demonstrated a highly efficient feed conversion ratio (FCR), ranging from 1.58 to 8.90, depending on the substrate used (Broeckx *et al*., 2021). This means that between 1.58 kg and 8.90 kg of substrate such as food waste, palm kernel waste, brewers spent waste is required to generate 1 kg of black soldier fly larval biomass, reflecting substrate-dependent efficiency in biomass conversion., making them especially suitable for sustainable animal feed production (Makkar et al, 2014; Spranghers et al., 2017).

With the global population projected to reach 9.7 billion by 2050, there is increasing pressure on existing food systems, particularly in regions like Africa, where food insecurity and high feed costs present significant challenges for livestock

production (Chisoro *et al.,* 2023). Insect farming especially using BSF offers a practical, cost-effective, and scalable solution to address these issues by providing an alternative protein source that is both sustainable and nutritionally adequate (Odongo *et al*., 2024).

The nutritional composition of Black Soldier Fly (BSF) larvae is known to be significantly influenced by the substrate on which they are reared (Spranghers *et al*. (2017). Therefore, it is imperative to assess how different locally available organic by-products affect their nutrient profile. Previous studies have underscored the nutritional value of BSF larvae and their efficacy as animal feed (Barragan-Fonseca *et al.,* 2017; Spranghers *et al*., 2017). For instance, Barragan-Fonseca *et al.* (2017) highlighted their potential as a sustainable protein source, while Spranghers *et al*. (2017) demonstrated that the larvae's nutrient content can be modulated by the type of rearing substrate. Other research has explored dietary enhancements, such as enriching BSF larvae with omega-3 fatty acids (Barroso *et al*., 2017), further underscoring the versatility and adaptability of BSF as a feed component.

Moreover, comprehensive reviews by Makkar *et al*. (2014), Kannan *et al*. (2022), and Fukuda *et al*. (2022) have documented the potential of BSF as a protein source for various livestock species, including poultry, swine, aquaculture species, and even cattle. In many cultures, edible insects such as Black Solidier Fly (BSF) are also recognized as traditional food sources, offering culturally appropriate solutions with strong prospects for future integration into food systems (Shit 2021). In many parts of Africa, substantial quantities of agro-industrial by-products such as corn bran, millet bran, tigernut bran, and wheat bran are generated during grain processing. Unfortunately, these nutrient-rich residues are often underutilized or discarded due to spoilage concerns (Archibong, *et al*., 2018; Kittur *et al*., 2025). These by-products, rich in fiber, carbohydrates, and essential nutrients, hold significant potential as cost-effective and sustainable rearing substrates for BSF larvae (Kittur *et al.,* 2025).

This study, therefore, investigates the nutritional composition of black soldier fly larvae reared on four different agricultural by-products; corn bran, millet bran, tigernut bran, and wheat bran to compare their nutritional profiles to those of larvae reared on commercially available poultry mash. The outcomes of this research are expected to inform optimal, low-cost BSF rearing strategies that can enhance their utility as a sustainable protein source, ultimately contributing to improved food security and reduced livestock feed costs across Africa.

MATERIALS AND METHODS

The study was conducted in the Postgraduate Laboratory of the Department of Zoology and Environmental Biology, Lagos State University, Ojo. The laboratory is situated on the first floor of the Faculty of Science's new building (6º27’58’.2’’N, 3°12’01.5’E). The study was conducted at a temperature of 28 °C ± 0.5 and relative humidity 70 ± 0.5%, photoperiod 12:12 (L:D).

Collection of Material

Poultry mash was obtained from the local market, the commercially available brand in Lagos.

The corn bran was produced by blending yellow maize into a paste, and the fluid was extracted, which is the pap commonly known as akamu or ogi.

The wheat bran was obtained by sieving wheat flour, which separated the fine flour

particles from the coarser bran and bran components.

The millet bran used for the study was obtained from a local kunu seller. They were neatly brought to the lab and sun-dried for 3 days.

Tigernut bran used for this study was obtained from blended hydrated tigernut seed. The bran was gotten from the tigernut drink after it was sieved, then it was sun-dried for three days (Archibong *et al*., 2018).

All the bran was individually dried in the laboratory oven at 50℃ for 2 hours. This was done to kill any weevils and their eggs present, preventing them from hatching and infesting the BSF larvae culture (Singh *et al*., 2019).

Preparation of Materials

Hermetia illucens larvae were reared on different food waste, which includes corn chaff, wheat bran, Tigernut bran, millet bran, and poultry mash. Each container of waste substrates was composed of 20mg/larvae/day, fifty newly emerging 1st instar larvae were introduced, and 100ml of distilled water was added daily to moisten the mixture, following Kinasih *et al*., (2018).
The setup was replicated four times for each rearing substrate. The medium was reared in the laboratory until they attained the prepupa stage. Matured prepupa were collected manually six days after their emergence from each replicate into separate containers, and they were packed and stored at -20 °C. (Dortmans *et al.,* 2017).

Moisture

Moisture was determined by gravimetric measurement after drying 5g of homogenized sample in a hot-air oven at 103 °C for 2 hours. The moisture content was then calculated (Kim *et al.,* 2023) as:

$$Moisture\ (\%) = \ weight\ loss\ \times \frac{100}{initial\ weight}$$

Ash

Ash content was determined by incinerating 2.5 g of the pretreated sample in a furnace at 600 °C for 3 hours, or until a light grey ash was produced. The ash was allowed to cool in a desiccator, before being weighed (Kim *et al*, 2023). The ash content was then calculated (AOAC, 2016) as:

$$Ash\ (\%) = \ weight\ of\ ash\ \times \frac{100}{initial\ weight}$$

Protein

The Kjeldahl method was performed according to a modification of method 981.10 of the AOAC International. A portion (1g) of the pretreated sample was hydrolyzed with 15 ml concentrated sulfuric acid containing two copper catalyst tablets in a heat-block at 420 °C for 2 h. After cooling, distilled water was added to the hydrolysates, followed by neutralization with dilute NaOH solution. The mixture was then diluted to 50 mL with distilled water. The nitrogen content was determined by the salicylate colorimetric method (Hach Method 10023) at 650 nm (Kim *et al*., 2023).
The nitrogen content in the sample was multiplied by a factor of 6.25 in order to determine total protein content.

$$Crude\ Protein\ (\%) = NH_3N\ (mg/\mathrm{L})\ x\ 6.25\ x\ 10^{-4}$$

Total Carbohydrate: Phenol Sulphuric acid Method

One gram of a homogeneously prepared sample was hydrolyzed with 10 ml of 0.5M HCl at 100°C for 4 hours. An aliquot of the hydrolysate was then reacted with 1 ml of 5% solution of phenol to form a yellow-brown complex. The complex was reacted with 5 mL of conc. sulfuric acid, and the mixture was incubated for 20 min at 25-30°C (AOAC, 2016). The resulting solution was measured with a spectrophotometer at 490 nm, against a blank and carbohydrate standard solutions.

Crude Fibre

Crude fibre was determined by extracting 2.5 g of the pre-treated sample, in a thimble, with hexane for 6 hours to free the sample of fat. Thereafter, 50 ml of 1.25% sulphuric acid was added to 1.25g of the residue to remove the digestible nutrient. The residue resulting from the mixture was filtered in a Buchner funnel, washed with hot distilled water, transferred to a beaker, and then boiled with 50 ml of 1.25% NaOH solution. The solution was filtered, and the residue washed with distilled water. Thereafter, the residue on the filter paper was ignited in a muffle furnace at 600 °C for 30 minutes. The ash was cooled in a desiccator and weighed (AOAC, 2016).

$$Crude\ Fibre\ (\%) = \ weight\ ash \times \frac{2 \times 100}{initial\ weight}$$

Crude Fat

The fat content was determined by extracting 10 g of sample with 25 ml of petroleum ether with a soxhlet extractor, at 60-70°C, for 2 hours. The extract was evaporated at low heat (40°C) and the residue allowed to cool in a desiccator before being weighed (AOAC, 2016). The crude fat was determined as (AOAC, 2016).

$$Crude\ fat\ (\%) = \ weight\ of\ residue \times \frac{100}{weight\ of\ sample\ extracted}$$

Sample Pre-treatment for Determination of Minerals and Heavy Metals

One gram each of the homogenized (pre-treated) sample was separately placed in a porcelain crucible and then ignited in a muffle furnace at 550 °C for 4 h, or until ashed. The ash was dissolved in 4 ml of (1+1) HNO_3, and the mixture was then heated on a heat block at 95°C for 10 min. The digest was filtered, and the filtrate was adjusted to 25 ml with distilled water and saved for the determination of the metals by Inductively Coupled Plasma-Optical Emission Spectrometry (Bertenelli *et al*., 2000; AOAC, 2016).

Calibration Standard Solutions

Standard multi-element calibration solutions of the metals (01.0-5.0 mg/L, each) were prepared for the calibration curves. The solutions were prepared from the stock standard reference solution of the individual metal (1000 µg/ml) by appropriate dilution, in a volumetric flask, with deionized water. A reagent blank and the prepared sample were determined against 3-5 calibration standard solutions of the individual metals. Metal quantitation in the sample solution was obtained with Agilent ICP Expert II software (AOAC, 2016).

Determination of Metals and Trace Elements by ICP-OES (EPA Method 200.7)

The EPA method was used for the determination of the specified metals in the

samples. Standard multi-element calibration solutions of the metals (1.0 – 5.0 mg/L, each) were prepared for the ICP-OES calibration curves (AOAC, 2016). The levels of the metals in the samples are in mg/100g, and calculated as follows:

$$metal\ (mg/100g) = \ mg/L \times \frac{Vf \times 0.1}{weight\ of\ sample}$$

Where: mg/L = concentration of sample solution, V_f = final adjusted volume of digested sample (ml) = 25ml, 0.1 = factor for conversion from mg/kg to mg/100g (AOAC, 2016)..

RESULTS

Black soldier flies were successfully reared on all the substrates, at an average rearing temperature of 28^{o}C and relative humidity of 76%.

The proximate composition analysis revealed significant variations in the nutritional content of *H.illucens* prepupa cultivated in all the waste tested (Table 1). Moisture content ranged from 36.16% in wheat bran to 82.84% in tigernut bran. Crude protein content was highest in corn bran (47.75%), followed by tigernut bran (44.43%), and lowest in millet bran (19.01%). Crude fat content was highest in corn bran (64.79%), followed by tigernut bran (54.70%), and lowest in millet bran (20.14%).

There was not much variation in the Crude fibre content in all the substrates, ranging from 1.26 ± 0.13 to 3.97±1.57, while Carbohydrate content varied significantly within the substrates with values between 2.18% and 7.26%, indicating that corn bran is also a good source of carbohydrates.

Overall, the results suggest that Tigernut bran and corn bran waste performed better in terms of nutritional quality for rearing *Hermetia illucens*, having high protein and fat content, while millet bran has the greatest amount of moisture.

Table 1: Proximate Composition of *Hermetia illucens* Larvae reared on Different food waste

Proximate Composition (%) Mean ± Sd	**Corn Bran**	**Poultry Mash**	**Tigernut Bran**	**Millet Bran**	**Wheat Bran**
Moisture	64.44 ± 0.75^b	45.11±0.55^d	82.84±0.37 ^{a}	51.68 ±0.59^c	36.16 ± 0.37^e
Crude Protein	47.75 ± 0.95^a	24.04 ±0.05^d	44.43± 0.17^b	19.01 ± 0.15^e	28.43± 0.21^c
Crude Fat	64.79 ± 0.17^a	23.88 ± 0.65^c	54.70±0.66^b	20.14 ± 0.33^e	21.93 ± 0.04^d
Crude Fibre	3.49 ± 0.16^b	3.29± 0.17^b	3.97±1.57^a	2.42 ± 0.10^c	1.26 ± 0.13^d
Ash	12.27 ± 0.37^a	1.50 ± 0.44^e	9.12±0.26^b	2.98 ± 0.02^d	5.94 ±0.09^c
Carbohydrates	7.26 ± 0.36 ^{a}	2.18 ±0.04^d	4.96±0.49^b	3.83 ± 0.33b^c	3.47 ± 0.57^c

Triplicate values are presented as Mean±Standard Mean Error; Means with different superscripts on the same rows are significantly different at 5% probability level according to LSD.

In terms of Mineral composition, prepupa reared on Corn bran and Tigernut bran recorded high Calcium content (193.32±0.71) and (103.33±1.83) which was significantly higher than those reared on standard poultry mash (Table 2). Similarly, there was no significant difference in the Sodium content of prepupa reared on Tigernut bran and Corn bran. Copper, Lead and Chronium were low in prepupa reared

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Table 2: Mineral composition of *Hermetia illucens* prepupa reared on different waste

	Calcium (mg/100g)	Magnesium (mg/100g)	Sodium (mg/100g)	Potassium (mg/100g)	Copper (mg/100g)	Chronium (mg/100g)	Lead (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Phosphorus (mg/100g)
Corn Bran	193.32±0.71 [a]	96.97±1.21 [b]	2.68±0.15 [ab]	622.07±2.41 [a]	0.011±0.001 [c]	0.001±0.0001 [c]	0.0002±0.000 [a]	19.86±1.02 [a]	34.75±0.90 [a]	579.86±5.40 [b]
Poultry Bran	15.46±0.39 [e]	20.50±0.34 [e]	1.53±0.23 [c]	264.57±8.99 [d]	0.03±0.001 [b]	0.001±0.000 [c]	0.0002±0.000 [a]	3.95±0.211 [d]	8.60±0.42 [d]	312.65±4.68 [c]
Tigernut	103.33±1.83 [b]	107.68±0.56 [a]	3.23±0.19 [a]	527.02±5.05 [b]	0.014±0.001 [c]	0.001±0.000 [c]	3.34±3.33 [a]	12.17±0.53 [b]	26.13±1.43 [b]	628.77±5.71 [a]
Millet Bran	19.91±0.40 [d]	26.27±0.65 [d]	2.40±0.25 [b]	209.53±9.82 [e]	0.053±0.001 [a]	0.001±0.000 [c]	0.001±0.000 [a]	1.25±0.13 [e]	6.81±0.14 [d]	196.82±3.75 [d]
Wheat Bran	35.80±1.43 [c]	41.95±0.81 [c]	0.96±0.06 [c]	296.16±3.75 [c]	0.0103±0.0001 [c]	0.001±0.000 [c]	0.000±0.000 [a]	7.813±0.168 [c]	11.57±1.06 [c]	191.24±1.40 [d]

Triplicate values are presented as Mean±Standard Mean Error; Means with different superscripts on the same column are significantly different at 5% probability level according to LSD.

DISCUSSION

Research on *Hermetia illucens* (Black Soldier Fly, BSF) is increasingly motivated by the need for sustainable alternatives to conventional protein sources in livestock and aquaculture feeds. Rising demand and costs associated with fishmeal and soybean meal have intensified interest in environmentally and economically viable feed ingredients (Shit, 2021). Black soldier fly larvae (BSFL) are particularly suitable in this regard due to their capacity to efficiently convert organic waste into nutrient-dense biomass (Siddiqui et al., 2022). This study evaluated the nutritional potential of BSF prepupae reared on selected agricultural waste substrates, with the aim of assessing their suitability as cost-effective nutrient sources for poultry and livestock production.

The proximate composition of BSF prepupae differed significantly among the tested substrates relative to poultry mash. Protein content, a key nutritional requirement for poultry (Korver, 2024), varied notably across treatments. Prepupae reared on corn bran and tigernut bran recorded higher protein levels than those reared on wheat bran, millet bran, and poultry mash, indicating substrate-dependent nutrient accumulation. The protein content observed in this study (19.01–47.75%) aligns with values reported by Spranghers et al. (2017), who documented prepupal protein levels of 33.1–43.1% when larvae were reared on restaurant waste. These findings confirm that substrate composition strongly influences the protein yield of BSF prepupae.

Crude fat content also varied significantly across substrates. Prepupae reared on corn bran (64.79 ± 0.17%) and tigernut bran (54.70 ± 0.66%) exhibited substantially higher lipid levels than those reared on poultry mash (23.88 ± 0.65%), while millet bran produced the lowest fat content (20.14 ± 0.33%). Elevated lipid accumulation in larvae reared on corn and tigernut bran suggests their suitability for producing energy-rich feed ingredients, consistent with observations by Muhammad *et al.* (2022). Corn bran produced higher crude fibre, ash, and carbohydrate levels than poultry mash, further confirming that rearing substrate composition plays a significant role in shaping the chemical profile of BSFL, as reported by Meneguz *et al*. (2018).

Comparative proximate analysis further highlights substrate effects on larval composition. Spranghers *et al*. (2017) reported higher moisture, protein, and fat contents in larvae reared on tigernut-based substrates compared with wheat chaff, a trend partially reflected in the present study. While corn bran supported higher crude protein levels, poultry mash produced a more balanced fat–protein ratio and lower ash content, which may influence digestibility. Lower ash levels in poultry-mash-fed larvae suggest reduced incorporation of indigestible material, whereas higher ash content in wheat-based substrates may reflect increased mineral or non-organic fractions.

Mineral composition varied across substrates but remained within nutritionally relevant ranges. Larvae reared on poultry mash contained higher levels of calcium (15.43 mg/100 g), magnesium (20.50 mg/100 g), and phosphorus (312.65 mg/100 g), indicating their potential value for mineral supplementation in animal diets. In contrast, larvae reared on wheat chaff and corn bran showed higher concentrations of iron and zinc, which are essential trace elements for poultry and fish nutrition (Nguyen *et al*., 2015; Barragan-Fonseca *et al.*, 2017). Specifically, larvae reared on corn bran recorded higher iron (9.35 mg/100 g), phosphorus (345.79 mg/100 g), and zinc

(17.30 mg/100 g) compared with those reared on poultry mash.

Notably, prepupae reared on tigernut bran exhibited a high calcium content (103.33 ± 1.83 mg/100 g), corroborating the findings of Omeje *et al.* (2022), who reported high calcium levels in whole tigernut. This suggests that tigernut-based substrates may enhance calcium bioaccumulation in BSF prepupae.

From an economic and sustainability perspective, corn bran and tigernut bran are agricultural by-products that are often underutilized or discarded, making them relatively inexpensive compared to commercial poultry mash. Their use as BSF rearing substrates may therefore reduce feed production costs while contributing to waste valorization. However, further studies are required to evaluate BSF growth performance, feed conversion efficiency, and scalability when reared on tigernut bran to fully establish its practical applicability in commercial production systems

CONCLUSION

In conclusion, the proximate composition analysis revealed that corn bran and tigernut bran are nutrient-rich ingredients that can be used to formulate balanced poultry feed. However, proper drying and processing are necessary to ensure the quality and safety of these ingredients

Also using black soldier fly larvae for waste management can convert agricultural by-products into high-quality feed. This practice not only reduces waste but also provides an additional income stream through larval production. By integrating black soldier fly farming into their operations, farmers can diversify their income. Selling larvae to aquaculture or livestock producers can provide additional revenue streams.

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Conflict of interest

The authors declare that there is no conflict of interest to declare.

CRediT author statement

AAO: Conceptualization, Project administration, Funding acquisition, Writing- Review &Editing, Methodology AKO: Investigation, Writing-Original draft preparation, Writing-Review &Editing GAO: Investigation, Formal analyses, AK: Investigation, Writing-Original Draft preparation; GZO: Formal analyses, Data curation, Visualization, Writing-Original Draft preparation; OML: Investigation, Formal analyses, Writing-Original Draft preparation;

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