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Evaluation of *Musca domestica* (House fly) larvae production from organic waste

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Abstract

The objective of the study was to investigate the effect of organic waste (pig manure and chicken layer droppings) on the production of house fly larvae (HFL) and its nutritive value. A completely randomised design was used, with three treatments (pig manure, chicken layer dropping and equal combination of the pig and chicken excreta) replicated six times. The data for biomass reduction, larvae wet and dry weight, moisture, ash, crude fibre, crude protein, fat, calcium and phosphorus were analysed using analysis of variance. While the least square means were generated using the Tukey's honestly significant difference. Pig manure produced the highest yield of HFL significantly ($P < 0.05$), as indicated by both wet (3.61 g) and dry (0.63 g) larvae weight. Introduction of HFL reduced organic waste by 39–42%. Furthermore, results indicated HFL to contain high protein 50-53%, considerable levels of Ca (1.32–1.465%) and P (1.72–2.09%) on as is basis. It can be concluded that pig manure and chicken layer droppings are suitable substrates for the production of HFL, which contain a suitable nutritional value for use as a protein source in animal diets. The study recommends further studies on HFL production on a larger scale for inclusion in animal diets.

Keywords: Poultry manure, droppings, insect protein.

1. Introduction

The world population is increasing rapidly and predicted to reach 9 billion by the year 2050 (United Nations, 2009), creating a higher demand for food to feed the growing population (Dar & Gowda, 2013). Due to increase in population and disposable income, the global demand for animal protein is increasing (Food & Agriculture Organization, 2009). Broiler production represents one of the most economical and easiest means of bridging the supply-demand gap of animal protein in human diets, due to their rapid growth rate and superior feed conversion ratio (Khurso, Andrew, & Nicholas, 2012). Broiler production feed cost takes up about 70% of operating costs (Teguia & Beynen, 2005), of which these diets contain mainly grains which are also consumed by humans, leading to competition. Therefore, to feed the rapidly growing human population, we need innovative changes in food production, of which many potential solutions may be incompatible with other challenges such as conservation of biodiversity and climate change mitigation (Berg, De Noblet-Ducoudré, Sultan, Lengaigne, & Guimberteau, 2013).

The poultry industry in developing countries has undergone rapid development, increasing its production and output (Téguia, Mpoame, & Mba, 2002). The cost and scarcity of feedstuffs, particularly the protein sources

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such as soybean cake, groundnut cake and fish meals are major factors limiting the further increase of commercial poultry production in developing countries (Adeniji, 2007). To tackle these problems, an innovative approach to feed production could be insect-derived protein sources using organic waste. This is in line with Sustainable Development Goals (SDG) of the United Nations to achieve food security and improved nutrition by finding innovative changes in food production.

Insects and their larvae are high in protein and fats, which are consumed daily by free-range or organic poultry production including wild birds and constitutes a large portion of their diets (Miao, Glatz, & Ru, 2005). Insect and their larvae have been utilised as a source of protein successfully in monogastric animals (Teguia & Beynen, 2005; Adeniji, 2007; Van Huis, 2012; Pieterse & Pretorius, 2014). Insect larvae can be produced from recycling organic waste such as manure and kitchen waste, which has been promising in fly species (El Boushy, Klaassen, & Ketelaars, 1985; Van Huis, 2012).

Production of house fly larvae (HFL) not only provides animal protein but also reduces the biomass of organic waste by lowering moisture content between 40-60% (Zhang, Wang, Zhu, Suneethi, & Zheng, 2012; Wang, Zhang, Czapar, & Winkler, 2013; Zhu et al., 2015). Biomass reduction provides an opportunity to easily handle and store organic matter (Pieterse & Pretorius, 2014) and can also be used as soil fertiliser (Zhu et al., 2015). However, there are minimal studies done on the production of house fly larvae in Namibia. Therefore, the objective of the study was to investigate the production of HFL using pig manure and layer chicken droppings at Neudamm campus.

2. Methodology

The study was conducted at the University of Namibia, Neudamm Campus located approximately 30 km east of Windhoek on the B1 road to Hosea Kutako International Airport and the town of Gobabis. The study explored two locally available organic waste (pig manure, layer chicken dropping), in a completely randomised design. The study consisted of three treatments namely layer chicken droppings (LCD), pig manure (PM) and a mixture of 50% layer chicken droppings and 50% pig manure (MIX) replicated six times. The nutritional content of HFL and its efficiency to utilise organic waste contained within the different substrates was evaluated.

2.1 Organic substrates and larvae growth

Three treatments replicated six times were used in a completely randomised design: 1) LCD, 2) PM and 3) MIX. The substrates were obtained and weighed into batches of one kg each then placed in 2 Litre (L) treatment containers which had openings on the top for aeration. After that, each substrate was moistened with 100 ml of water, to create a conducive environment for flies to lay their eggs. Furthermore, 5 g of ruminant offal was added to each treatment as a fly attractant. The study utilised a methodology as described by Odesanya, Ajayi, Agbaogun, & Okuneye (2011). The treatments were exposed to house flies for eight days, in temperature level of 25–30 ºC and light-controlled room. The samples were left in a fixed position for eight days, and thereafter larvae were harvested. Before the actual study trial begins, preliminary trials were done to determine optimal larvae stage for harvesting. Harvesting of larvae is discussed under section 2.3.

2.2 Biomass reduction

The treatment biomass reduction by house fly larvae was determined by comparing the weight of the substrate before exposure of treatment to house flies and after the production of larvae, as indicated in Formula 1.

$$Biomass\ reduction = \frac{Substrate\ weight - ((substrate\ weight + maggot\ weight) - larvae\ weight)}{Substrate\ weight} \times 100$$

2.3 Larvae harvesting

Harvesting of house fly larvae was done at day eight. The floating method of harvesting was used as described by Sogbesan, Ajuonu, Musa, & Adewole (2006). Warm water at ±50 ºC was placed in separate containers for each treatment replicate which killed the larvae enabling them to float. The larvae were then harvested using a sieve. The harvested larvae from each treatment were weighed separately. The wet weight (WW) was taken after harvesting; the larvae were then oven-dried for 24 hours at 105 °C to obtain the dry weight (DW).

2.4 Chemical analysis

The larvae were analysed for moisture, ash, fat, crude fibre (CF), crude protein (CP) and mineral content (phosphorus (P) and calcium (Ca)), at the Ministry of Agriculture Water and Forestry's analytical laboratory. The proximate analysis of the larvae samples was done according to acceptable standard methods as provided by the Association of Official Analytical Chemists International (2002).

2.5 Statistical analysis

The data were analysed using analysis of variance (ANOVA) procedure in the Statistical Analytical System (SAS) (2009). The least-square means were generated using the Tukey's HSD (honestly significant difference). The assumptions for normality and homoscedasticity were investigated before further analyses were done. The tests were considered significant at $P < 0.05$.

3 Results

The results are reported on as is basis. Treatment did not significantly ($P > 0.05$) influence biomass reduction, which ranged between 40–50% (Table 1). Furthermore, the results show that treatment did significantly ($P < 0.05$) affect wet and dry weight. Poultry manure larvae produced more larvae with a significantly higher wet (27.06 g) and dry weight (5.41 g) as compared to LCD (6.30 and 0.90 respectively) and MIX (3.61 and 0.63 respectively) which were not significantly different from one another (Table 1).

Table 1: House fly larvae biomass reduction and larvae yield

Parameters	Treatments			P-value
	PM	LCD	MIX	
Biomass reduction (%)	42.12 ± 0.95a	39.08 ± 2.08a	39.28 ± 0.97a	0.0620
Larvae wet weigh (g)	27.06 ± 4.55a	6.30 ± 2.46b	3.61 ± 1.68b	0.0002
Larvae dry weight (g)	5.41 ± 1.01a	0.90 ± 0.39b	0.63 ± 0.30b	0.0001

Values are the means and ± standard errors. Means with different superscripts within the same row differ significantly.

For proximate analysis, treatments did not significantly ($P > 0.05$) influence moisture, ash, CF and fat content of larvae (Table 2). However, treatment did significantly ($P < 0.05$) affect CP, with each treatment being statistically different from one another; PM 49.94%, LCD 50.81% and MIX 52.87%. The combination of pig and poultry (MIX) excreta produced larvae with a higher CP (52.9%) while pig manure had the least CP (49.9%) content (Table 2). The phosphorus and calcium content of the larvae were not significantly ($P > 0.05$) influenced by treatment (Table 2).

Table 2: Proximate analysis, P and Ca results of larvae on as is basis

Parameters (%)	Treatments			P-value
	PM	LCD	MIX	
Moisture	4.30 ± 0.01a	4.52 ± 0.01a	4.56 ± 0.01a	0.2025
Ash	10.72 ± 1.22a	12.84 ± 1.22a	10.16 ± 1.22a	0.1755
CF	10.13 ± 0.05a	9.43 ± 0.05a	9.54 ± 0.05a	0.0916
CP	49.94 ± 4.83c	50.81 ± 4.83b	52.87 ± 4.83a	0.0010
Fat	13.94 ±14.57a	8.16 ±14.57a	12.28 ±14.57a	0.4105
Ca	1.38 ± 0.01a	1.46 ± 0.01a	1.32 ± 0.01a	0.3276
P	1.72 ± 0.03a	2.09 ± 0.03a	1.72 ± 0.03a	0.2068

Values are the means and ± standard errors. Means with different superscripts within the same row differ significantly.

4. Discussion

Exposure of poultry and pig manure to house fly lead to a 39–42% reduction in organic matter, although no treatment differences were observed. Biomass reduction of organic matter is essential as it helps reduce the bulk of the waste and enables easy storage disposal or further usage (soil fertiliser) of the decomposed matter. These results are in agreement with other researchers who reported 40–56% organic matter reduction using HFL (Sheppard, 1983; Newton et al., 2005). The substrate biomass reduction by the HFL is attributed by the ability of the manure to attract flies and the number of larvae laid on the substrate resulting in reduced substrate biomass.

Although the treatment did not significantly influence biomass reduction, there was a significant ($P < 0.05$) treatment difference for larvae produced. The results showed that PM produced the highest yield of larvae translated by the obtained wet and dry weights when compared to LCD and MIX substrate (Table 1). The differences in larvae produced could be attributed to the tendency of insect to exhibit marked preferences for the particular substrate for oviposition (Zvereva & Zhemchuzhina, 1988), which in this study house fly was mostly attracted to poultry manure. However, sites for oviposition could have been influenced by other factors such as level of oxygen, moisture, nutritive value of the substrate and the presence or absence of an oviposition attractant, in turn affecting the number of larvae produced (Shipp & Osborn, 1967; Lysyk, 1991; Zhu et al., 2012). Since oxygen, moisture and nutritive value of substrates were not tested in this study, one cannot base increased yield on any of the factors. However, during this study, it was sensed that PM had a strong aroma compared to others; this could have attributed to their significantly higher yield of larvae. The lower larvae yield of the other two treatments could have been attributed to the water holding capacity of the two substrates, as egg hatching would not occur if substrate moisture level is too low or waterlogged (Odesanya et al., 2011), or by high density of the substrates which decreases the aerobic condition affecting development and survival of eggs and larvae (Aniebo, Erondu, & Owen, 2008).

Poultry manure, LCM and MIX larvae had CP content of 50, 51 and 53% respectively. The CP content of HFL in this study is in range with that reported by various authors ranging between 40–60% (Inaoka, Okubo, & Yokota, 1999; Aniebo & Owen, 2010; Odesanya et al., 2011). Hwangbo et al. (2009) reported a higher CP (64%) content in house fly larvae grown on chicken droppings sprinkled with powdered milk and sugar. Fasakin, Balogun, & Ajayi (2003) reported lower CP (45%–48%) in house fly larvae. Higher protein values found in HFL could be attributed to the higher nutritional content of the substrates, as an author with higher CP values included additives to their substrates. Shipp and Osborn (1967) reported a large number of egg collection and hatching of house fly feed milk-based diets. Furthermore, the fat contact obtained in this study was low (8.16–13.94%) even though reported on as is basis, compared to other authors ranging between 16.35–25.3% (Inaoka et al., 1999; Hwangbo et al., 2009; Aniebo & Owen, 2010). According to Tran, Heuzé,

& Makkar (2015), fatty acid profiles of insect larvae are pre-determined by the fatty acid content of the substrates on which they are grown, which could have led to the high variability in fat content obtained in this study and other authors.

The CF (9–10.13%) content on as is basis reported in this study is higher than that reported by Aniebo and Owen (2010) and Odesanya et al. (2011). However, it is important to note that Odesanya et al. (2011) and Aniebo and Owen (2010) harvested their larvae at day four, which could have led to low CP content as the exoskeleton is still forming. Mineral results for P and Ca indicated no significant ($P < 0.05$) differences although biologically LCM produced HFL high in P (2.09%) and Ca (1.46%) while lower in MIX being 1.72% and 1.32%, respectively. The phosphorous obtained in this study was high compared to that reported Nzamujo (1999) and by Odesanya et al. (2011) being 0.97% and 1.2% respectively.

4 Conclusion

It can be concluded that HFL can be produced at Neudamm Campus using PM, LCD and an equal combination of PM and LCD, with the addition of a fly attractant. The HFL produced was found to contain suitable nutritional composition for use as alternative protein sources in animal feed, with CP content as high as 53%. Furthermore, house fly larvae were proven to reduce organic matter used by 40–50%, making organic waste easier to handle, store and can potentially be used as a soil fertiliser for crop production. This study warrants further studies looking into the correlation between the nutritional value of substrates and larvae, digestibility of HFL and its effect on the growth of monogastric and ruminant animals.

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