Original Research Article

Production and valorization of maggot meal: sustainable source of proteins for indigenous chicks

.

ABSTRACT

Aims: The feed industry needs new sources of highly digestible protein to substitute other valuable limited protein sources of animal origin such as fishmeal in animal feed. The aim of this study was to exploit the potential of the housefly larvae (maggots) in production of a low-cost, high-quality protein source to supplement feeds for poultry farmers.

Methodology: A trial on production of maggot meal was conducted at the farm of the University of Dschang, using substrates such as: cow dung, chicken manure and pig manure. These substrates were supplemented with fish waste which was used as a seed. A completely randomized design with three treatments (substrates) and four replicates was used. After harvest, the maggots were dried and ground to get maggot meal which was used in the diets of 45 on-day-old, non-sexed indigenous chicks. For growth experiments, a random design of three treatments and three replicates was used. Fishmeal was partly and totally substituted by maggot meal in two experimental diets, which were used to feed two groups of 15 chicks. A third group of 15 chicks was fed with a control diet, without maggot meal. Each chick was considered as an experimental unit and was fed for a period of eight weeks.

Results: Maggots were harvested four days after oviposition regardless of the substrate. Supplement with fish waste, maggots production of differences substrates doesn't show significant difference (P>0.05). The productivity of pig manure was slightly higher (260.32±73.18g), followed by chicken manure (254.12±50.59g) and cow dung (249.97±72.44g). The chicks subjected to the experimental diet in which the fishmeal has been totally substituted by maggot meal recorded significantly higher average weight gain (886.60±158.50g) as compared to those subjected to the partially substituted and control diets, which recorded 650.59±103.50g and 611.20±136.90g, respectively at the end of the experiment.

Conclusion: The results indicated that maggot meal can be used as an alternative to fishmeal in poultry feed.

Keywords: Farmer, Poultry, Fishmeal, Housefly larvae, Substrate.

1. INTRODUCTION

Intensification of agricultural production into a profitable and competitive livestock enterprise is one of the options to increase food production and reduce urban and rural poverty in Africa [1]. The poultry industry is one of the fastest growing agribusinesses in sub-Sahara Africa providing income and employment opportunities for the population [2]. In Cameroon for instance, the poultry sub-sector accounts for about 55% to the livestock sector and contributes 30% of the agricultural gross domestic product (GDP). Therefore, it is an important part of rural household livelihoods as a source of food, income, nutrition, insurance against emergencies and has the potential to reduce poverty. The annual global turnover and sale of commercial feed is estimated at US$350 billion and FAO projects that production will have to increase by 70% to be able to feed the world in 2050, as meat and fish outputs are expected to double [3].

Ingredients for animal feed include soybeans, fish oil, and several grains, with fishmeal being the major protein source. However, a major constraint for further development of meat and fish production to feed the increasing world population is that, land availability for soybean cultivation is diminishing globally, while marine overexploitation has continued to reduce the abundance of small pelagic forage fish from which fishmeal and fish oil are derived [4]. The growing scarcity of resources to produce these increasingly demanded ingredients has doubled their prices during the last five years, while the feed cost representing 60-70% of meat production costs is already prohibitive and cannot be afforded by resource-poor farmers. It will therefore not be a sustainable option to continue to rely on fishmeal and soybean as protein source in feed production [3]. This situation is also threatening the survival of producers in Cameroon, hence the need for both viable and sustainable alternatives. The industry is searching for alternative protein sources for growing sectors of poultry [1].

Insects such as Black Soldier Fly (BSF) and House Fly (HF) plays a significant role in recycling many forms of waste and other accumulated nutrients in the environment [5,6]. The residual organic matter which has not been assimilated is also decomposed and used easily by plants and other organisms. Insects are potentially, more active agents for biodegradation compared with other invertebrates because their growth periods are relatively short. Larvae of dipterans flies are especially interesting as they can develop in a wide diversity of media, have a high reproductive capacity and a relatively short life cycle. Fly larvae is a very good source of protein (CP, 45-73%) and the essential amino acids and fatty acids [7,8,9]. Its utilization as substitute of soybean and fishmeal in chick's [10,11] and pig diets [12] has been tested with outstanding success. Several studies have shown that improving the diet of local chicks with conventional balanced feeds significantly increases their productivity [13]. The aim of this study was therefore to recycle waste from the farm of research and application of the University into maggot meal and evaluate the effects of their supplementation in the local chicks' diets.

2. MATERIALS AND METHODS

2.1 Study area

The present study was conducted at the farm of research and application of the University of Dschang. The farm is in the western region of Cameroon between 5°25'–5°30' North Latitude and 10°-10°5' East Longitude and at an average Altitude of 1410m, with an equatorial climate. The data of the meteorological station of Dschang from 2001 to 2009 shows that there are two seasons: a long rainy season from March to October and a short dry season from November to February. The rainfall varies between 1500-2000mm per year. The average annual temperature is around 21°C with average annual sunstroke of 1800hours and a relative humidity varying between 40-97%. The air is perpetually fresh and tends to saturation early in the morning, hence the regular presence of fog or mist in the atmosphere before sunrise.

2.2 Production of maggot meal and determination of fly species

Maggot production was carried out in plastic containers (Ø11.30cm×5.53cm), using animals manures supplemented with fish waste. Each container was respectively half full of 1000g of fresh cow dung, chicken manure and pig manure collected the same morning from their respective rearing units at the farm and, supplemented with 500g of fish waste obtained from the University restaurant. All the substrates were simultaneously exposed to the flies for 24hours for natural oviposition. After this, the containers were covered with a plastic mesh to enhance the substrates temperature and avoid further oviposition to ensure maggots of similar ages. The substrates were watered once or twice per day depending on the daily temperature. Larvae were harvested before pupation at the third instar approximately 4 days of growth [14], and introduced into the hot water to kill before dried for 24hours in a drying device which included two incandescent bulbs of 100watts mounted in a crate. Dry maggots were ground by hand milling to get maggot meal that could be incorporated into the chicks' diets. After harvest, the maggots were weighed according to the substrate used to feed them using an electronic health monitor scale (precision ± 0.1g), before and after drying. During production, the daily temperature of different substrates was monitored twice per day (morning and evening), using a probe thermometer.

Fly species involved in the seeding of different substrates were collected using a sweep net and preserved in 90% ethanol. They were subsequently identified using a binocular loupe and identification keys [15,16,17], based on morphological characters.

2.3 Maggot meal in indigenous chicks' diet

The evaluation of the nutritional value of maggot meal in chicks' diet was conducted over a period of eight weeks with 45 on-day-old, non-sexed indigenous chicks. The experimental room was about 14m^2 with a floor covered with a deep litter of wood shaving and, was disinfected using the conventional protocol in poultry farms in Cameroon. Water and feed were offered *ad libitum* and the prophylaxis plan was applied to the chicks properly. A completely randomized design was used to allocate the chicks to three treatments. The first batch received a standard control diet D_0; the second an experimental diet D_1 where the fishmeal was substituted at 50% by the maggot meal and finally the third an experimental diet D_2 where the fishmeal was 100% substituted by the maggot meal (Table 1). The adaptation period lasted for one week, during which chicks received the control pelleted diet. Initial weight of the chicks was taken together at the beginning. They were then individually weighed weekly from the second week till the end of the experiment. The feed consumptions and the left were weekly monitored. The parameters evaluated were the diets digestibility and growth performances of chicks such as feed intake, weight gain, mortality rate and feed conversion rate.

Table 1. Centesimal composition of the chicks diets during the starting and growth period

	Starting period			**Growth period**		
Ingredients	**D_0**	**D_1**	**D_2**	**D_0**	**D_1**	**D_2**
Cornmeal	53	53	53	58	58	58
Durum bran	8	8	8	8	8	8
Palm kernel cake	4	4	4	4	4	4
Peanut cake	10	10	10	5	5	5
Cotton cake	6	6	6	6.5	6.5	6.5
soybean meal	10	10	10	10	10	10
Fishmeal	5	2.5	-	4.9	2.45	-
Maggot meal	-	2.5	5	-	2.45	4.9
Calcined bone	1.5	1.5	1.5	1.5	1.5	1.5
CMAV (2%)	2.5	2.5	2.5	2	2	2
Cooking salt	-	-	-	0.1	0.1	0.1

2.4 Statistical analysis

Data collected were analyzed using IBM SPSS Statistics version 22.0. They were submitted to the parametric test of ANOVA (analysis of variance) with 95% confidence interval to determine the significance of the treatments (P=0.05). When a significant difference was found, Tukey post-hoc test was performed.

3. RESULTS

3.1 Production of different substrates and identification of fly species

Under test conditions, maggots were harvested day 4 after oviposition regardless of the substrate (Table 2). Supplement with fish waste, maggot's production of differences substrates doesn't show significant difference (DF=2; F=0.02; P=0.97).

Table 2. Maggot's production of different substrates after four days of incubation

Substrate	Substrate quantities (g)	Incubation periods (days)	Wet weight (g)	Dry weight (g)
Pig manure + Fish waste	1500	4	260.32±73.18	62.02±29.63
Chicken manure + Fish waste	1500	4	254.12±50.59	50.30±25.05
Cow dung + Fish waste	1500	4	249.97±72.44	46.67±28.87

Daily temperature variation of different substrates did not show significant difference (DF=2; F=3.62; P=0.07). However, chicken manure revealed a slightly higher temperature change, followed by cow dung and pig manure (Figure 1).

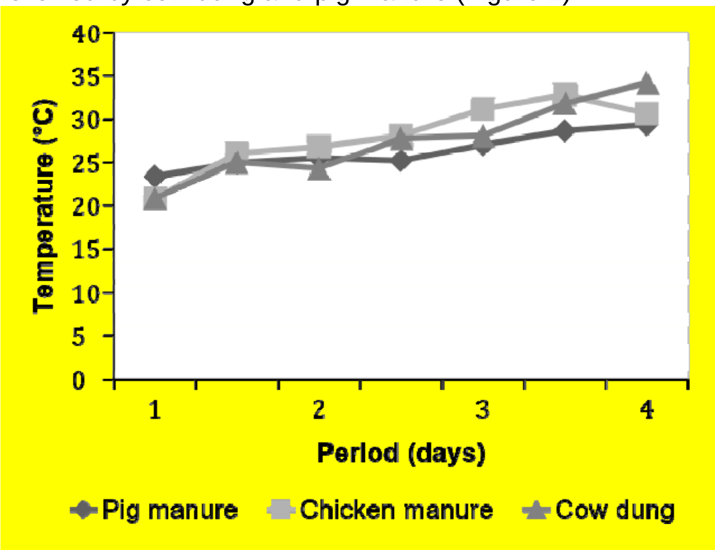

Fig. 1. Daily temperature variation of different substrates during the incubation period

Flies involved in the seeding of different substrates belonged to two different families (Calliphoridae and Muscidae). The Calliphoridae were represents by the genus *Lucilia* and *Chrysomyia,* while the Muscidae were represents by the genus *Musca.* The genus *Lucilia* was the most abundant (47%), followed by the genus *Musca* (38%) and the genus *Chrysomyia* (15%).

3.2 Performance of maggot meal in the indigenous chicks feeding

The average feed intake (per chick/week) increased significantly with diet from the second week till the end of the experiment (DF=2, F=3.30, P=0.00). During the first week, it was about 57.70g/chick/week, and increased gradually to reach 312.10g, 306.30g and 302.40g respectively in the chicks fed with D_0, D_1 and D_2 diets at the end of the starting period. During growth period, feed intake also increased from 382.30g to 703.30g in chicks fed with

D_0 diet, from 381.70g to 738.60g in the chicks fed with D_1 diet and finally from 393.20g to 752.20g in the chicks fed with D_2 diet (Figure 2).

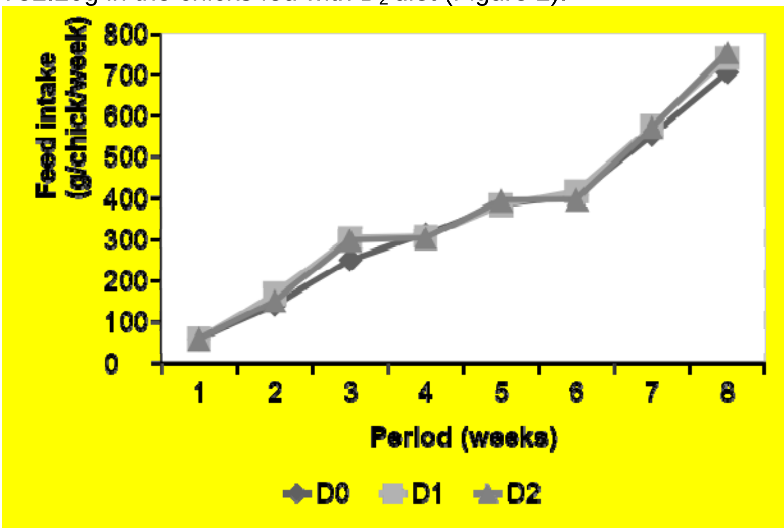

Fig. 2. Average feed intake of chicks subjected to different diets during starting and growth periods

The weight change of chicks subjected to different diets did not show significant difference during the first two weeks. However, from the third week till the end of the experiments, the weights of the chicks fed with D_2 diet significantly increased when compared to other treatments. Figure 3 shows that, during the starting period the chicks subjected to D_2 diet had record a significant high average weight gain (220.80±66.10g), followed by chicks subjected to the control diet D_0 (170.80±64.1g), and chicks subjected to D_1 diet (159.80±41.80g). During growth period, the average weight gain of the chicks doubled regardless of the diet. At the end of the test, the chicks on the D_2 diet still recorded a significantly greater weight gain (625.80±114.60g), followed by chicks on the D_1 diet (450.80±71.23g), and chicks on the D_0 diet (349.20±100.38g) (Table 3). The weight gain was calculated by making the difference between two consecutive weekly weight changes.

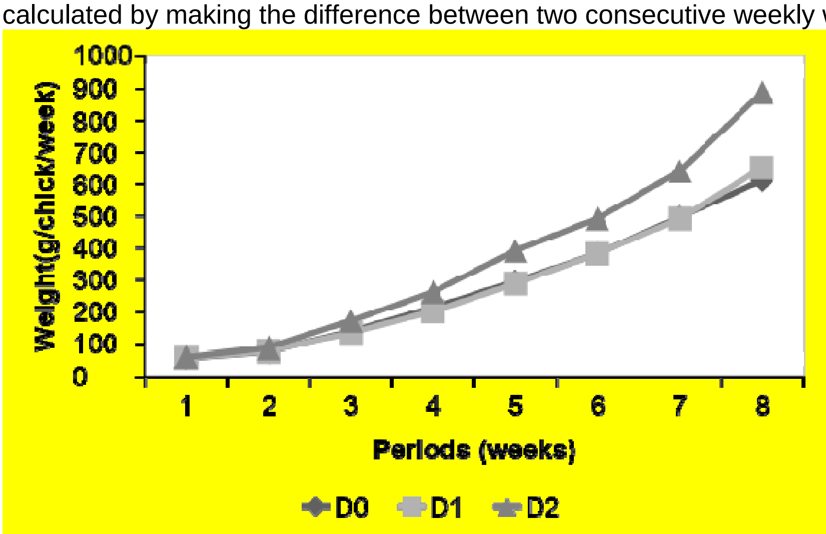

Fig. 3. Weight changes of chicks subjected to different diets during starting and growth period

Table 3. Average weekly weight gain of chicks subjected to different treatments during starting and growth periods (g/chick/week)

		Starting period (weeks)			
		1	2	3	4
Starting diets	D_0	16.9±09.6	19.1±16.9	61.0±32.6[ab]	73.7±24.5[ab]
	D_1	17.9±09.7	19.1±10.0	55.7±17.8[b]	67.1±20.7[b]
	D_2	19.8±07.9	28.6±12.6	82.3±25.1[a]	90.1±26.7[a]
		Growth period (weeks)			
		5	6	7	8
Growth diets	D_0	83.7±38.6[b]	86.6±38.6	114.8±43.2[b]	115.3±40.2[c]
	D_1	87.9±87.9[b]	93.2±23.9	110.0±38.4[b]	159.6±26.7[b]
	D_2	130.5±38.1[a]	99.9±47.6	149.2±43.9[a]	246.3±20.6[a]

Values within columns marked with same letters are not significantly different (p<0.05).

The feed conversion rate of chicks was determined by dividing the average weight of feed intake by the average weight gain of chicks at the end of each week. During starting period, It showed significant difference only in the second week, however during growth period it showed significant differences in the fifth, sixth and eighth weeks (Table 4). Generally, the chicks subjected to the experimental diet D_2 recorded the lowest feed conversion rate, followed by the chicks subjected to experimental diet D_1 and finally the chicks subjected to control diet D_0.
Throughout the study, no mortality or signs of toxicity were recorded during both starting and growth period.

Table 4. Feed conversion rate of chicks subjected to different diets during starting and growth periods

		Starting period (weeks)			
		1	2	3	4
Starting diets	D_0	1.1±0.1	1.9±0.4[ab]	2.0±0.7	1.6±0.6
	D_1	1.0±0.2	2.3±0.5[a]	2.4±0.5	1.6±0.4
	D_2	1.0±0.2	1.8±0.4[b]	1.8±0.6	1.2±0.4
		Growth period (weeks)			
		5	6	7	8
Growth diets	D_0	1.4±0.5[a]	1.2±0.5[a]	1.3±0.5	1.2±0.3[a]
	D_1	1.4±0.3[ab]	1.1±0.3[ab]	1.2±0.3	1.2±0.2[a]
	D_2	1.1±0.3[b]	0.9±0.3[b]	0.9±0.3	0.9±0.2[b]

Values within columns marked with same letters are not significantly different (p<0.05).

5. DISCUSSION

Maggots were harvested four days after oviposition regardless of the substrate. This result confirms the observations of Mensah *et al*. [18] who reports that maggots can be produced in various types of locally available substrates. Although not significantly different, production was slightly higher with pig manure, followed by chicken manure and cow dung. This is because pig and chicken manures are less rich in fiber and therefore provide a better diet for maggots. In addition, mixed with the fish waste these substrates produce a fouler odour which attracts many flies that come to feed and lay there. This result is similar to those of Ekoue and Hadzi [19] and Bouafou *et al*. [20] which show that the type of substrate is an important factor influencing the yield production of maggots.

The temperatures recorded in the different substrates are almost identical. They are between 20-25°C at the beginning of the experiment, and then progressively change depending on the day temperature and the fermentation rate of the substrates to reach 30-35°C on the fourth day of incubation. This variation has led to a significant production of maggots. This result corroborates that of Keiding [21], which shows that the development time of maggots depends on their medium temperature. The works of Axtell [22] and Loa [20] also show that the variation of the medium temperature is inversely proportional to the development time of housefly larvae.

The feed intake of chicks subjected to experimental diets D_1 and D_2 were slightly higher than that of chicks subjected to control diet D_0. This result can be explained by the fact that, Maggot meal enhances the food appetizing that favors its ingestion by the chicks. This result is consistent with the work of Loa [23] which shows that maggots are a preferred food for poultry. In addition, it opposes that of Agodokpessi *et al*. [11] which revealed that the incorporation of maggot meal at 10% as a substitute for fishmeal in a diet limits dietary intake in turkey poults. They justify their observation by the fact that the energy richness of the diets favoured by a particularly high rate of fat from the maggot meal decreases the ingestion of food.

The low average weekly weight gain of chicks in this study is due to the fact that, the growth rate of local breeds is particularly slow. These weight gains remained almost identical during the first two weeks, but increases considerably from the third week until the end of the experiment regardless of the diet. For this purpose, the total substitution of fishmeal by maggot meal in the diet D_2 has significantly increased the weight gain of the chicks compared to the other two diets D_0 and D_1. This result can be explained by the fact that, maggot meal is an alternative source of protein that can be used to substitute other valuable limited protein sources of animal origin in poultry feed. This is in accordance with the work of Bouafou *et al*. [24,25] which show that maggot meal is an abundant source of animal protein comparable to fishmeal commonly used in animal feed.

Generally, the chicks subjected to the experimental diet D_2 recorded the lowest feed conversion rate, followed by the chicks subjected to experimental diet D_1 and finally the chicks subjected to control diet D_0. This result is consistent with the work of Picard *et al*. [26] which shows that a higher energy concentration in a diet lowers the feed conversion rate of chicken in all climates.

4. CONCLUSION

Supplemented with fish waste, pig manure has a higher productivity in maggots, followed by chicken manure and cow dunk. In all substrates, maggots reach maturity after four days and can be harvested and dried for 24hours at 40°C and milled to get maggot meal which can be incorporated in the chicks' diets. Their valorization as a source of proteins in the local chicks' diet was zootechnical benefit. A total substitution of the fishmeal by this protein source in the experimental diet D_2 has significantly increased the chicks' weight and improves their feed conversion rate. A partial substitution in the experimental diet D_1 was certainly helpful but not enough to induce a significant change. Maggot meal could replace that of fish in the poultry diet. It's however necessary that more diversified studies be done to valorise this new protein source.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

Authors' Contributions

Authors PN, JMK and TT Conceived and designed the study. Author DD performed the study, wrote the protocol, wrote the first draft of the manuscript, and managed the literature searches. Authors MDL and MT performed the statistical analysis. Authors FM and PN managed the analyses of the study. All authors read and approved the final manuscript.

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