Asian J. Med. Biol. Res. 2022, 8 (4), 216-224; https://doi.org/10.3329/ajmbr.v8i4.62497

Asian Journal of Medical and Biological Research
ISSN 2411-4472 (Print) 2412-5571 (Online)
https://www.ebupress.com/journal/ajmbr/

Article

Culture and production of *Lucilia sericata* Meigen (1826) larvae for rearing stinging catfish *Heteropneustes fossilis* (Bloch, 1794) using poultry waste

Abdus Satter[1*], Md. Ahsan Bin Habib[2], Hadi Hamli[3], Abdulla-Al-Asif[3] and Jamil[4]

[1]Department of Fisheries, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Melandah, Jamalpur, Bangladesh
[2]Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[3]Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia, Bintulu Sarawak Campus, Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia
[4]Department of Fisheries Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, 2202, Bangladesh

*Corresponding author: Abdus Satter, Department of Fisheries, Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University, Melandah, Jamalpur, Bangladesh. Email: satter@bsfmstu.ac.bd

Received: 09 October 2022/Accepted: 17 November 2022/Published: 24 November 2022

Abstract: The fly larvae (*Lucilia sericata*) are being used as an alternative protein source in any kind of animal feed as it reduces the cost of preparation of feed. This current study focused on the physico-chemical and proximate properties of raw poultry waste, while this study also revealed the production process of fly larvae and the proximate composition of it. The poultry waste was collected from Suvro poultry farm, Sutiakhali, Mymensingh, then the physic-chemical properties of the raw poultry waste were determined using different procedures. Three treatments were considered for production of fly larvae, T_1 (3 kg), T_2 (6 kg) and T_3 (9 kg) in a 15 kg capacity tray with three replications. After production, the proximate composition were also measured of fly larvae. Physico-chemical properties such as, color, odor, texture, temperature, pH, total solids (TSS+TDS), chemical oxygen demand, dissolved oxygen, alkalinity, available N, available P, and fiber in raw poultry waste were determined and presented. Proximate composition such as, moisture, total N, total P, available N, total Ca, ash and crude fiber were found in significant amount in the poultry waste. It was found that T_3 (1350±68g) produced highest volume of live maggot compared to the other treatments, but T_2 (17.50±1.10%) produced highest percentage volume. The proximate compositions of fly larvae were assessed and found 56.60±0.25% protein value in it, suggesting that fly larvae could be the protein replacer in fish feed. The result of this study revealed cheap protein source in aquaculture production, such as production and rearing of stinging catfish *Heteropneustes fossilis*, and the findings might be helpful for cost reduction in aquaculture operation.

Keywords: *Lucilia sericata*; raw poultry waste; physic-chemical; fly larvae; proximate composition

1. Introduction

Different agro-industries, including sugar mills, fertilizer factories, and poultry farms, discharge a significant amount of waste and effluent into the waterways and other terrestrial areas, and managing these wastes is a constant concern for the government and other stakeholders (Ayilara *et al*., 2020; Modak *et al*., 2019; Reza and Islam, 2019; Samad *et al*., 2011; Alam and Hossain, 2009). The wastes released from poultry farms may be used to recycle nutrients through the growth of fly larvae, microalgae, bacteria, and fungi (Gold *et al*., 2020; Markou *et al*., 2018; Glatz *et al*., 2011). High levels of organic nutrients, chemical and biological oxygen demands (COD and BOD), total dissolved solids (TDS), total suspended solids (TSS), Nitrate-N, Ammonia-N, Phosphorus-P, and inorganic nutrients are all present in these wastes (Izzah *et al*., 2020; Kwon *et al*., 2020; Yaseen and Scholz, 2019; Abdel-Raouf *et al*., 2012; Habib *et al*., 2005). These organic and inorganic nutrients in waste contribute to the growth of microalgae and the biosynthesis of significant amounts of protein, lipids, carbohydrates, and ash (Su *et al*., 2022; Melo *et al*., 2018). Chicken manure can encourage the growth and synthesis of additional protein, lipids, and carbohydrates by bacteria, fungus, microalgae, and fly larvae (Hasnol *et al*., 2020; Cammack and Tomberlin, 2017; Islam *et al*., 2018). Fly larvae, especially flies (*Lucilia sericata*), can use these nutrients as a cheap alternative (Zhang *et al*., 2021; Mazza *et al*., 2020; Parry *et al*., 2020; Firoozfar *et al*., 2011).

For the process of raising larvae, especially fly larvae, raw chicken manure includes several essential nutrients, for example, nitrogen, phosphorus, calcium (Bortolini et al., 2020; Lalander et al., 2019; Moon et al., 2001). These nutrients that are not utilized can be recycled, which produces additional support for the growth of other species and lowers their production costs (Manogaran *et al*., 2022; Szogi *et al*., 2015). The fly (*L. sericata*) maggot was considered one of the important animal that can be grown in the chicken manure medium (Ali Khan *et al*., 2012; Hwangbo *et al*., 2009).

Studies have shown that maggot meal may be a very effective replacement for fish meal, which serves as an excellent source of protein for making fish feed for commercial or small-scale aquaculture (Jahan *et al*., 2020; Medard *et al*., 2018; Djissou *et al*., 2016; Aniebo *et al*., 2009). Different animal and fish species were used in experiments to determine the impact of using maggot meal instead of other types of protein (Xu *et al*., 2022; Khan *et al*., 2016; Makinde and John, 2015; Aniebo *et al*., 2009). In most cases, maggot meal considered as cheapest and effective nutrient for animal production, including catfish *Heteropneustes fossilis* (Satter *et al*., 2022; Evangelista *et al*., 2005).

The nutritional content analysis of processed poultry waste such as, dried, hydrolyzed, and urea-molasses treated were conducted previously (Adli *et al*., 2018; McNab *et al*., 1974; Wehunt *et al*., 1960), however we did not find any study that determined the nutritional, physical and chemical content of raw poultry manure. Therefore, this current study was conducted to determine the nutritional, physical and chemical contents of raw poultry manure for producing and rearing catfish *Heteropneustes fossilis*; additionally the maggot production was also compared in different amount of poultry waste. This study will help to understand the nutritional availability of poultry waste and the production capacity of maggot in different amount of poultry waste.

2. Materials and Methods

2.1. Study area and periods

The experiments were conducted in the wet laboratory, Department of Aquaculture, Suvro poultry farm, Sutiakhali, Mymensingh, and laboratory of the Department of Animal Nutrition, Bangladesh Agricultural University (BAU), Mymensingh from January 2016 to May 2016 (Figure 1).

2.2. Collection and preparation of poultry waste

The poultry waste was collected from Suvro poultry farm, Sutiakhali, Mymensingh. The poultry farm used to grow and produce fly larvae (maggot) near the farm. Some raw waste was sun-dried grinded, and packed in polythene bag to keep in the laboratory for aerobic digestion and chemical analyses.

2.3. Determination of physico-chemical properties of poultry waste (PW)

Physico-chemical properties of digested PW were analyzed in the laboratories of Live Food Culture, Nutrition and Water Quality of the Faculty of Fisheries, BAU, Mymensingh. The color, odor and texture were evaluated by the human sensory organ. The temperature, the pH and dissolved oxygen (DO) of the digested PW were measured by Celsius thermometer, pH meter (Model HI 98129, HANNA) and digital oxygen meter (Model Nutron DO-5509), respectively using methods described by Islam *et al*. (2016). The chemical oxygen demand was evaluated following the protocols of Hills (1982) and Bortolini *et al*. (2020).The total suspended solid (TSS) and total dissolved solid (TDS) of poultry waste were measured by the procedure of Whitehead (1976) and Larney *et al*. (2014). The alkalinity, total phosphorus (P%) and total nitrogen (N%) of digested PW were measured using APHA (2005) and Das *et al*. (2021) protocols. The crude fiber content of digested PW was determined using the protocols of AOAC (2016).

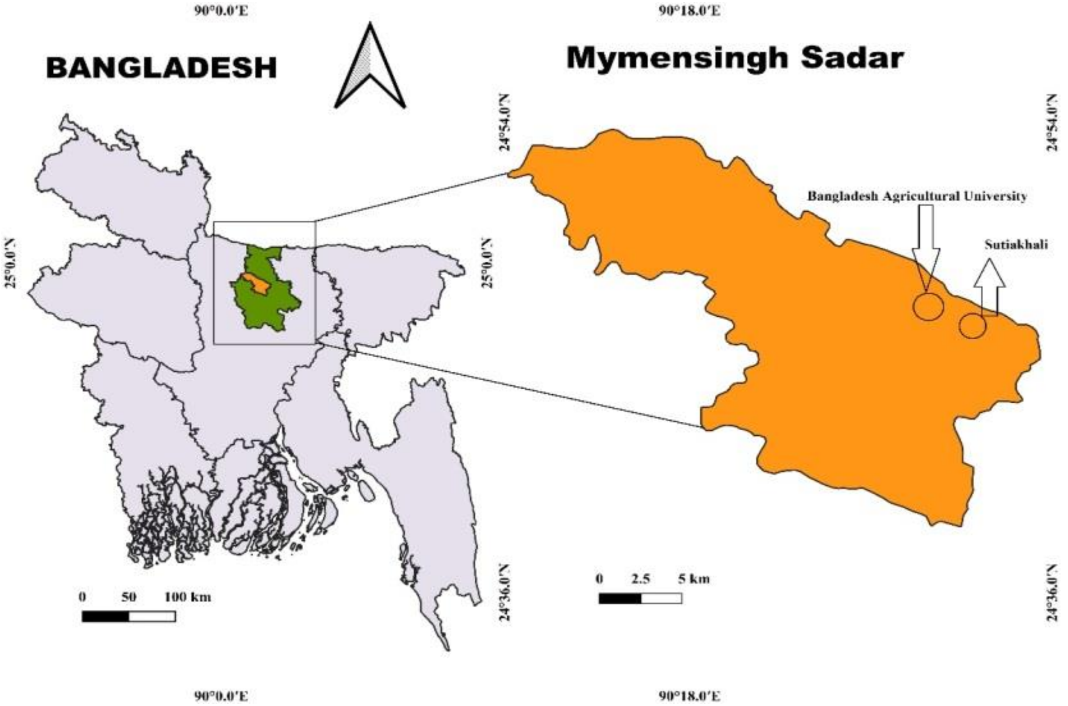

Figure 1. Poultry waste was collected from Sutiakhali, and lab analysis were conducted in Bangladesh Agricultural University.

2.4. Production and chemical analysis of fly (*Lucilia sericata*) larvae

The fly (*L. sericata*) usually lays eggs on raw poultry waste (PW) and their larvae grow. The flies were allowed to lay eggs in one day old PW in trays of 10 kg capacity (Figure 2A) just nearby a poultry farm situated at Sutiakhali. The fly larvae (maggot) were hatched out at the morning of 2nd day and became big in size ready for collection at the end of 3rd day (Figure 2B). Fly larvae maggot (*L. sericata*) were grown in three different amount of poultry waste namely, T_1 (3 kg), T_2 (6 kg) and T_3 (9 kg) in a 15 kg capacity tray in triplicates under shade (Figure 2A).

Figure 2. production process of fly; A. trays containing raw poultry waste for production of fly (*L. sericata*) larvae (maggot), B. maggot grown in trays on poultry waste on 3rd day, C. oven dried maggot on tray, D. oven dried maggot on tray.

These larvae were collected on 4th day morning. First, the grown larvae in PW were taken on mosquito net, placed in pond water and allowed to washout all the dart materials from inside the net. Then the net contained the remaining materials was taken out from water and the solid materials were carefully removed. The larvae were picked up using spoon and forceps and kept in plastic bottles. The bottles containing larvae were carried to the laboratory and cleaned using tap water. Some other portion of larvae (maggot) was dried in oven at 50ºC overnight (Figure 2 C,D) and the dried maggot was ground, sieved, powder of larvae was packed in polythene bags and kept in deep freeze for future use as ingredient of feed and chemical analysis.

2.5. Determination of proximate composition of poultry waste and larvae

Proximate composition such as moisture, crude protein, crude lipids, ash and nitrogen free extract (NFE) of poultry waste, and fly larvae were analyzed according to standard procedures given by AOAC (2005), Bhuiyan et al. (2018), Nayeem *et al*. (2019) and Khatun *et al*. (2018).

2.6. Data analysis

Three replications were maintained for collecting all the parameters. The collected data were analyzed for mean and standard error (SE) using SAS 9.4 (SAS Institute, 2014). The map was prepared using QGIS Version 3.26.3 (QGIS Development Team, 2019).

3. Results

3.1. Physico-chemical characteristics of raw poultry waste

The color of the poultry waste (PW) was grey with bad smell (odor); while the texture was found almost semi-solid. The temperature of PW ranged between 28.30 and 29.50°C, while the pH values of PW varied between 8.10 and 8.25. The presence of total solid in digested PW (total suspended solids and total dissolved solids) found to be in ranged between 8854 and 8864 mg/L. The dissolved oxygen (DO) of digested PW was ranged between 0 and 0.12 mg/L; while the Chemical Oxygen Demand (COD) demand was ranged from 13120 to 13215 mg/L. The alkalinity of digested PW was found 530 to 540 mg/L; while the available N and P was found ranged between 2.60 to 2.70 mg/L and 6.80 to 7.90 mg/L. The Crude fiber was found to be varied from 8.90 to 10.30% in the digested PW (Table 1).

Table 1. Physico-chemical characteristics of raw poultry waste just after collection.

Characteristics of raw poultry waste	Findings
Color	Grayish
Odor	Bad smell
Texture	Semi-solid
Temperature	28.30-29.50ºC
pH	8.10-8.50
Total solids (TSS + TDS)	88540-88640 mg/L
Chemical oxygen demand	131200-132150 mg/L
Dissolved oxygen	0-0.12 mg/L
Alkalinity	530-540 mg/L
Available N	2.60-2.70 mg/L
Available P	6.80-7.90 mg/L
Fibre	8.90-10.30%

3.2. Proximate composition of poultry waste on dry weight basis

Moisture was measured from semi-solid wet poultry waste ranged between 16.73 to 17.73% (17.23±0.50%). Total N of poultry waste was varied from 3.94 to 4.50 % (4.30±0.15%). Total P was found to be ranged from 6.80 to 7.90 mg/L. Available N was found to vary from 2.12 to 2.50% (2.25±0.12%). Total Ca of poultry waste was varied from 14.95 to 15.75% (15.45±0.34%). It was found that ash content of poultry waste was very high and ranged from 22.95 to 26.65% (24.55±0.62%). Crude fiber in poultry waste was not high in amount but ranged from 8.90 to 10.30% (9.60 ± 0.24%) (Table 2).

Table 2. Chemical composition (%) of poultry waste on dry basis.

Moisture	Total N	Total P	Available N	Total Ca	Ash	Crude Fiber
17.23±0.50	4.30±0.15	5.03±0.18	2.25±0.12	15.45±0.34	24.55±0.62	9.60±0.24

3.3. Production and chemical analysis of fly larvae in poultry waste

It was found the T_3 produced highest amount of live maggot (1350±68 g) followed by T_2 (1050±40 g) and T_1 (480±20 g) (Table 3). The percent production estimation suggested that, T_2 (17.50±1.10 %) produced highest percent of live maggot from poultry waste followed by T_1 (16.00±1.15 %) and T_3 (15.00±0.95 %). The higher dry weight of maggot was found in T_3 (138.70±7.40), followed by T_2 (109.20±6.70) and T_1 (49.50±3.55).

Table 3. Production of fly larvae (maggot) in different amount of poultry waste.

Treatment	Production of live maggot (g)	Percentage of production	Dry weight (g)
T_1	480±20	16.00±1.15	49.50±3.55
T_2	1050±40	17.50±1.10	109.20±6.70
T_3	1350±68	15.00±0.95	138.70±7.40

It was recorded that moisture content of maggot was 10.88±0.10%, where crude protein was 56.60±0.25%, crude lipids was 15.80±0.10%, ash content was 15.40±0.07% and NFE (nitrogen free extract) was 1.22±0.02% (Table 4).

Table 4. Average proximate composition (%) of fly (*L. sericata*) larvae (Maggot) grown in different trays.

Name of ingredient	Moisture	Crude protein	Crude lipids	Ash	NFE*
Maggot	10.88±0.10	56.60±0.25	15.80±0.10	15.40±0.07	1.22±0.02

*NFE (Nitrogen free extract) = 100 – (crude protein + crude lipids + ash)

4. Discussion

Production of fly (*L. sericata*) maggot using raw and digested poultry waste, the use of live maggot as protein source and maggot meal as the fish meal replacer in the production of the stinging catfish, *Heteropneustes fossilis* were the main key goal of this research. However, the physical and chemical composition of raw poultry was described by several researches while the color of the waste were grayish to black according to their states and the odors generated were due to the presence of volatile organic compounds (VOCs), ammonia (NH_3), hydrogen sulfide (H_2S), greenhouse gases, and particulate matter (Kopec´ *et al*., 2018; Kalus *et al*., 2017; Passos *et al*., 2014; Yetilmezsoy and Sakar, 2008). The semi-solid texture of raw poultry waste comprised a pH value of above 7.5, referring the alkaline condition of the material (Pizarro *et al*., 2019; Finch *et al*., 2014). The total suspended solid of poultry waste was reported 5,020 ± 380 mg/L in the research of Yetilmezsoy and Sakar (2008), however the present study suggested the range can be varied from 8854-8864 mg/L due to the mixture of the other organic particles with the raw poultry waste. The chemical oxygen demand of the digested poultry waste found higher due to high organic material content, resulting the low dissolved oxygen (DO) and high biologically active organics (Yetilmezsoy and Sakar, 2008; Whitehead, 1976). The total alkalinity of the digested poultry waste found to be higher (530-540 mg/L), due to high mineral contents especially the mollusk shells fed during the broiler production system; while studies also found moderate alkalinity of 170±30 mg/L in the poultry waste (Wasserfurth *et al*., 2019; Rehman *et al*., 2012). The available nitrogen content of the digested poultry waste was found to be 2.60-2.70 mg/L, while the raw form might have slightly higher nitrogen content than the digested form (Elasri and El amin Afilal, 2016). The presence of phosphorus in the waste was found 6.80-7.90 mg/L, while phosphorus in the mineral form of poultry waste can be considered one of the great organic source (Waldrip *et al*., 2011; Sarker *et al*., 2009).

The production of live maggot were ranged between 480 ± 20g and 1350 ± 68g, while the dry weight of the produced maggot ranged between 49.50 ± 3.55g and 138.70 ± 7.40g using 3 and 12kg poultry waste. Different studies suggested to use the cow dung, human waste, fruit waste, spend coffee ground, soybean dregs, etc. and they found different production rate and dry weight (Gougbedji *et al*., 2021; Permana and Ramadhani Eka Putra, 2018; Banks *et al*., 2014).

The fly larvae comprised high protein, 56.60±0.25%, lipids 15.80±0.10% and ash content 15.40±0.07%, referring the potentiality of the maggot placing as feed material, especially as the protein source for human or cultured animal (Odesanya *et al*., 2011). However, the price of the protein found always high in the market and considered one of the greatest challenges for reducing the price of the aquaculture final product (Hua *et al*., 2019; Fry *et al*., 2018; Dickson *et al*., 2016; Hyuha *et al*., 2011). There are many different sources of protein, and most of them require to culture in farm which need to keep high standard and as we were seeking for a cheap and standard protein source, considering fly larvae as the most inexpensive and low maintenance production-able protein source (Tippayadara *et al*., 2021; Egerton *et al*., 2020; Chen *et al*., 2019; Al-Thobaiti *et al*., 2018).

5. Conclusions

Therefore, it can be said that poultry waste is an ideal environment for the development of fly larvae (maggot). Maggot is a highly suitable food item, one of the main ingredients of feed as well as live or frozen food for fish post-larvae, fry, or fingerlings, according to nutritional analysis and proximate composition (herbivorous, carnivorous and omnivorous fishes). The use of fly larvae in fish feed production might reduce the cost of aquaculture operation.

Acknowledgements

The research team would like to acknowledge the logistic and technical support of the Department of Aquaculture, Bangladesh Agricultural University.

Data availability

The data of this current investigation will be available upon valid request by any authority from the corresponding author.

Conflict of interest

None to declare.

Authors' contribution

Abdus Satter: conceptualization, methodology, analysis and manuscript writing; Md. Ahsan Bin Habib: Supervision, conceptualization, methodology, reviewing and editing; Hadi Hamli: reviewing and editing; Abdulla-Al-Asif: data analysis, interpretation, graphical presentation and map preparation, reviewing and editing; Jamil: reviewing and editing. All authors have read and approved the final manuscript.

References

Abdel-Raouf N, AA Al-Homaidan and IBM Ibraheem, 2012. Microalgae and wastewater treatment. Saudi J. Biol. Sci., 19: 257–275.

Adli DN, O Sjofjan and M Mashudi, 2018. A study: nutrient content evaluation of dried poultry waste urea molasses block (dpw-umb) on proximate analysis. J. Il.-Il. Pet., 28: 84–89.

Al-Thobaiti A, K Al-Ghanim, Z Ahmed, EM Suliman and S Mahboob, 2018. Impact of replacing fish meal by a mixture of different plant protein sources on the growth performance in nile tilapia (*Oreochromis niloticus* L.) diets. Brazilian J. Biol., 78: 525–534.

Alam R and MD Hossain, 2009. Wastewater quality of natural gas fertilizer factory, Fenchuganj and water quality of Kushiara River at the down stream. Env. Mon. Asse., 154: 127–133.

Ali Khan HA, Ali Shad S and W Akram, 2012. Effect of livestock manures on the fitness of house fly, *Musca domestica* L. (Diptera: Muscidae). Parasitol. Res., 111: 1165–1171.

Aniebo AO, ES Erondu and OJ Owen, 2009. Replacement of fish meal with maggot meal in african catfish (*Clarias gariepinus*) diets. Rev. Cient. Udo Agri., 9: 666–671.

AOAC, 2005. Official methods of analysis. AOAC International.

APHA, 2005. Standard methods for the examination of water and wastewater (21st ed.). American Public Health Association.

Ayilara MS, OS Olanrewaju, OO Babalola and O Odeyemi, 2020. Waste management through composting: Challenges and potentials. Sustainability, 12: 1–23.

Banks IJ, WT Gibson and MM Cameron 2014. Growth rates of black soldier fly larvae fed on fresh human faeces and their implication for improving sanitation. Trop. Med. Int. Heal., 19: 14–22.

Bhuiyan MRR, Zamal H, Billah MM, Bhuyan MS, Al-Asif A and MH Rahman, 2018. Proximate composition of fish feed ingredients available in Shibpur upazila, Narsingdi district, Bangladesh. J. Entom. Zool. Stud., 6: 1345–1353.

Bortolini J, MHF Tavares, DT Freitag and O Kuczman, 2020. Removal of solids and chemical oxygen demand in poultry litter anaerobic digestion with different inocula. Ambi. Água Interdis. J. App. Sci., 15: 1–15.

Bortolini S, LI Macavei, SJ Hadj, G Foca, A Ulrici, F Bernini, D Malferrari, L Setti, D Ronga and L Maistrello, 2020. *Hermetia illucens* (L.) larvae as chicken manure management tool for circular economy. J. Clea. Prod., 262: 121289.

Cammack JA and JK Tomberlin, 2017. The impact of diet protein and carbohydrate on select life-history traits of the black soldier fly *Hermetia illucens* (L.) (Diptera: Stratiomyidae). Insects, 8: 1–14.

Chen Y, J Ma, H Huang and H Zhong, 2019. Effects of the replacement of fishmeal by soy protein concentrate on growth performance, apparent digestibility, and retention of protein and amino acid in juvenile pearl gentian grouper. PLoS ONE, 14: e0222780.

Das P, M Salman, MA Islam, S Suraiya, and M Haq, 2021. Proximate composition, amino acids, and fatty acids contents of dried shrimp products available in Jashore region, Bangladesh. Asian J. Med. Biol. Res., 7: 138–146.

Dickson M, A Nasr-Allah, D Kenawy and F Kruijssen, 2016. Increasing fish farm profitability through aquaculture best management practice training in Egypt. Aquaculture, 465: 172–178.

Djissou ASM, DC Adjahouinou, S Koshio and ED Fiogbe, 2016. Complete replacement of fish meal by other animal protein sources on growth performance of *Clarias gariepinus* fingerlings. Int. Aqua. Res., 8: 333–341.

Egerton S, A Wan, K Murphy, F Collins, G Ahern, I Sugrue, K Busca, F Egan, N Muller, J Whooley, P McGinnity, S Culloty, RP Ross and C Stanton, 2020. Replacing fishmeal with plant protein in Atlantic salmon (*Salmo salar*) diets by supplementation with fish protein hydrolysate. Sci. Rep., 10: 1–16.

Elasri O and M El amin Afilal, 2016. Potential for biogas production from the anaerobic digestion of chicken droppings in Morocco. Int. J. Recyc. Org. Wast. Agric. 5: 195–204.

Evangelista AD, NR Fortes and CB Santiago, 2005. Comparison of some live organisms and artificial diet as feed for Asian catfish *Clarias macrocephalus* (Günther) larvae. J. App. Ichth., 21: 437–443.

Finch HJS, AM Samuel and GPF Lane, 2014. Fertilisers and manures. In: Lockhart and Wiseman’s Crop Husbandry Including Grassland. Edited by: Finch HJS, AM Samuel and GPF Lane, Elsevier, pp. 63–91.

Firoozfar F, H Moosa-Kazemi, M Baniardalani, M Abolhassani, M Khoobdel and J Rafinejd, 2011. Mass rearing of *Lucilia sericata* Meigen (Diptera: Calliphoridae). Asian Pac. J. Trop. Biomed., 1: 54–56.

Fry JP, NA Mailloux, DC Love, MC Milli and L Cao, 2018. Feed conversion efficiency in aquaculture: Do we measure it correctly? Env. Res. Lett., 13: 024017.

Glatz P, Z Miao and B Rodda, 2011. Handling and treatment of poultry hatchery waste: A review. Sustainability, 3:216–237.

Gold M, CM Cassar, C Zurbrügg, M Kreuzer, S Boulos, S Diener and A Mathys, 2020. Biowaste treatment with black soldier fly larvae: Increasing performance through the formulation of biowastes based on protein and carbohydrates. Was. Man., 102: 319–329.

Gougbedji A, P Agbohessou, PA Lalèyè, F Francis and MR Caparros, 2021. Technical basis for the small-scale production of black soldier fly, *Hermetia illucens* (L. 1758), meal as fish feed in Benin. J.Agri. Food Res., 4:100153.

Habib MAB, FM Yusoff, SM Phang and S Mohamed, 2005. Experimental production and chemical composition of Culex mosquito larvae and pupae grown in agro-industrial effluent. Asian Fish. Sci., 18: 107–119.

Hasnol S, K Kiatkittipong, W Kiatkittipong, CY Wong, CS Khe, MK Lam, PL Show, WD Oh, TL Chew and JW Lim, 2020. A review on insights for green production of unconventional protein and energy sources derived from the larval biomass of black soldier fly. Processes, 8: 523.

Hills DJ, 1982. Chemical characteristics of and methane production from Turkey manure. Poul. Sci., 61: 677–684.

Hua K, JM Cobcroft, A Cole, K Condon, DR Jerry, A Mangott, C Praeger, MJ Vucko, C Zeng, K Zenger and JM Strugnell, 2019. The future of aquatic protein: Implications for protein sources in aquaculture diets. One Earth, 1: 316–329.

Hwangbo J, EC Hong, A Jang, HK Kang, JS Oh, BW Kim and BS Park, 2009. Utilization of house fly-maggots, a feed supplement in the production of broiler chickens. J. Env. Biol., 30: 609–614.

Hyuha TS, JO Bukenya, J Twinamasiko and J Molnar, 2011. Profitability analysis of small scale aquaculture enterprises in central Uganda. Int.J. Fish. Aqua., 3: 271–278.

Islam MM, R Hassan, BMN Sharif, MM Rahaman, MA Islam and MR Amin, 2016. Water quality, feeding management and cost-benefit analysis of a fish hatchery in Jessore district of Bangladesh. Asian J. Med.

Biol. Res., 2: 414–421.
Islam O, S Akter, MA Islam, DK Jamee and RI Khan, 2018. Preparation of wastelage with poultry droppings and rice straw (*Oryza sativa* L.) as a cattle feed. Asian J. Med. Biol. Res., 4: 251–258.
Izzah N, H Abdul, MM Hanafiah and NH Halim, 2020. Phytoremediation of TSS, NH_3-N and COD from sewage wastewater by *Lemna minor* L ., *Salvinia minima*, *Ipomea aquatica* and *Centella asiatica*. App. Sci., 10: 1–12.
Jahan H, NS Ema, MS Hossain, MA Pervin, R Akter and Z Hossain, 2020. Growth performance study of Silver barb (*Barbonymus gonionotus*) by replacing fishmeal with soybean meal in the diet. Asian J. Med. Biol. Res., 6: 149–154.
Kalus K, S Opali, D Maurer, S Rice, JA Koziel, M Korczy, Z Dobrza, R Ko and B Gutarowska, 2017. Odour reducing microbial-mineral additive for poultry manure treatment. Front. Env. Sci. Eng., 11: 1–9.
Khan S, RU Khan, A Sultan, M Khan, SU Hayat and MS Shahid, 2016. Evaluating the suitability of maggot meal as a partial substitute of soya bean on the productive traits, digestibility indices and organoleptic properties of broiler meat. J. Anim. Physiol. Anim. Nut., 100: 649–656.
Khatun S, MM Rahman, and CC Sarkar, 2018. Comparative overview of different fish feed industries in Noakhali region of Bangladesh. Asian J. Med. Biol. Res., 3: 488–493.
Kopec´ M, K Gondek, M Mierzwa-hersztek and J Antonkiewicz, 2018. Factors influencing chemical quality of composted poultry waste. Saudi J. Biol. Sci., 25: 1678–1686.
Kwon G, JH Nam, DM Kim, C Song and D Jahng, 2020. Growth and nutrient removal of *Chlorella vulgaris* in ammonia-reduced raw and anaerobically-digested piggery wastewaters. Env. Eng. Res., 25: 135–146.
Lalander C, S Diener, C Zurbrügg and B Vinnerås, 2019. Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (*Hermetia illucens*). J. Clea. Prod., 208: 211–219.
Larney FJ, AF Olson, JJ Miller and BC Tovell, 2014. Soluble salts, copper, zinc, and solids constituents in surface runoff from cattle manure compost windrows. Canadian J. Soil Sci., 94: 515–527.
Makinde A and O John, 2015. Maggot meal: a sustainable protein source for livestock production-a review. Adv. Life Sci. Tech., 31: 8.
Manogaran MD, R Shamsuddin, MH Mohd Yusoff, M Lay and AA Siyal, 2022. A review on treatment processes of chicken manure. Clea. Circ. Bioeco., 2:100013.
Markou G, L Wang, J Ye and A Unc, 2018. Using agro-industrial wastes for the cultivation of microalgae and duckweeds: Contamination risks and biomass safety concerns. Biotechnol. Adv., 36: 1238–1254.
Mazza L, X Xiao, K Rehman, M Cai, D Zhang, S Fasulo, JK Tomberlin, L Zheng, AA Soomro, Z Yu and J Zhang, 2020. Management of chicken manure using black soldier fly (Diptera: Stratiomyidae) larvae assisted by companion bacteria. Was. Man., 102: 312–318.
McNab JM, DWF Shannon and R Blair, 1974. The nutritive value of a sample of dried poultry manure for the laying hen. British Poul. Sci., 15: 159–166.
Medard G, O N'golo, B Yacouba, O Mamadou, O Allassane and Y Kouakou, 2018. Substitution of the fish meal by the earthworm and maggot meal in the feed of Nile tilapia *Oreochromis niloticus* reared in freshwater. Int. J. Fish. Aqua., 10: 77–85.
Melo RG, AF Andrade, RP Bezerra, DS Correia, VC Souza, AC Brasileiro-Vidal , Viana DA Marques and ALF Porto, 2018. *Chlorella vulgaris* mixotrophic growth enhanced biomass productivity and reduced toxicity from agro-industrial by-products. Chemosphere, 204: 344–350.
Modak M, EH Chowdhury, MS Rahman and MN Sattar, 2019. Waste management practices and profitability analysis of poultry farming in Mymensingh district: A socioeconomic study. J. Bangladesh Agri. Univ., 17: 50–57.
Moon RD, JL Hinton, SD O'Rourke and DR Schmidt 2001. Nutritional value of fresh and composted poultry manure for house fly (Diptera: Muscidae) larvae. J. Econ. Entomol., 94: 1308–1317.
Nayeem MA, A Hossain, MH Hannan and S Mondal, 2019. Comparative analysis of nutritional quality of different fish feed available in greater Noakhali region, Bangladesh. Asian Australas. J. Food Saf. Secur., 3: 1–14.
Odesanya BO, SO Ajayi, BKO Agbaogun and B Okuneye, 2011. Comparative evaluation of nutritive value of maggots. Int. J. Sci. Eng. Res., 2: 1–5.
Parry NJ, E Pieterse and CW Weldon, 2020. Stocking rate and organic waste type affect development of three Chrysomya species and *Lucilia sericata* (Diptera: Calliphoridae): Implications for bioconversion. J. App .Entomol., 144: 94–108.
Passos AMA, PM Rezende, ER Carvalho and AM Aker, 2014. Residual effects of the organic amendments poultry litter, farmyard manure and biochar on soybean crop. Agri. Sci., 5: 1376–1383.

Permana AD and JEN Ramadhani Eka Putra, 2018. Growth of black soldier fly (*Hermetia illucens*) larvae fed on spent coffee ground. IOP Conf. Ser. Ear. Env. Sci., 187: 012070.

Pizarro MD, G Céccoli, FF Muñoz, LS Frizzo, LD Daurelio and CA Bouzo, 2019. Use of raw and composted poultry litter in lettuce produced under field conditions: microbiological quality and safety assessment. Poul. Sci., 98: 2608–2614.

QGIS Development Team, 2019. QGIS geographic information system, GNU GPLv2. Open Source Geospatial Foundation Project.

Rehman MSU, A Khalid, S Liaquat, CT Mehmood, T Mahmood and S Mehmood, 2012. Color and COD removal from poultry litter leachate using an ozonation process. Env. Eng. Man. J., 11: 1467–1474.

Reza SMS and S Islam, 2019. Utilization potential of waste from sugarcane factory of Bangladesh as partial replacement of cement in concrete. J. Env. Treat. Tech., 7: 109–112.

Samad MA, MI Ali , D Paul and SMA Islam, 2011. An environmental impact study of Jamuna urea fertilizer factory at Tarakandi in Jamalpur with radiological indices. J. Env. Sci. Nat. Reso., 4: 27–33.

Sarker BC, MA Alam, MM Rahman, AFMT Islam, 2009. Waste management of commercial poultry farms in Bangladesh. J. Inno. Dev. Stra., 3: 34–37.

SAS Institute, 2014. SAS 9.4 for Windows (9.4). SAS Institute Inc.

Satter A, MAB Habib, A Al-Asif, H Hamli and A Hossain, 2022. Replacement of fish meal by *Lucilia sericata* Meigen (1826) live larvae and powdered meal in production of stinging catfish *Heteropneustes fossilis* (Bloch, 1794) post-larvae. AACL Bioflux, 15: In press.

Su M, M Dell'Orto, B Scaglia, G D'Imporzano, A Bani and F Adani, 2022. Growth performance, biochemical vomposition and nutrients recovery ability of twelve microalgae consortia isolated from various local organic wastes grown on nano-filtered pig slurry. Molecules, 27: 1–19.

Szogi AA, MB Vanotti and KS , 2015. Methods for treatment of animal manures to reduce nutrient pollution prior to soil application. Cur. Poll. Rep., 1: 47–56.

Tippayadara N, MAO Dawood, P Krutmuang, SH Hoeseinifar, H Van Doan and M Paolucci, 2021. Replacement of fish meal by black soldier fly (*Hermetia illucens*) larvae meal: Effects on growth, haematology, and skin mucus immunity of Nile Tilapia, *Oreochromis niloticus*. Animals, 11: 193.

Waldrip HM, Z He and MS Erich, 2011. Effects of poultry manure amendment on phosphorus uptake by ryegrass, soil phosphorus fractions and phosphatase activity. Biol. Fertil. Soi., 47:407–418.

Wasserfurth P, I Schneider, A Ströhle, J Nebl, N Bitterlich and A Hahn, 2019. Effects of mineral waters on acid–base status in healthy adults: Results of a randomized trial. Food Nut. Res., 63: 1–11.

Wehunt KE, HL Fuller and HM Edwards, 1960. The nutritional value of hydrolyzed poultry manure for broiler chickens. Poul. Sci., 39: 1057–1063.

Whitehead WK, 1976. Monitoring poultry processing waste water with total organic carbon. Poul.Sci., 55: 679–684.

Xu Y, H Su, T Li, J Lv, J Liu and X Bai, 2022. Effects of fly maggot protein replacement of fish meal on growth performance, immune level, antioxidant level, and fecal flora of blue foxes at weaning stage. Animals, 12: 1480.

Yaseen DA and M Scholz, 2019. Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review. Int. J. Env. Sci. Tech., 16: 1193–1226.

Yetilmezsoy K and S Sakar, 2008. Improvement of COD and color removal from UASB treated poultry manure wastewater using Fenton's oxidation. J. Haz. Mat., 151: 547–558.

Zhang J, J Zhang, J Li, JK Tomerlin, X Xiao, K Rehman, M Cai, L Zheng and Z Yu, 2021. Black soldier fly: A new vista for livestock and poultry manure management. J. Integ. Agri., 20: 1167–1179.