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INFLUENCE OF THE SUBSTRATES ON THE PRODUCTIVITY AND THE NUTRITIONAL VALUE OF HOUSEFLY LARVAE (*Musca domesticus*) MEAL FOR BROILERS NUTRITION

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ABSTRACT: The present study was assigned to assess the production and nutritional value of maggots (housefly larvae, *Musca domestica*) meals produced in chicken droppings and pig slurry as substrates and their effects on growth performance and serological parameters of broiler chicks at the starter phase. A control ration without animal meal (R0) was compared to three other rations containing respectively 5% fishmeal (FM), blood meal (BM) and maggots (MA). The rations were randomly distributed to 4 groups (T0, FM, BM, and MA) of 56 chicks each. Slurry supplemented with bovine blood has been shown to be more productive than other substrates, with a maximum production of 246.75 g per 2 kg of substrate after five days of incubation. The highest average temperature (28.28 ± 3.43°C) was recorded in chicken droppings around 12 hours of the day. The pupae appear before the 10th day and breeding was no longer productive after the 15th day, both in hen droppings and in pig manure supplemented or not with blood. The humidity and temperature variations in the two substrates did not have any noticeable effects on the production and chemical composition of the maggots. Proximate analysis of maggot flour revealed a high content of protein (41-57%), ash (7.31-8.26%) and minerals such as phosphorus (5.25-5.55%), calcium (1.92-3.92%) and magnesium (7.04-7.92%). The growth performance and development of regulatory organs and digestive organs such as liver, kidneys, intestine, and bursa of Fabricius of the chicks were not significantly affected by the dietary treatments. In conclusion, the production and nutritional value of maggots depend on the type and composition of the substrate and can be safely use as proteins sources in broilers at the starter phase of production.

Keywords: Animal manure, Broiler chicken, Fish meal, Maggot meal, Ration.

INTRODUCTION

One of the main solutions for the sustainability of the family animal production in Africa is the valorization of non-conventional locally available feed resources that are economically more profitable in animal feed formulation. In family poultry nutrition, the efforts are being made to promote new local sources of protein, such as the meal of insects, cockroaches, termites, grasshoppers, earthworms and maggots (Mensah et al., 2007; Tshinyama, 2009; Ndadi, 2010; Bouafou et al., 2011; Finke, 2013; De Smet et al., 2018).

Maggots are produced in household waste (Bouafou et al., 2008; Diener et al., 2009; Beskin et al., 2018), brewery dregs (Hardouin et al., 2000), animal droppings and the rumen contents of ruminants (Akilimali et al, 2019; Balengola, 2012). Maggot meal is rich in fat, protein and potentially essential amino acids (Hatab et al., 2020). They are used as food for animals, especially fish and local poultry (Mensah and Ekue, 2002; Biasato et al., 2019). Its nutritional value is broadly comparable to that of meat, fish, soybean and cotton meal which are conventionally used in livestock feed (Barragan-Fonseca et al., 2018). In terms of economic benefits, Téguia et al. (2002) and Hardouin and Mahoux (2003) reported that the substitution of fishmeal by maggot meal reduced the cost of fish production by 18 to 20%. The use of this flour could offer a great opportunity for the development of poultry production in the tropics where maggots can be easily produced throughout the year and at low cost.

To safely prescribe maggot meal in animal feed, further investigation is necessary as maggots produced in animal droppings could be a source of transmission of fecal bacteria to farm animals (Charlton et al., 2015; De Smet et al., 2018). The study of the plasma parameters of growing rats fed on dried maggot meal-based diet did not revealed any abnormalities (Bouafou et al., 2011). However, the biometrics of their kidneys and livers revealed changes in weight, with their kidneys losing weight of around 6.6% and their livers increasing by 10.60% suggesting to pay more attention on the potential toxicity of the maggot meal produced in animal droppings to feed another animals. The main objective of this study was to promote the usage of locally available and less expensive protein resources (such as larvae meal) of animal origin in farm animal production.

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MATERIALS AND METHODS

Ethical approval

The present study has been performed in agreement with the guidelines of the ethical standards from the 1964 Helsinki declaration and latterly amendment approval code ♯ CU/11/F/34/19♯.

Study area

The present study was carried out at the Teaching and Research Farm (FAR) of the University of Dschang, located in the agro-ecological zone of the West Highlands of Cameroon at an altitude of 1410 m, at10° 26'longitude East and 5° 26' latitude North. The area receives between 1,500 and 2,000 mm of rainfall per year, with temperatures ranging from 10 to 25°C. The climate is equatorial of Cameroonian type, with a dry season ranging from mid-November to mid-March and the rainy season from mid-March to mid-November. The average annual insulation is 1873 hours and the average relative humidity is 76.8%.

Maggot production

The organic substrates used to produce the maggots consisted of chicken droppings and pig slurry. The fresh chicken droppings were collected from the henhouses at the Teaching and Research Farm of the University of Dschang on the ground under batteries of broiler cages. The pig slurry was collected at the piggery of the same farm, previously cleaned the day before. The blood of freshly slaughtered beef, used to attract flies, was collected at the municipal slaughterhouse of Dschang of Cameroon.

The production of the maggots was carried out in the plastic colanders inside which were introduced 2kg of substrates (chicken droppings or pig slurry) enriched or not with 100g of fresh beef blood. The colander was placed on a basin intended to collect the maggots which passed through the mesh. The breeding was conducted in an enclosure covered with transparent paper where flies could enter and exit freely (Figure 1). The entire device was stored in the open air and the smell of the substrate attracted flies that came to lay freely in the shelter from hash weather. The experimental design consisted of 4 treatments (chicken droppings, chicken droppings enriched with fresh blood, pig slurry and pig slurry enriched with fresh blood) replicated 4 times.

The temperature of the substrate was taken every day at 8a.m. and 12a.m. using a thermometer (Strengthened 76 mm immersion, ZEAL Made in England). The maggots were harvested in a series of 4 basins per treatment on the 5th, 10th and 15th day after sowing. During harvesting, the device was placed under the sun, and the maggots, fleeing the heat of the sun, fell into the collecting vessel. The harvested maggots were weighed fresh and oven dried at 70°C for at least 24 hours and then reweighed. The flours obtained were then mixed and incorporated into the feed of the chicks as a source of protein. The proximate analysis of maggots was carried out for protein, ash and mineral content (AOAC, 1990).

Figure 1 - Maggot production device in the present study

Experimental chicks

In the present study, 224 day-old Cobb 500 strain chicks with average mean weight 38.91 g were randomly assigned to 16 experimental units of 14 chicks and litter brooded for 4 weeks. The chicks were vaccinated against infectious bronchitis (H120®), Newcastle disease (Hitchner B1®) on the 7th and 18th day, and against Gumboro disease (IBA Gumboro®) on the 10th day. An anti-stress (Tetracoli®) was administrated to the chicks via drinking water after vaccinations. An anticoccidial (Vetacox®) and vitamins (Amintotal®) were administrated to the chicks via drinking water during 3 days each week.

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Experimental diets

Fish meal, blood meal and other ingredients were purchased from the market in the town of Dschang. Four experimental rations were formulated (Table 1) with the control ration (T0) free from ingredient of animal origin. The rations FM, BM, and MA contained fishmeal, blood, and maggots respectively. Each experimental ration was assigned, at random, to 4 experimental units in a completely randomized design replicated 4 times. Chicks were fed *ad libitum* throughout the trial period.

Table 1 - Composition of experimental diets

Ingredients	T0	FM	BM	MA
Maize	54	54	54	54
Wheat bran	6.5	7.5	11	6
Soybean meal	25	21.5	18	21
Cotton seed meal	5.5	5.5	5.00	7
Fishmeal	0	5	0	0
Blood meal	0	0	5	0
Maggot meal	0	0	0	5
Bone meal	1	1	1	0
Seashell	1	1	1	0
Premix 5% *	5	5	5	5
Total	100	100	100	100
Calculated chemical composition				
Crude proteins (%)	23.01	24.72	23.11	22.59
Metabolizable energy (kcal/kg)	2,878.31	2,896.21	2,949.69	2,888.76
Calcium (%)	1.12	1.43	1.12	1.33
Available phosphorus (%)	0.49	0.65	0.51	0.6
Lysine (%)	1.29	1.38	1.42	1.15
Methionine (%)	0.43	0.48	0.42	0.40
Price of feed (fcfa/kg)	247	240	230	228

* Premix 5%: Crude protein = 40%, Lysine = 3.3%, Methionine = 2.40%, Calcium = 8%, Phosphorus = 2.05%, Metabolizable energy = 2078kcal / kg. T0 = Ration without animal meal; FM = Ration containing 5% fish meal; BM = Ration containing 5% blood meal; MA = Ration containing 5% maggot meal

Data collection

Feed intake and live body weight gain were recorded weekly. At the beginning of the trial and every 7 days thereafter, the birds in each experimental unit were individually weighed and the weekly weight gain was calculated as the difference between 2 consecutives averages weekly weights. The feed conversion ratio was calculated as the ratio of the feed consumed during the week on the weekly weight gain. At the 28 days old, 08 chicks per treatment group were taken at random, fasted for 24 hours, and weighed, bled, scalded, plucked and eviscerated for carcass evaluation. The relative weight of kidneys, liver, intestine and bursa of Fabricius was calculated [(organ weight / fasting animal body weight) x 100]. Intestine length (from duodenal loop to the cloaca) was measured and its density (intestine weight / intestine length) calculated.

The price per kilogram of the feed was evaluated based on the ingredient prices on the local market at the study period. The cost of production of kilogram of live weight of the chicken was estimated by multiplying the cost of kilogram of feed by the feed conversion ratio.

Statistical analysis

The collected data were subjected to one-way analysis of variance (ANOVA) for the effects of the substrate type, moisture content and temperature on larvae growth, and nutritive value of maggots produced on chick's growth performance. When there were significant differences between treatments groups, the Waller Duncan multiple ranged test was applied to separate means, and difference were considered significant at $p<0.05$. The statistical software SPSS 20.0 (Statistical Package of Social Sciences) was used for the analyses.

RESULTS

Variation of temperature and water content of substrate

Table 2 summarizes the changes in water content, temperature of chickens droppings and pig slurry during incubation and growth of maggots. Regardless of the type of substrate, the highest temperature was recorded at 12 a.m. as the heat increases during the day. When considering the pig slurry and chicken droppings separately, the statistical analysis revealed no significant difference ($P>0.05$) at 8 a.m. and 12 a.m., between the substrate without blood and substrates enriched with blood. When considering the types of substrate separately, the analysis of variance revealed a significant difference ($P<0.05$) between the slurry containing blood and the same substrate without blood, for the water content. When comparing the two types of substrate, it appears that the water content was higher ($P<0.05$) in the pig slurry.

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Maggot production as affected by the type of substrate

From Table 3 which summarizes the production of maggots as a function of the type of substrate, it appears that the highest production was recorded on the 5th day with the pig slurry enriched or not with blood. On the 10th day, production was higher with chicken droppings. Overall, it is obvious that the production is greater when blood is used as fly bait regardless of the substrate considered. When considering the pig slurry or chicken droppings separately, the analysis of variance revealed no significant difference (P>0.05) on the 5th and 10th day of incubation between the substrate without blood and the one enriched with the blood.

Nutritional value of maggots as affected by the substrate

Table 4 summarizes the variation of the nutritional value of maggots as affected by substrate. Maggots produced in droppings and slurry were comparable for the content of ash, potassium, sodium, phosphorus and magnesium. The iron and calcium contents are lower in the maggots produced respectively in the slurry enriched or not with bovine blood. The enrichment of chicken droppings with blood induced a substantial increase in the protein content of maggots, while the opposite effect was recorded with pig slurry enriched with blood. Overall, maggot meal is an important source of animal protein (41-57%) for farm animals.

Growth performance and cost of production of broiler chicks

Results in Table 5 shows that with the exception of feed intake, all other growth parameters studied were significantly affected (P <0.05) by the treatments. Overall, fishmeal induced the highest live weight (935.90 g) and feed conversion ratio (1.64) of all the treatments groups. However, these performances were statistically comparable (P> 0.05) to the performances of the chicks fed on maggot meal (895.97 g and 1.72 respectively). Although not significant, chicks fed on maggot meal recorded more weight gain (857.06 g) than chicks fed on blood meal (836.73 g). Compared to the control ration (441.47 FCFA), the production cost of a kg of live weight of the chick was lower with fishmeal (393.95 FCFA), blood meal (407.05 FCFA) and maggot meal (409.98 CFA).

Development of regulatory and digestive organs

The effects of different treatments on the development of regulatory and digestive organs of the chicks are summarized in Table 6. ANOVA did not reveal any significant difference (P>0.05) between treatments regardless of the parameter considered.

Table 2 - Variation of water content (%) and temperature (°C) of substrates

Variables	Chicken droppings	Chicken droppings +blood	Pig slurry	Pig slurry +blood
Water content	46.18 ± 29.13	51.04 ± 15.65	68.40 ±1.84[a]	87.47 ± 4.49[b]
Average temperature at 8 a.m.	20.03 ± 1.56	20.54 ± 1.72	20.23± 1.84	24.75 ± 3.47
Average temperature at 12 a.m.	28.28 ± 3.43	27.82 ±3.74	27.15± 2.87	—

[a, b]: the means with the same superscripts on the same line are not significantly different (P>0.05)

Table 3 - Production of maggots as affected by the substrate

Biomass (g)		Substrates				MSD	P-value
		Pig slurry	Pig slurry +blood	Chicken droppings	Chicken droppings +blood		
Day 5	Fresh biomass	131.25[c]	246.75[d]	6.67[a]	47[b]	26.02	0.001
	Dry biomass	34[c]	59.25[d]	1.25[a]	16.50[b]	6.11	0.001
Day 10	Fresh biomass	28.75[ab]	19.50[a]	26.25[ab]	60.75[b]	5.60	0.022
	Dry biomass	10.75[a]	Nd	12.25[a]	28[b]	2.90	0.001

[a, b, c, d]: the means with the same superscript on the same line are not significantly different (P>0.05). MSD: mean standard deviation, Nd: not determined.

Table 4 - Nutritive value of maggots as affected by the substrate

Nutrients	Substrates			
	Chicken droppings	Chicken droppings + blood	Pig slurry	Pig slurry + blood
Crude protein (%DM)	41.01	50.85	57.14	54.41
Ash (%DM)	8.26	7.92	7.31	7.82
Potassium (g/kg)	0.924	0.971	0.924	0.833
Sodium (g/kg)	0.055	0.057	0.055	0.055
Phosphorus (g/kg)	5.251	5.554	5.327	5.478
Calcium (g/kg)	3.920	2.800	1.920	2.560
Magnesium (g/kg)	7.047	7.793	7.928	7.651
Iron (mg/kg)	0.306	0.306	0.306	0. 281

DM: dry matter

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Table 5 - Variation of chick's performances and cost of production as affected by the treatments

Growth Parameters	Dietary treatments				P-value
	T0	FM	BM	MA	
Feed intake (g)	1480.66 ± 55.36	1579.02 ± 58.24	1482.59 ± 35.61	1503.23 ± 62.27	0.076
Live weight (g)	912.03 ± 38.26^{a}	935.90 ± 18.41^{a}	856.92 ± 28.47^{b}	895.97 ± 4.02^{ab}	0.007
Weight gain (g)	884.47 ± 43.24^{ab}	911.87 ± 15.74^{a}	836.73 ± 8.62^{c}	857.06 ± 4.02^{bc}	0.004
Feed/weight ratio	1.78 ± 0.08^{a}	1.64 ± 0.05^{b}	1.76 ± 0.07^{a}	1.72± 0.04^{ab}	0.047
Cost Kg/LW	441.47 ± 20.34^{a}	393.95 ± 13.70^{b}	407.05 ± 16.50^{b}	409.98 ± 10.25^{b}	0.007

$^{a, b, c}$: means with the same superscript in the same column are not significantly different (P>0.05). LW: Live weight; T0: Ration without animal meal; FM: Ration containing 5% fishmeal; BM: Ration containing 5% blood meal; MA: Ration containing 5% maggot meal.

Table 6 - Development of the regulatory and digestive organs of chicks as affected by treatments

Organs	Dietary treatments				P-value
	T0	FM	BM	MA	
Regulatory organs(% LW)					
Kidney	0.690 ± 0.10	0.742 ± 0.07	0.692 ± 0.12	0.558 ± 0.26	0.427
Liver	2.14 ± 0.19	2.19 ± 0.35	2.22 ± 0.21	2.51 ± 0.69	0.311
Digestive organs					
Live weight (% LW)	4.59 ± 0.75	5.82 ± 0.97	4.88 ± 0.76	5.00± 1.19	0.078
Intestinal length (cm)	175.62 ± 19.50	186.00 ± 19.47	173.37 ± 11.19	172.12 ± 14.99	0.347
Intestinal density (g/cm)	0.026 ± 0.003	0.031 ± 0.004	0.028 ± 0.004	0.028 ± 0.005	0.159
Bursa of Fabricius (g)	0.690 ± 0.16	0.742 ± 0.20	0.692 ± 0.14	0.558 ± 0.18	0.215

T0: Ration without animal meal; FM: Ration containing 5% fishmeal; BM: Ration containing 5% blood meal; MA: Ration containing 5% maggot meal.

DISCUSSION

The result of the present study confirms the observations of many others authors (Mensah et al., 2007; Beskin et al., 2018) according to which fly larvae can be produced in various substrates available locally and unsolicited by humans. The larval stage is a very important stage of development in livestock feed because the larvae are rich in nutrients such as proteins, fats and minerals and is easily digestible by the animal. Regardless of the type of substrate used, high productivity of fly larvae was recorded on the 5th day after seeding. The decrease observed in all substrates on the 10th day can be explained by a low availability of organic matter which decreases as the maggots develop. Between the 10th and the 15th day, a transformation of the larvae into pupae is observed. This result confirms the findings of Hardouin et al. (2000) who reported that between 5 and 14 days of feeding, maggots enter the cocoon phase (mutation phase) during which they no longer feed and bury themselves in the substrate a few inches away until an adult fly has developed. This stage no longer contains the nutrients and according to Hardouin et al. (2000) and Hardouin and Mahoux (2003), the pupae are protected by a rigid envelope consisting essentially of keratin, the digestibility of which is greatly reduced in animals, although it is also a nitrogen product. Akilimali et al. (2019) also reported that it is important to determine the range of recommendable days to obtain the maximum number of larvae and the minimum number of pupae since it is preferable that farm animals receive the fewer pupas possible. Whatever the explanation, prolonging the rearing of maggots beyond the 15th day would have no justification.

Regardless of the humidity level and with substrates enriched or not with blood, no significant difference (P>0.05) was recorded between the substrates for the variation of temperature of the substrates. The temperature varied between 25 and 36°C during the day, with a humidity rate varying between 70 and 76% and 82 to 84% for the pig slurry and the chicken droppings respectively. These observations confirm those of Diener et al. (2009) who reported that fly eggs need a lot of humidity and the development of these larvae requires very high relative humidity. In addition, Keiding (1986) reported that the length of the house fly's reproductive cycle is a function of temperature and that the percentage of eggs hatched is maximum between 15 and 40°C. Below 8°C and above 42°C, all eggs die before hatching and the most favorable temperature for larval development is 35°C.

Proximate analyzes of the maggot produced in the present study revealed high levels of protein and minerals. These results are in agreement with the findings of Bouafou et al. (2008) and Barragan-Fonseca et al. (2018) who reported that maggot meal has protein content comparable to that of animal meal. The present results showed that maggots are less rich in minerals such as potassium, sodium and iron compared to other animal meal. Dashefsky et al. (1796) reported that housefly pupae meal contained sufficient phosphorus, which is highly bioavailable in poultry. This finding may suggest that the mineral content of the fly depends on its stage of development.

The ANOVA revealed no significant difference (P>0.05) between all batches of chicks for feed intake. However, the chicks fed on maggot meal tend to consume more than chicks fed on the control ration without animal meal. This result

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confirms the findings of Loa (2000) who revealed that maggots are a preferred food for poultry compared to cereals. Similarly, the present result agree with the findings of Bouafou et al. (2008 and 2011) who reported that, rats fed on dried maggot meal have zootechnical performances comparable to rats fed on fish and meat meal with regard to feed intake, coefficients of feed and protein efficiency, apparent and real digestibility.

Chicks fed on maggot meal recorded a body weight comparable (P>0.05) to that of all other batches of chicks. This result corroborates those of Bouafou et al. (2011) who reported that the incorporation of maggot meal in the feed is very suitable for optimal growth of young rats. Interesting results have also been reported by Malekani (2001), Cicogna (2000), De Marco et al. (2015), and by Mensah and Ekue (2002) who have successfully incorporated maggots into the feed of pets and farm animals. Likewise, Mensah et al. (2007), with a ration containing 11% maggot meal, crushed corn kernels, red oil, onion, *Moringa oleifera*, table salt and shell oyster ash, recorded interesting results in growth rate of Muscovy ducklings (1.3 kg at 8 weeks of age) and reduction in their mortality rate (less than 6%). Thus, this feed, coupled with good breeding behavior, ensures good start of day-old ducklings. This result can be explained by the fact that the protein content of maggot flour is comparable to that of animal meal as previously reported by Bouafou et al. (2008). In the same way, Sonaiya and Swan (2004) reported that maggots are potential protein sources that can be used as a supplement to low-protein or low-quality diets such as cassava and sweet potato.

The cumulative feed conversion ratio was significantly (P<0.05) lower with the ration containing fishmeal. While, chicks fed on maggot meal were comparable (P>0.05) to all other groups of chicks including the control, for this parameter. The present result contradicted the findings of Bouafou et al. (2008) who reported that rats fed on maggot meal based diet generally had the best zootechnical performance than those fed on fish or meat meal.

ANOVA result did not reveal any significant difference (P> 0.05) between treatments groups for the development of digestive organs regardless of the parameter considered. However, there is a downward trend in the relative kidney weight, bowel length, and the relative weight of the bursa of Fabricius, but with an upward trend in the relative weight of the liver with maggot meal compared to all other groups. This result corroborates the findings of Bouafou et al. (2011) who concluded from a study on the biometrics of growing rats fed on maggot meal based diet at a rate of 10%, observed a decrease in the weight of their kidneys of 6.60% and an increase in liver weight of 10.60% compared to controls.

With maggot meal, the cost of production of kg live body weight was comparable to rations containing fish and blood meals. These results confirm those of Hardouin et al. (2000), Téguia et al. (2002), de Hardouin and Mahoux (2003) who concluded that, from a technical and economic point of view, maggot meal could partly replace fish meal in monogastric feed, such as hens, guinea fowl, even pigs and fish. Similarly, Bouafou et al. (2006) reiterated that this practice makes it possible to improve at very low cost the performance of animals fed on unbalanced diet, as is often the case in family animals breeding.

CONCLUSION

The productivity of housefly larvae varies significantly with the type of substrate used. Pig slurry enriched with fresh blood has a higher and greater productivity over time. The most suitable period for harvesting maggots is between the 5th and 10th day, whatever the substrate. The temperature of the substrate for good productivity is above 25°C. Whatever the type of substrate, maggots are appreciable source of protein and minerals, particularly calcium and magnesium. Maggot meal can be used up to 5% in feed for the production of chicks at a lower cost, without abnormalities in the regulatory organs of the broiler chick at the starter phase.

DECLARATIONS

Authors' contribution

All authors were contributed equally.

Conflict of interests

The authors declare that they have no competing interests.

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