



On station maggot production using poultry litter as substrate: assessment on the quantity and the chemical quality of the litter before and after maggot production in Burkina Faso

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ABSTRACT

The maximization of organic substrates production for land sustainable management is a major challenge for agricultural production in countries like Burkina Faso. The objective of this study was to assess the quantity and the quality of organic substrates produced by poultry activity on station. Therefore, 54 local chickens at eighteen months old were allocated to 3 batches (boxes), with 18 chickens per batch. Rice husk was spread on the floor of the 3 boxes as litter for the chickens. The chickens were reared on the litter for 6 months in semi-confinement. Then, the poultry litter (PL) was used as substrate for maggots' production. The quantities and the chemical characteristics of the raw PL as well as the residues of the litter after maggots' production (RMP) were determined, and, simulations were done to estimate the quantities of organic substrates and the chemical nutrients that poultry farms can produce. The results show a production of 226.06 kg DM of PL after 6 months of semi- confinement, with a decrease of 30.33% when the PL was used to produce maggots. Carbon and nitrogen contents also registered a decreased of 8.83 and 8.39% respectively when PL was used to produce maggots. However, with phosphorus and potassium contents, an increase of 49.12 and 34.21% were noted, respectively. It was concluded that small poultry farmers with 30 to 100 adult chickens, could produce the equivalence of 100 to 300 kg of fertilizer (NPK (15-15-15)) in semi-confinement condition.

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Keywords: local poultry, litter, organics substrates, maggot production, fertilizer, small farm.

INTRODUCTION

The use of organic substrates for the restoration of soil production capacity has been demonstrated by many researchers (Habimana et al., 2014; Koulibaly et al., 2015; Olaiya et al., 2015; Gomgnimbou et al., 2019; Traoré et al., 2019; Tshala Upite et al., 2019). Blanchard et al. (2014) showed that there was a diversity of organic substrates that are produced and used by the farmers in rural

area. Despite this diversity, the quantities need for farm activities remain low. According to Vall et al. (2011), the organic manure needs per farm are between 7 and 28%, depending on the level of integration between crop and livestock production in western Burkina Faso.

The investigations of Coulibaly et al. (2018) showed that poultry farming is an activity that can contribute to farm organic manure production from 26.46 to 35.72% in

western Burkina Faso. The work of Ouédraogo et al. (2015) showed that despite the socio-economic and nutritional importance of local chickens, they are raised mostly in scavenging system. However, this rearing system does not promote the collection of these birds manure. The increasing of the flock size (more than 100 birds) associated with improving nutrition through the introduction of maggots and termites in birds feeding for intense could contribute to reduce scavenging of chickens in rural areas (Coulibaly et al., 2018). Ruminants stomach content, poultry manure and pig manure were mentioned as animal origin residues that attract flies, and therefore, are potentially suitable for fly larvae production (Bloukounon-Goubalan et al., 2017). Sanou et al. (2019) showed that poultry litter was the best substrate to produce maggots, with a production output of more than 80 g of maggot per 4 kg of poultry litter (dry matter basis). The maggots consume the organic substrates and reduce its quantity and quality during their development inside the substrate.

This paper, which focuses on the aspect of poultry manure production and collection, (i) assesses the amount of organic substrates that can be generated by poultry activity, (ii) gives the chemical qualities of these organic substrates and (iii) estimates the amounts of nutrients that can be provided by these organic substrates according to the type of poultry farmers.

MATERIALS AND METHODS

Study site

The study was conducted at the experimental station of the Institute of Rural Development (IDR) of Nazi Boni University (UNB). The UNB site is located on the way going to Banzon from Bobo-Dioulasso the second big city of Burkina Faso, at about 15 km west of Bobo-Dioulasso in the Hauts-Bassins region, between 4° 25' west longitude and 11° 12' North latitude (Figure 1). The study site belongs to the southern Sudanese climate, whose annual rainfall is between 800 mm and 1200 mm (Fontes and Guinko, 1995).

Average rainfall for the last ten years (2006-2015) is 1065.45 mm with the lowest in 2011 (775.4 mm) and the highest in 2014 (1278.3 mm). Rainfall in 2017 was 747.9 mm for 82 days.

Production of poultry litter

Fifty-four (54) local chickens (females) aged eighteen (18) months were used. These chickens were randomly divided into three batches with 18 birds per batch. Before the introduction of the chickens into the boxes, rice husks were spread on the floor as litter at 51.29 kg, 53.21 kg and 51.88 kg of dry matter (DM) for batches 1, 2 and 3 respectively.

The chickens were raised inside the boxes in semi-confinement for 6 months from January to June 2017, with six hours of scavenging per day in a yard provided, and receiving a supplementary feed composed of cracked maize and dried fish powder. An acceptability test with maggots was done during one month (February 2017). Feed supplement was given three times per day (8h00, 12h00 and 15h00). Water was available *ad-libitum*. At the end of the experiment, the quantities of poultry litter (droppings and rice husk) were weighed per batch.

Production of the litter residues after maggot's production

Containers of 0.32 m² surface and 0.20 m deep each, were used for maggot production. In each container, 3.30 kg of the dry poultry litter was humidified with 7 liters of water and then well mixed. The containers were exposed for 24 hours in the shade to attract the flies for egg laying. The containers were then covered with bags allowing more or less air circulation inside the containers. The maggots were harvested 4 day after covering, by the method of migration using mesh sieves of 3 mm and with the benefit of the light allergic property of the maggots. The production was done in 3 steps to allow the harvesting of the whole maggots in one day. The first step was to start production with 3 containers. The second step was to use a serial

of 3 other containers to start with the maggot production the day corresponding to the harvesting of the maggots from the first step. The third step consisted in launching a last production with 3 other containers the day of harvesting the maggots from the second step. The production of maggots was made in total with 9 metal containers.

Determination of chemical parameters

Dry matter contents of the poultry litter before and after maggot production was determined by placing 1 kg sample from each batch in an oven at 105 ° C for 72 hours.

Total carbon (C), total nitrogen (N), total phosphorus (P-total), total potassium (K-total) and pH_{H2O}, of poultry litter (PL) and residues of maggots' production (RMP) were determined. The analyses were done at the laboratory of the Department of *Gestion des Ressources Naturelles et Système de Production (GRN-SP) of INERA Farako-Ba (Bobo-Dioulasso)*. Soil pH_{H2O} was determined according to the ratio 1/2.5 through a suspension of organic substrate sample in the distilled water (AFNOR, 1981). Total C was determined by Walkley and Black (1934) procedure. Total N and total P were determined by KJELDAHL digestion method (Hillebrand et al., 1953). Total K was dosed using flame photometer after mineralisation of organic substrate samples.

Estimation of the quantities of the poultry litter before and after maggots production according to farm type

The typology performed by Coulibaly et al. (2018) in western Burkina Faso was used. Ended, this author used 5 types of poultry farms to estimate litter production: *Type 1 (109 chickens), Type 2 (30 chickens), Type 3 (43 chickens), Type 4 (55 chickens) and Type 5 (115 chickens)*. The quantity (Q) of poultry litter (PL) or the residues after maggots production (RMP) was calculated for a year according to the following formula:

$$Q \text{ (kg)} = \frac{Nb * q}{18} * 2 \text{ (with } Nb = \text{ number of } \\ \text{poulties per type of farms, } q = \text{ the quantity of } \\ \text{PL or RMP gotten with 18 poulties during 6} \\ \text{months of experiment, } 2 = \text{ the number of PL} \\ \text{or RMP production per year, the duration of} \\ \text{a production being 6 months).$$

Estimation of N, P₂O₅ and K₂O quantities of the poultry litter before and after maggots production according to farm type.

The amount of nitrogen (Q_N) was estimated as follows:

$$Q_N \text{ (kg)} = N(\%) * Q, \text{ with } N(\%) = N \\ \text{content in the PL or RMP and } Q = \text{ quantity of} \\ \text{PL or RMP estimated per type of farms.}$$

The amount of phosphorus pentoxyde (Q_{P2O5}) was estimated as follows :

$$Q_{P2O5} \text{ (kg)} = Q * (P * \frac{MP2O5}{MP}), \text{ with } Q = \\ \text{quantity of PL or RMP estimated per type of} \\ \text{farms, } P = \text{ phosphorus content in the PL or} \\ \text{RMP, } MP2O5 = \text{ molar mass of phosphorus} \\ \text{pentoxyde and } MP = \text{ molar mass of} \\ \text{phosphorus.}$$

The amount of potassium oxide (Q_{K2O}) was estimated as follows:

$$Q_{K2O} \text{ (kg)} = Q * (K * \frac{MK2O}{MK}), \text{ with } Q = \\ \text{quantity of PL or RMP estimated per type of} \\ \text{farms, } K = \text{ potassium content in the PL or} \\ \text{RMP, } MK2O = \text{ molar mass of potassium} \\ \text{oxide and } MK = \text{ molar mass of potassium.}$$

Data analysis

Data were subjected to Microsoft Excel software, version 2010, for means calculations and tables generation. Xlstat software 2018.5 version was used to perform analysis of variance (ANOVA), and means separation was done at 5% confidence interval using the Newman-Keuls test.

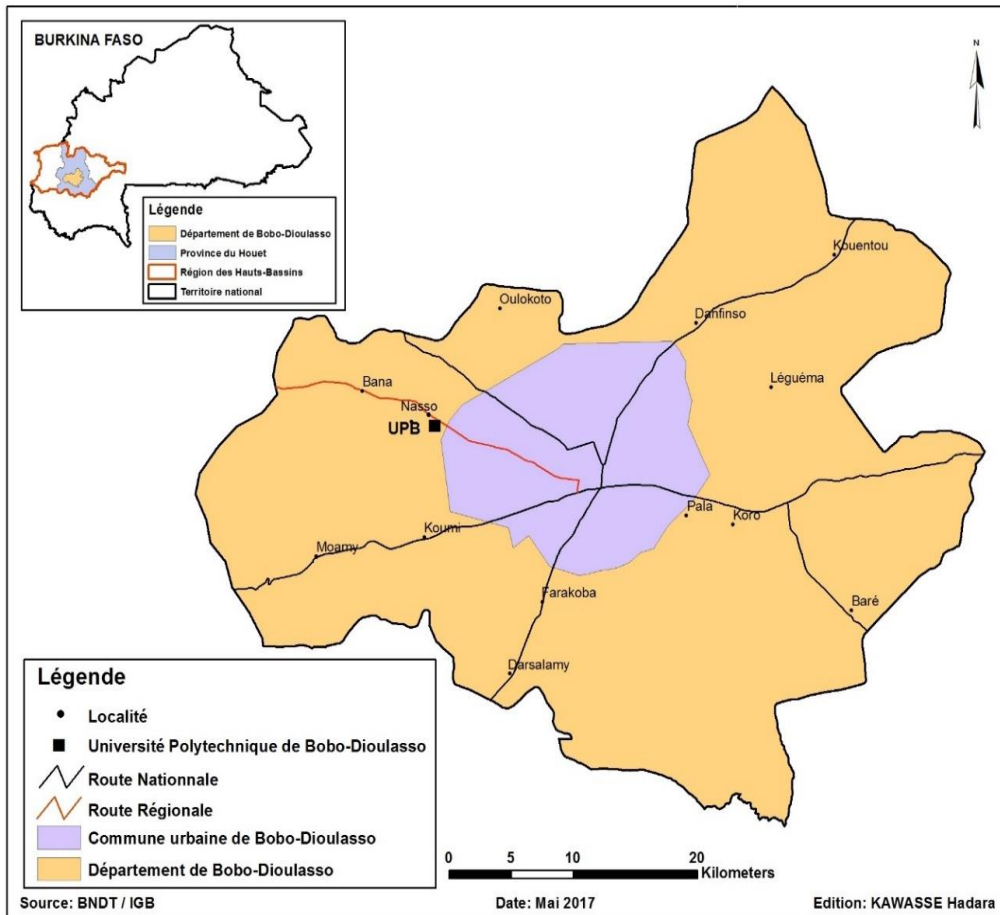


Figure 1 : Localisation of the site.

RESULTS

Evaluation of the poultry litter quantity

Table I gives the quantities of the poultry litter (PL) produced. The quantity of the PL produced by 18 birds after 6 months varied between 218.89 and 237.83 kg. The means quantity was 226.06 ± 7.84 kg (with 12.56 kg/chicken).

Dry matter and chemical characteristics of the substrates before and after maggots' production

The chemical characteristics of the poultry litter (PL) and the residues after maggots' production (RMP) are shown in

. The data show a decrease in PL weight of 30.33% after maggots' production. There is also a decrease in total nitrogen and organic carbon contents of the RMP compared to the PL. On the other hand, the residues after maggot production were higher in phosphorus and potassium contents and pH than the LV. The mineral matter in the RMP ($24.685 \pm 1.26\%$) was also significantly higher compared to the PL ($17.425 \pm 0.57\%$). The Analysis of variance showed significant differences ($p < 0.05$) between the PL and the RMP for the different parameters, except the C / N ratio.

Assessment of organic substrates produced by the different types of poultry farmers

The results of the estimate gave 2 888 and 2 006 kg for the poultry litter (PL) and the

residues after maggots production (RMP), respectively for poultry farmers (Type 5) with higher number of chickens (Table 3). Poultry farmers with lower number of chickens (Type 2), produced less than 1 tonne of PL and RMP.

Estimation of the possible quantities of N, P₂O₅ et K₂O in the PL and the RMP according to farmers type

Table 4 shows that type 5 farmers with 115 chickens would produce 79.12 kg of N, 71.04 kg of P₂O₅ and 49 kg of K₂O with crude

poultry litter. Type 2 poultry farmers with small number of poultries (30 chickens) would produce only 20.85 kg of N, 18.72 kg of P₂O₅ and 12.91 kg of K₂O.

After maggot production, it was observed that the amount of N, P₂O₅ and K₂O could increase with the number of chickens (Table 5). However, the amount of N and K₂O could decrease after the poultry litter being used for maggot production. Conversely, the amount of P₂O₅ could increase from 1 to 2 kg after maggot production.

Table 1 : Quantity of poultry litter produced.

Poultry batch	*Poultry litter (kg de DM)
Lot 1 (n = 18)	218.89
Lot 2 (n = 18)	237.83
Lot 3 (n = 18)	221.47
Average ± SD	226.06 ± 7.84

DM : dry matter; SD = standard deviation. *rice husk and poultry manure obtained after 6 months

Table 2: Dry matter and chemical characteristics of poultry litter (PL) and residues of maggots' production (RMP).

	DM (kg)	MM (%)	pH _{H2O}	C (%)	N (%)	C/N	P-total (mg/kg)	K-total (mg/kg)
PL	3.33 ^a ± 0.10	17.43 ^b ± 0.57	7.43 ^b ± 0.07	47.90 ^a ± 0.33	2.74 ^a ± 0.10	17.51 ± 0.70	10 741.41 ^b ± 3735.66	14 078.52 ^b ± 363.62
RMP	2.32 ^b ± 0.19	24.69 ^a ± 1.26	7.57 ^a ± 0.17	43.67 ^b ± 0.73	2.51 ^b ± 0.22	17.52 ± 1.59	16 017.58 ^a ± 1199.95	18 894.38 ^a ± 899.21
F	100.81	246.475	5.006	246.475	8.230	0.001	16.274	221.869
Pr > F	< 0.0001	< 0.0001	0.04	< 0.0001	0.011	0.979	0.001	< 0.0001
Significant	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes

DM = dry matter; MM = mineral matter; PL = poultry litter; RMP = residues of maggots' production ; C = carbon; N : nitrogen ; P-total : total phosphorus ; K-total : total potassium .

Table 3 : Estimation of organic substrates quantities produced per type of poultry farmers.

Types of poultry farmers	Type 1	Type 2	Type 3	Type 4	Type 5
Nb of poultries (Coulibaly et al., 2018)	109	30	43	55	115
PL (kg)	2 728	761	1 068	1 389	2 888
RMP (kg)	1 895	529	742	965	2 006

Nb = number; PL = poultry litter; RMP = residues of maggots' production

Table 4 : Estimation of quantity of N, P₂O₅ et K₂O that could be brought by PL per type of poultry farmers.

Types of poultry farmers	Type 1	Type 2	Type 3	Type 4	Type 5
N (kg)	74.74	20.85	29.27	38.07	79.12
P ₂ O ₅ (kg)	67.11	18.72	26.28	34.18	71.04
K ₂ O (kg)	46.29	12.91	18.12	23.57	49.00

N = nitrogen, P₂O₅ = phosphorus pentoxyde, K₂O = potassium oxide

Table 5 : Estimation of quantity of N, P₂O₅ et K₂O that could be brought by RMP per type of poultry farmers.

Types of poultry farmers	Type 1	Type 2	Type 3	Type 4	Type 5
N (kg)	47.59	13.27	18.63	24.24	50.37
P ₂ O ₅ (kg)	69.53	19.39	27.22	35.41	73.60
K ₂ O (kg)	43.15	12.04	16.90	21.98	45.68

N = nitrogen, P₂O₅ = phosphorus pentoxyde, K₂O = potassium oxide

DISCUSSION

The mean quantity of the poultry litter (PL) produced in 6 months was 12.56 kg per bird. Therefore, the estimated annual production is 25.12 kg / bird. According to the data found by Coulibaly et al. (2018), this estimated quantity is 81.40%, 79.77% and 23.5% higher than the quantities produced in rural areas, respectively for extensive system (4.67 kg / bird / year), semi-intensive system (5.08 kg / bird / year) and confinement system (19.21 kg / bird / year). The contribution of

the rice husk as litter could explain this important variation of the organic substrates (OS) produced in the current experiment. Feed supplement type as well as the method of feeding could also explain this production of OS. The results also show that the quantity of the PL decreased by 30.33% after maggots production, and the same situation was seen with the PL carbon and nitrogen contents which decreased from 8.83 and 8.39%, respectively, after maggot production. Similar results were also obtained with different

substrates including poultry manure by other authors (Zhu et al., 2012, Bloukounon-Goubalan et al., 2017). The decrease in the PL weight, and the carbon and nitrogen contents could be explained by the decomposition of the molecular carbon chains compounds by the maggots and the other micro-organisms according to Recou et al. (2017) who reported that in the presence of decomposed carbon, micro-organisms assimilate the available nitrogen during decomposition and contribute to the storage of organic matter by humification. Newton et al. (2005) who observed similar results, related this to the conversion (by the larvae into their biomass) of the residual proteins and other nutrients from the organic substrates.

Mineral matter, pH, total phosphorus and total potassium levels were higher in the RMP compared to their values in the PL used for maggot production. Bloukounon-Goubalan et al. (2017) justify the increasing of the pH through ammonia production during the ammonification and mineralization of organic nitrogen following the maggots' activities. The present results on phosphorus (P) and potassium (K) are discordant with the results of Newton et al. (2005) who obtained 44.1% and 55.8%, respectively for P and K with pig manure used to produce larvae of *Hermetia illucens* (black soldier fly). The present results could be explained by the nature of the larvae that are derived from *Musca domestica* and *Calliphora vomitoria*. It can also be hypothesized that the nature of the organic substrate used could influence the utilization of the nutrients by the larvae. The interaction between maggots and other micro-organisms might also be a hypothesis to justify the richness of the residues in P and total K.

The simulation results showed that poultry farmers can produce from 761 to 2888 kg of poultry litter annually with 30 and 115 birds respectively. When the poultry litter is used for maggot production, this would give 529 to 2006 kg of residues after maggots' production for 30 and 115 birds respectively. According to the works of Coulibaly et al. (2018), these quantities of organic substrates

are higher than the substrates produced by the same poultry farmers (between 196 and 800 kg) with the same number of birds. The use of organic substrates derived from the poultry activity in soil fertilization that was pointed out already by several authors (Agbede et al., 2013; Zhu et al., 2015; Habib et al., 2015; Adekiya et al. 2016). In addition, the results of this study show that these organic substrates can bring significant quantities of N, P₂O₅ and K₂O for the farmers. Therefore, poultry household with 30 bird could produce the equivalence of 100 kg of NPK (15-15-15). For poultry farmers with 100 birds, these could produce the equivalence of 300 kg of NPK (15-15-15).

Conclusion

The study shows that poultry rearing in semi-confinement with the use of rice husk as litter can allow poultry farmers to increase their organic matter production by over 70% compared to their current practice. The chemical quality of the organic matter showed that small poultry farmers can produce the equivalence of 100 to 300 kg of the complex NPK (15-15-15). The organization of poultry farming around these issues can be an important additional source of organic manure production that can contribute to sustainable management of soil fertility.

COMPETING INTERESTS

The authors declare that there is no conflict of interest with other research.

AUTHORS' CONTRIBUTIONS:

KC, FS, SP, JPN, MBS conceived the study. KC and MBS conducted and analyzed the experiments shown in the text. KC prepared the first draft. All authors reviewed the results and approved the final version of the manuscript.

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