INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 17, No. 6, p. 519-528, 2020

RESEARCH PAPER OPEN ACCESS

Nutritional composition of house fly larvae (*Musca domestica*) reared on different mixture ratio of cattle blood with organic wastes

Lailatul Ferdousi[1*], Nahid Sultana[2], Ummey Hafsa Bithi[3], Sharmin Akter Lisa[3], Nasima Momtaz[2], Md. Mamunur Rashid[3], Md. Badrul Islam[1]

[1]*BCSIR Laboratories, Rajshahi, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh*

[2]*BCSIR Laboratories, Dhaka, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhanmondi, Dhaka-1205, Bangladesh*

[3]*Institute of Food Science & Technology (IFST), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhanmondi, Dhaka-1205, Bangladesh*

Key words: Cattle blood, Housefly, Maggot, Protein, Organic waste.

http://dx.doi.org/10.12692/ijb/17.6.519-528 Article published on December 28, 2020

Abstract

Cattle blood is an animal byproduct enriched with protein and minerals. However, the improper management of cattle blood has a bad impact on the environment and human health. This study was aimed to analyze the nutritional content of housefly larvae including proximate, mineral and fatty acid compositions reared on different mixture ratios of cattle blood with cattle manure and vegetable wastes. The experimental diets of housefly larvae were: T1 (1:3:1), T2(2:2:1) and T3(1:1:3) mixture of cattle blood, cattle manure and vegetable wastes respectively. The results showed that the moisture content of larvae varied ranges 85% to 90% among treatments. The crude protein (56.27±1.87%) and ash content (11.17±1.13%) were highest in maggots or larvae of T2, but maggots of T3 were highest in crude fat (29.17±2.95) and crude fiber (9.25±1.12). Differences in the fatty acid profile of maggots were small. Larval fatty acid profiles were characterized by high levels of palmitic acid, palmitoleic acid and oleic acid in all treatments. On the other hand, the mineral contents differed substantially. Larvae reared on T_2 were high in Ca, P, K, Fe and Zn exception Mn and Cu compared to other treatments.

* **Corresponding Author:** Lailatul Ferdousi ✉ laila.sujata@gmail.com

Introduction

Waste management is a major challenge globally in both developed and developing countries. Inappropriate treatment of waste creates a negative impact on the health, environment, social and economic life of the community (Sumantri, 2010). In Bangladesh, a total of 7.690 kton waste is produced daily in the six-city corporations (Huda *et al.*, 2014). It was accounted that nearly 68–81% of produced from organic matters, 7–11% from paper, 3–4% from plastic and 9–16% from textile, wood, leather, rubber, metal, glass and others (Alamgir and Ahsan, 2010). The organic matter is generally higher than any other waste source caused by the use of animal by-products, fresh vegetables and foods and lack of food processing industries. One source of organic waste, cattle blood which is available in most abattoirs in Bangladesh. Cattle blood is currently not efficiently used and spoiled in sewerage from abattoirs in Bangladesh. Waste is considered as a resource rather than a problem, additionally, the McKinsey Global Institute declared that food waste placed third of fifteen identified resources with productive opportunities (Dobbs, 2011). Consequently, bioconversion has got attention for its environmentally friendly, sustainable and renewable properties to address organic waste by insect rearing.

The house fly (*Musca domestica*, Linnaeus, 1758; Diptera) is widely known as a pest and a key vector of diseases both larvae (maggots) and adult flies. Housefly maggots can grow on a wide range of decaying organic wastes, including animal manure and feed (Hogsette and Farkas, 2000). The maggots are a potential supply of aquaculture feeds for more than 50% crude proteins (in dry weight) which are higher than those in soybean, meat and bone scrap (Akpodiete *et al.*, 1997; Iniguez *et al.*, 1994) and a promising source of limiting amino acids, such as lysine, methionine and phenylalanine (Ocio and Vinaras, 1979). Additionally, maggots contain a variety of biologically active substances, including antimicrobial peptides, lectins and chitins (Fu *et al.*, 2009; Hou *et al.*, 2007). It was observed that maggot proteins may stimulate the animal appetite when it adding to animal feed (Zhu *et al.*, 2012). Nutritional value of housefly larvae and pupae reared in manure were similar to that of fish meal or animal proteins (Akpodiete *et al.*, 1997; Miller *et al.*, 1974; Ocio and Vinaras, 1979). Recently, chitosan from maggots was even used in cosmetics and medicines (Ai *et al.*, 2008; Jing *et al.*, 2007). Previous literature mentioned that house fly maggots can develop some substrates for example pig manure (Viroje and Malin, 1988; Zhu *et al.*, 2012), cattle blood and wheat bran (Aniebo *et al.*, 2008), cattle blood and gut contents (Dankwa *et al.*, 2002), cattle gut and rumen contents (Ekoue and Hadzi, 2000), fish guts (Ossey *et al.*, 2012) and a mixture of egg content, hatchery waste and wheat bran (Ebenso and Udo, 2003).

Presently, there are no data that explains house fly growth and nutritional content in cattle blood mixture with manure and vegetable media. In the present study, we have examined the impact of different mixture ratios of cattle blood with cattle manure and vegetable wastes on the *M. domestica* larval proximate, mineral and fatty acid compositions.

Materials and methods

Rearing of the adult flies

The *M. domestica* was captured from the wild in Dhaka, Bangladesh. The experimental culture of *M. domestica* was conducted in the insectary of the Biological Research Division, BCSIR from March to June 2019. Geographically, our study area lies in the co-ordination of 23°44´30˝ N and 90°22´49˝ E. Every 500 adults were cultured in one 50 *50*50 cm mesh cage (0.2 mm pore size). *M. domestica* colonies were maintained on a diet of 2:2:1 sugar powdered: milk: hen egg at 27°C with a photoperiod of 14:10 (L:D) h cycle. Small white bags filled with moist wheat bran and brown sugars (4:1) were kept in the colony cages as oviposition medium. Every other 12 h, the concentrated eggs were collected and inoculated into different culture mediums.

Experimental feeding of maggots of M. domestica

Three experimental diets were made by cattle blood, cattle manure and vegetables in different ratios (Table

1). The vegetable waste composed of spoiled gourds, rotten carrots, peel of green papaya, bottle gourd and potato wastes cut into small pieces. After four-six days of cultivating, the maggots and culture medium were separated and dried in the oven (105°C).

Proximate analysis

Harvested maggots were processed by oven drying at a temperature of 105°C. Crude protein (AOAC, 1990), crude fat (Folch, 1957), and crude fiber of dried samples were estimated using standard procedures (AOAC, 1980) and all were replicated thrice in a completely randomized design. Crude protein content was determined using the Kjeldahl method and calculated by multiplying total nitrogen with a conversion factor of 6.25. A soxhlet apparatus was used for the determination of fat content. The crude fiber was estimated by using a total 5 g defatted sample boiling with 1.25% dilute H_2SO_4 and 1.25% dilute NaOH solution respectively. The boiling sample was transferred in the crucible and dried overnight at 80°C. The crucible was heated in a muffle furnace at 600°C for 1 hour.

Minerals

At first, 10g dried maggots powder in the beaker were placed in a muffle furnace covered by a watch glass remaining a slight gap at 150°C for 1 h and then the samples were ashed with 550°C keeping for 4-5 h. The ash was white and free from carbon. After ashing, 1-3 mL of concentrated nitric acid and distilled water (1:1) were added in the cooled beakers to wet the sample and for the complete removal of unwanted carbon particles which was then heated on a hot plate at about 150°C under a fume hood chamber until all the fumes removed or almost to dryness. Then the beakers were returned to the furnace setting the temperature directly at 550°C for 2-3 h and cooled. The ash was then dissolved in 10 mL of concentrated nitric acid warming on a hot plate at 180-200 °C for 5-10 min to aid in solution by keeping a watch glass on each beaker and heated until boiling. After the complete dissolved of ash, the beakers containing the sample were taken out from the hot plate and cooled at room temperature. Then the samples were taken in 50 mL calibrated volumetric flasks rinsing several times with deionized water and made up to the mark. The flasks were shaken well to uniform mixing the samples and then filtered to previously cleaned and labeled 100 mL non-transparent plastic bottles with Whatman™ qualitative 1 filter paper (125 mm dia.*100 circles) and preserved in the laboratory for metal analysis. Three replicates were made for each sample preparation in both of the above processes.

The analysis of metals was conducted following the previous report (Hasan *et al.*, 2020). The minerals such as Zn, Ca, Cu, Fe, Mn, and Ni were analyzed using atomic absorption spectrometer (AAS) (Model: AA240FS, Varian, Australia), Na and K were determined by a flame photometer (Model: PFP7, Jenway, UK), P was estimated with UV-Visible Spectrophotometer (Model: UV-1650PC, SHIMADZU, Japan). The details of the analytical procedure are described elsewhere (APHA, 1998). The results of the minerals were expressed as dry mass (DM) of BSF larvae.

Fatty acid

The fatty acid composition lipid from BSF prepupae was extracted using the chloroform: methanol (2:1, v/v; containing BHT 0.1 mg/100 g) (Floch *et al.*, 1957). The fatty acid composition was estimated by preparing methyl esters and analyzing them by gas chromatography (AOCS, 1992).

The gas chromatography (Model 14B SHIMADZU, Japan) with a flame ionization detector (GC-FID) was loaded with software class GC-10 (Version-2.0). The GC was prepared with a flame ionization detector (FID) and capillary column, with dimension 15 m length and 0.25 mm ID. The functional condition was automated at oven temperature 150°C (hold time 5 min), 8°C /min-190°C (hold time 0 min), 2°C/min-200°C (hold time 10 min), injection port temperature 250°C and detector temperature 250°C. Fatty acid peaks were identified from standard fatty acid mixtures. Nitrogen was used as a carrier gas, flow rate 20 ml/min and aliquots of 1 µl FAME (formed by esterification of fish oil samples) were injected and

the peaks of fatty acids were documented for their particular holding time and areas by the data processor unit of GC.

Data analysis

The recorded data were analyzed using Statistical software, SPSS of version 22.0. Descriptive statistics, mean and standard deviation (SD) were calculated first. Then to test the equality of these parameters, an analysis of variance (ANOVA) was performed. A few parameters varied significantly ($p<0.05$). Finally, the Duncan Multiple Rank Test (DMRT) of Post Hoc series of tests were performed.

Result and discussion

Proximate analysis showed (Fig. 1-6) that the moisture content of maggots was comparable among the treatments, ranging between 85.91±1.41 % and 90.57±1.28 % (Fig.1). These results are in close agreement with (Odesanya *et al.*, 2011; Sogbesan *et al.*, 2005) ensuring the high water content of maggots.

Table 1. Composition of artificial diets for *M. domestica*

Ingredients	T1	T2	T3
Cattle blood	200g	400g	200g
Cattle manure	600g	400g	200g
Vegetables	200g	200g	600g

In contrast, crude protein, crude fat, crude fiber and ash contents were significantly affected by the rearing substrate (Fig. 1-6). Maggots reared on treatment three (T3) was low in crude protein (39.59±2.51%on dry weight), compared to those reared on the other treatments. Crude protein of maggots (Fig.2) reared on T2 media was highest among the crude protein of other treatments which was higher than that of previously reported by Aniebo *et al.*, 2008 and Odesanya *et al.*, 2011 but slightly lower with Hussein *et al.*, 2017. However, it is far from Calvert *et al.* (1971) who accounted for 63%.

Table 2. Fatty acid compositions of housefly maggot percentage (dry weight basis).

Name of fatty acids	T1	T2	T3
Lauric Acid (C12:0)	1.54	0.49	0.69
Myristic Acid (C14:0)	6.97	3.89	9.23
Palmitic Acid (C16:0)	27.14	35.68	20.28
Stearic Acid (C18:0)	7.23	4.32	11.78
Total Saturated Fatty Acids	42.88	44.38	41.98
Palmitoleic Acid (C16:1)	24.12	28.59	25.56
Oleic Acid (C18:1)	21.34	18.54	20.02
Monounsaturated Fatty Acids	45.46	47.13	45.58
Linoleic Acid (C18:2) (Omega-6)	9.68	7.59	11.43
Linolenic Acid (C18:3) (Omega-3)	1.98	0.9	1.01
Polyunsaturated Fatty Acids	11.66	8.49	12.44
Total Unsaturated Fatty Acids	57.12	55.62	58.02

The crude protein of maggots depends on rearing substrate for example 47.1% on cattle blood and wheat bran (Aniebo *et al.*, 2008), 48% on poultry manure (Odesanya *et al.*, 2011) and 59% on cattle manure (Hussein *et al.*, 2017). So, previous studies support our results in this study that the range of crude protein between 39-63% (Calvert *et al.*, 1971; Fasakin *et al.*, 2003; Gado *et al.*,1982; Atteh and Ologbenla,1993). The fat content of maggots reared on T2 (Fig 3) was lowest among those of other treatments. The results of fat contents in this study were largely supported by previous investigations that

the range of fat content of maggots was within 14 - 37% (Atteh and Ologbenla, 1993; Adeniji, 2007; Ogunji., *et al.* 2015; Hwangbo., *et al.* 2009; Aniebo and Owen, 2007; Pretorius, 2011; Arong and Eyo, 2017). The ash content in maggots of T2 (Fig.4) was highest but lowest in crude fiber among the result of other treatments.

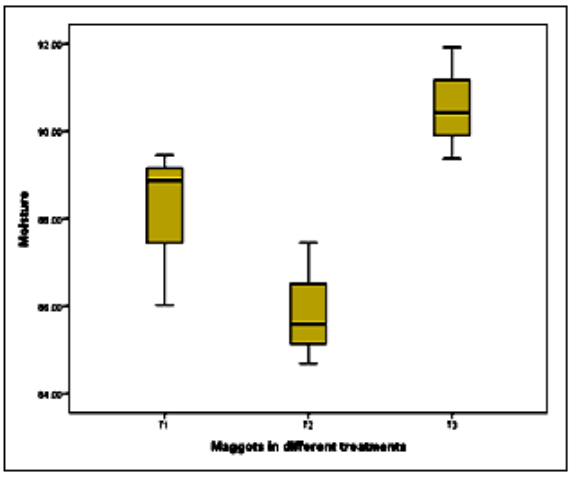

Fig. 1. Moisture (%) of maggots among treatments.

In early studies observed, the ranges of ash content and crude fiber were 4.50-10.68% and 3.14-9.95% respectively (Atteh and Ologbenla, 1993; Adeniji, 2007; Ogunji., *et al.* 2015; Hwangbo., *et al.* 2009; Aniebo and Owen, 2007; Pretorius, 2011; Arong and Eyo, 2017).

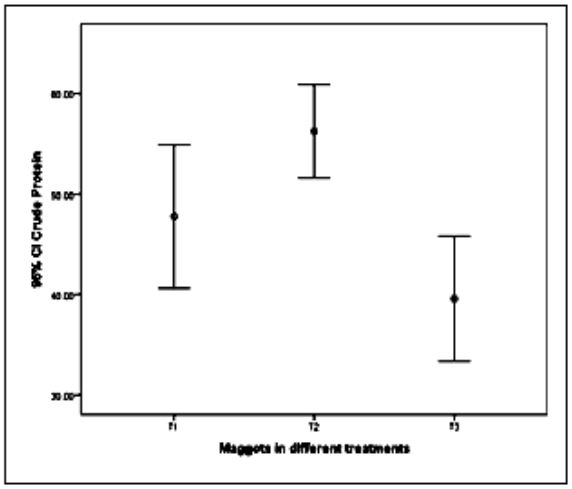

Fig. 2. Crude Protein (%) among treatments.

The current findings in this study strongly agreed with former investigations (Atteh and Ologbenla, 1993; Adeniji, 2007; Ogunji., *et al.* 2015; Hwangbo., *et al.* 2009; Aniebo and Owen, 2007; Pretorius, 2011; Arong and Eyo, 2017).

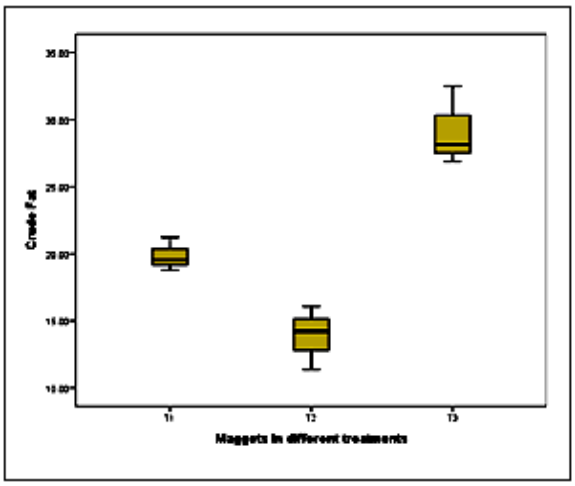

Fig. 3. Crude fat (%) of maggots among treatments.

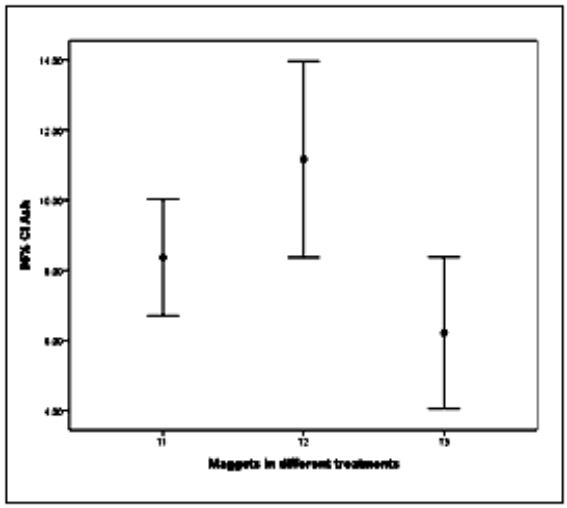

Fig. 4. Ash (%) of maggots among treatments.

It showed from the test results that all proximate compositions moisture, crude protein, crude fat, ash and crude fiber are significantly different in treatments ($p<0.05$) at a 5% level of significance.

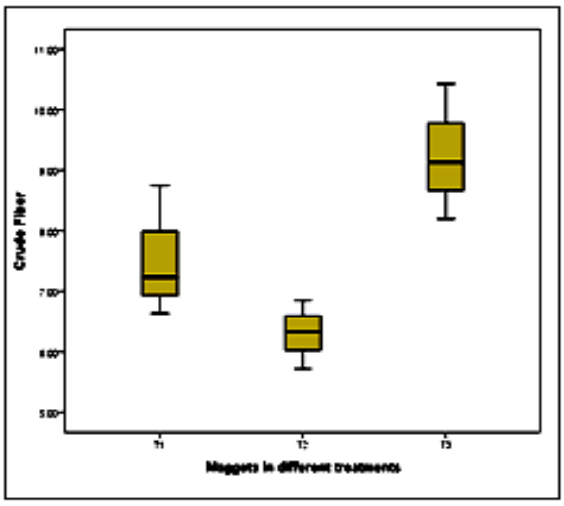

Fig. 5. Crude fiber (%) of maggots among treatments.

DMRT has been presented in Fig. 1 as alphabetical letters beside the means. Here, the means containing the same letter do not differ at a 5% level of significance. Consequently, the variation in proximate composition results between current findings and earlier findings may be due to rearing food sources, applied methodology, species and geographical location. The estimated mineral elements in this investigation were displayed in Fig. 7-13.

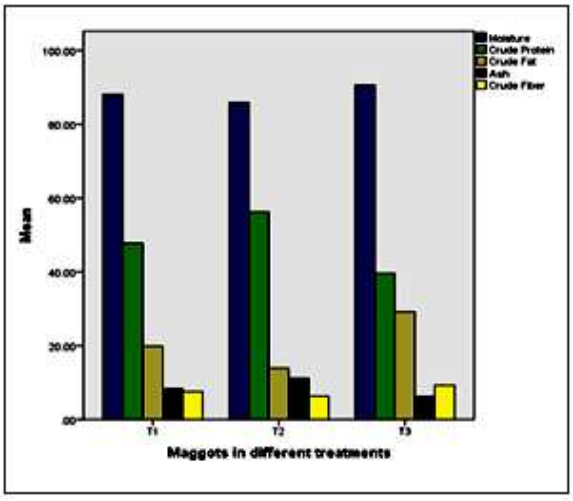

Fig. 6. Proximate composition of maggots treatments.

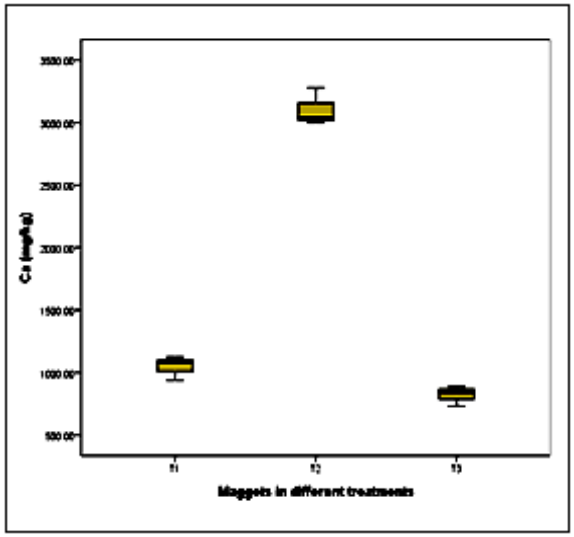

Fig. 7. Ca of housefly maggot mg/ kg (dry weight basis).

The levels ranged from Ca (822-3104 mg kg-1 on dry weight), P (9165-18400 mg kg-1 on dry weight), K (1016-1538 mg kg-1 on dry weight) and Fe (1528-2274 mg kg-1 on dry weight) were satisfactory while of the other minerals were all within a small range (Table 3).

The fluctuation of Calcium levels among treatments (Fig. 7) was strongly prominent, in contrast to other minerals. For example, the level of Ca in maggots of T2 was three folds than T1 but about four folds with T3.

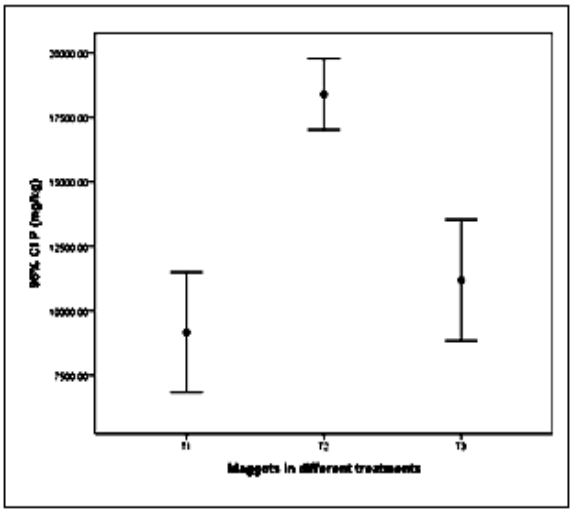

Fig. 8. P content of housefly maggot mg/ Kg (dry weight basis).

The mineral contents in maggots of T3 were higher among those results of other treatments except Cu and Zn. The level of minerals in this study was lower than the findings of Hussein *et al.* (2017) while similar to results of early reports that house fly maggots reared on different substrates (Makker *et al.*, 2014; Cadag *et al.* 1981; Fasakin *et al.*, 2003; Göhl ,1982; Hwangbo *et al.*, 2009; Odesanya *et al.*, 2011; Pretorius, 2011).

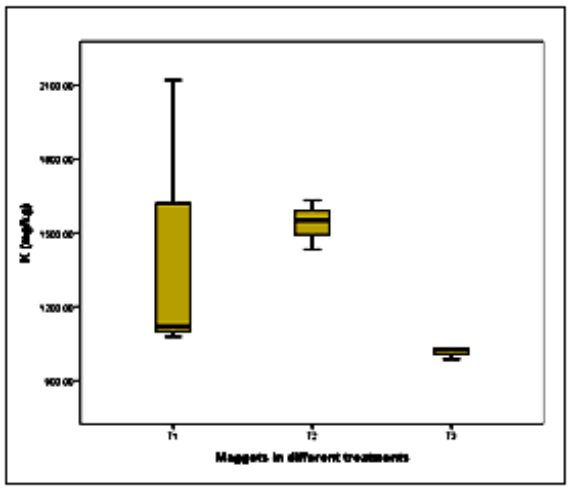

Fig. 9. K content of housefly maggot mg/ Kg (dry weight basis).

ANOVA tests show that except K and Mn ($p>0.05$), all

other mineral content of housefly maggot mg/ kg (dry weight basis) Ca, P, Cu, Fe and Zn are significantly different in different waste compositions ($p<0.05$) at 5% level of significance. DMRT has been presented in Fig. 3 to 7 as alphabetical letters beside the means. Here, the means containing the same letter do not differ at a 5% level of significance.

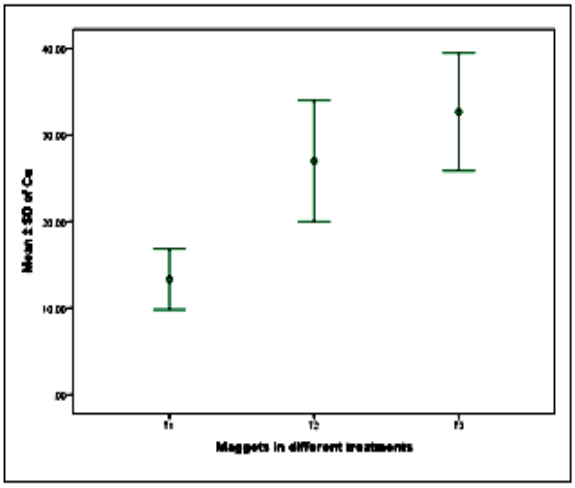

Fig. 10. Cu content of housefly maggot mg/ kg (dry weight basis).

The fatty acid profile is presented in Table 2, total of 8 types of fatty acid were recorded in all maggots among different treatments.

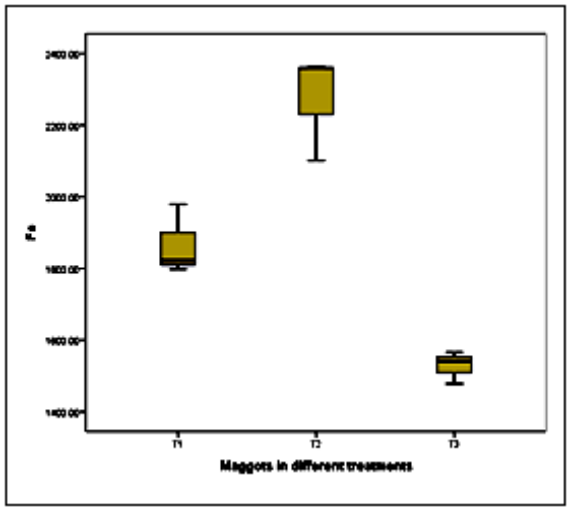

Fig. 11. Fe content of maggot mg/ kg (dry weight basis).

The investigated 8 fatty acids in maggots among treatments contained four Saturated Fatty Acids **(**SFA), 4 Unsaturated Fatty Acids (UFA) in which 2 were monounsaturated fatty acids (MUFA) and 2 were polyunsaturated fatty acids (PUFA). The fatty acid composition of the maggots was largely composed of saturated fatty MUFA which was45.46-47.13% of the total lipid in all maggots among different treatments. All groups were enriched with linoleic acid (7.59-11.43%).

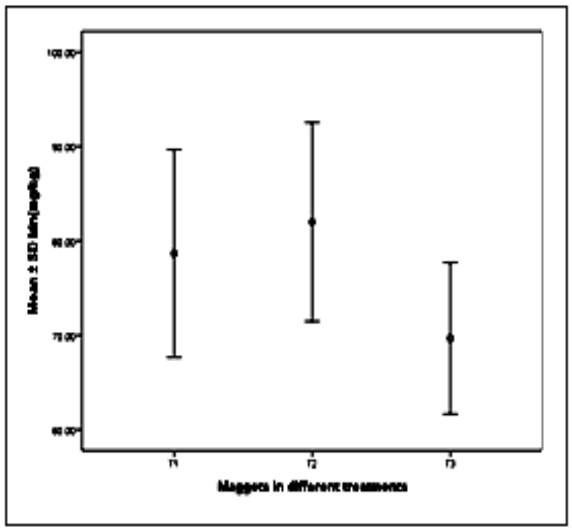

Fig. 12. Mn content of maggot mg/ kg (dry weight basis).

It was observed in these investigations that single fatty acid was largely influenced by substrate composition but the ranges of fatty acids (total SFA and total UFA) of maggots (Table 4) among treatments were not significantly varied. When comparing between the current ranges of fatty acid compositions with previous studies that maggots reared on different media were similar with our current results (Hwangbo *et al.*, 2009; Odesanya *et al.* 2011; Pretorius 2011; Hussein *et al.* 2017).

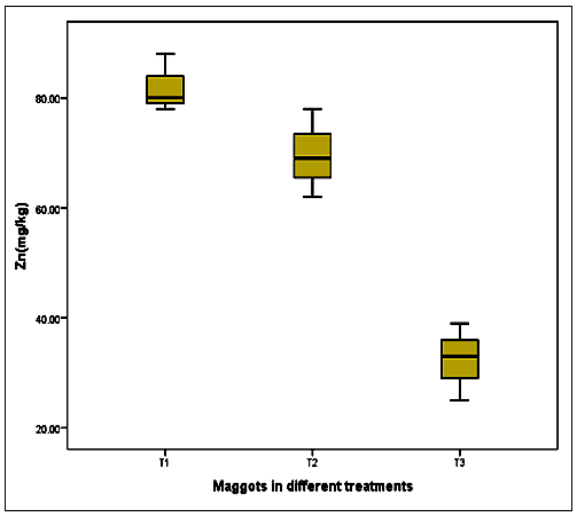

Fig. 13. Zn content of housefly maggot mg/ kg (dry weight basis).

Conclusion

Our findings indicate that the three experimental treatments gave different effects on housefly maggot nutritional value. The proximate compositions appear to be dependent on the rearing substrate. Furthermore, the highest protein content of maggots was produced by T2> T1> T3, the highest fat by T3> T1> T2, the ash content by T2> T1> T3 and the highest crude fiber content by T3> T1> T2. Moreover, the mineral element of maggots reared on T_2 media was highest among other treatments. The fatty acid compositions were not significantly different but all maggots from different treatments enriched with linolenic acid. Finally rearing system of *M. domestica* larvae on the mixture of cattle blood with cattle manure and vegetable wastes could deliver a high-quality insect resource with potential for being adopted in animal feed.

Acknowledgments

The authors acknowledge the Bangladesh Council of Scientific and Industrial Research (BCSIR) for funding to continue this research under the "Research and Development project".

References

Adeniji AA. 2009. Effect of replacing groundnut cake with maggot meal in the diet of broilers. International Journal of Poultry Science **6(11),** 822-825.

Ai H, Wang FR, Yang QS, Zhu F, Lei CL. 2008. Preparation and biological activities of chitosan from the larvae of housefly, *Musca domestica*. Carbohydrate Polymer **72,** 419–423.

Akpodiete OJ, Ologhobo AD, Oluyemi JA. 1997. Production and nutritive value of housefly maggot meal on three substrates of poultry faeces. Journal of Applied Animal Research **12,** 101–106.

Alamgir M, Ahsan A. 2007. Municipal solid waste and recovery potential: Bangladesh perspective. Journal of Environmental Health Science and Engineering **4,** 67–76.

Aniebo AO, Owen OJ. 2010. Effects of age and method of drying on the proximate composition of housefly larvae (*Musca domestica* Linnaeus) Meal (HFLM)". Pakistan Journal of Nutrition **9,** 485-487.

Aniebo AO, Erondu ES, Owen OJ. 2008. Proximate composition of housefly larvae (Musca domestica) meal generated from mixture of cattle blood and wheat bran. Livestock Research for Rural Development **20**.

AOCS. 1992. Fatty Acid Composition by GLC. Marine Oils. AOCS Official Methods Ce 1b-89, AOCS, Champaign, Italy.

APHA (American Public Health Association). 1998. Standard Methods for the Examination of Water and Wastewater, 22th edition, American Water Works Association, Water Environment Federation, USA.

Arong GA, Eyo VO. 2017. Evaluation of house fly (*Musca domestica*) maggot meal and termite (*Macrotermes subhyalinus*) meal as supplementary feed for African Catfish *Clarias gariepinus* (Burchell, 1822)". International Journal of Entomology and Nematology **3(1),** 042-050.

Atteh JO, Ologbenla FD. 1993. Replacement of fishmeal with maggots in broiler diets. Effects on performance and nutrient retention. Nigerian Journal of Animal Production **20,** 44-49.

Calvert CC, Martins RD, Eby HJ. 1971. Housefly pupae as food for poultry. Journal of Economic Entomology **62(1),** 939.

Dankwa D, Nelson FS, Oddoye EOK, Duncan JL. 2002. Housefly larvae as a feed supplement for rural poultry. Ghana Journal of Agricultural Science **35,** 185–187.

Dobbs ROJ, Thompson F, Brinkman M, Zornes M. 2011. Resources Revolution: Meeting the World's Energy, Materials, Food, and Water Needs. McKinsey Global Institute, McKinsey & Company.

Ebenso IE, Udo MT. 2003. Effect of live maggot on growth of the Nile perch, *Oreochromis niloticus* (Cichlidae) in South Eastern Nigeria. Global Journal of Agricultural Sciences **2,** 72–73.

Ekoue SK, Hadzi YA. 2000. Maggot production as a protein source for young poultry in Togo – preliminary observations. Tropicultura **18,** 212–214.

Fasakin EA, Balogun AM, Ajayi OO. 2003. Nutrition implication of processed maggot meals; hydrolyzed, defatted, full-fat, sun-dried and oven-dried, in the diets of *Clarias gariepinus* fingerlings. Aquaculture Research **9(34),** 733-738.

Feng Xiang Z, Wei Ping W, Chun Lai H, Ming-Guang F, Zhi Yong X, Xiao Yang C, Yan Lai Y, Man Y. 2012. Rapid production of maggots as feed supplement and organic fertilizer by the two-stage composting of pig manure. Bioresource Technology **116,** 485-491. https://doi.org/10.1016/j.biortech.2012.04.008.

Folch J, Lees M, Sloanestanley GH. 1957. A simple method for the isolation and purification of total lipids from animal tissues. Journal of Biological Chemistry **226,** 497-509.

Fu P, Wu JW, Guo G. 2009. Purification and molecular identification of an antifungal peptide from the hemolymph of Musca domestica (housefly). Cellular and Molecular Immunology **6,** 245–251.

Gado MS, El-Aggory SM, Gawaard AA, Mormond AK. 1982. The possibility of applying insect protein in broiler rations. Nutrition Abstract Review **43,** Abstract 76.

Hasan AB, Reza AHMS, Kabir S, Siddique MAB, Ahsan MA, Akbor MA. 2020. Accumulation and distribution of heavy metals in soil and food crops around the ship breaking area in southern Bangladesh and associated health risk assessment. SN Applied Sciences **2,** 155. https://doi.org/10.1007/s42452-019-1933-y

Hogsette JA, Farkas R. 2000. Secretophagous and haematophagous higher Diptera. In: Papp L, Darvas B (Eds.), Contributions to a Manual of Palearctic Diptera, General and Applied Dipterology **1,** 769–792.

Hou LX, Shi YH, Zhai P, Le GW. 2007. Antibacterial activity and in vitro antitumor activity of the extract of the larvae of the housefly (Musca domestica). Journal of. Ethnopharmacology **111,** 227–231.

Huda ASN, Mekhilef SA, Ahsan A. 2014. Biomass energy in Bangladesh: Current status and prospects. Renewable and Sustainable Energy Reviews **30,** 504–517.

Hussein M, Pillai VV, Goddard JM, Park HG, Kothapalli KS, Ross DA. 2017 Sustainable production of housefly (*Musca domestica*) larvae as a protein-rich feed ingredient by utilizing cattle manure. PLoS ONE **12(2),** e0171708. https://doi.org/10.1371/journal.pone.0171708

Hwangbo J, Hong EC, Jang A, Kang HK, Oh JS, Kim BK, Park BS. 2009. Utilization of house fly-maggots, a feed supplement in the production of broiler chickens. Journal of Environmental Biology **30(4),** 609-614.

Iniguez-covarrubias G, Franco-Gomez MD, Andrade-Maldonado GD. 1994. Biodegradation of swine waste by housefly larvae and evaluation of their protein-quality in rats. Journal of Applied Animal **6,** 65–74.

Jing YJ, Hao YJ, Qu H, Shan Y, Li DS, Du RQ. 2007. Studies on the antibacterial activities and mechanisms of chitosan obtained from cuticles of housefly larvae. Acta Biologica Hungarica **58,** 75–86.

Jonathan AA. 2012. Comparability of the proximate and amino acids composition of maggot meal, earthworm meal and soybean meal for use as feedstuffs and feed formulations. Elixir Applied Biology **51,** 10693-10699.

Makkar HP, Tran G, Heuzé V, Ankers P. 2014. State-of the-art on use of insects as animal feed. Animal Feed Science and Technology **197,** 1-33.

Miller BF, Teotia JS, Thatcher TO. 1974. Digestion of poultry manure *by Musca domestica*. British Poultry Science **15**, 231–234.

Myers HM, Tomberlin JK, Lambert BD, Kattes D. 2014. Development of black soldier fly (Diptera: Stratiomyidae) larvae fed dairy manure. Environmental Entomology **37,** 11–15.

Niu Y, Zheng D, Yao B, Cai Z, Zhao Z, Wu S, Cong P, Yang D. 2017. A novel bioconversion for value-added products from food waste using *Musca domestica*. Waste Management **61,** 455-460, https://doi.org/10.1016/j.wasman.2016.10.054.

Obeng AK, Atuna KA, Aihoon S. 2015. Proximate composition of housefly (Musca domestica) maggots cultured on different substrates as potential feed for Tilapia (*Oreochromis niloticus*). International Journal of Multidisciplinary Research and Development **2(5),** 102-103.

Ocio E, Vinaras R. 1979. Housefly larvae meal grown on municipal organic waste as a source of protein in poultry diets. Animal Feed Science and Technology **4,** 227–231.

Odesanya BOSO, Ajayi BKO, Agbaogun B, Okuneye. 2011. Comparative Evaluation of Nutritive Value of Maggots. International Journal of Scientific & Engineering Research **2,** 11.

Ogunji JO, Kloas W, Wirth M, Schulz C, Rennert B. 2008. Housefly maggot meal (magmeal) as a protein source for *Oreochromis niloticus* (Linn.). Asian Fisheries Science **21,** 319–331.

Ossey YB, Atsé BC, Koumi AR, Kouamé LP. 2014. Effect of Maggot Dietary Protein Level on Growth Performance, Feed Utilization, Survival Rate and Body Composition of *Heterobranchus longifilis* Larvae Reared in Aquarium. British Journal of Applied Science and Technology **4(13),** 2001-2010.

Ossey YB, Koumi AR, Koffi KM, Atse BC, Kouame LP. 2012. Use of soybean, bovine brain and maggot as sources of dietary protein in larval *Heterobranchus longifilis* (Valenciennes, 1840. Pl). Journal of Animal Science **15,** 2099–2108.

Pretorius Q. 2011. The Evaluation of Larvae of *Musca domestica* (Common House Fly) As Protein Source For Broiler Production. A Thesis in Stellenbosch University, Faculty of Agrisciences, Department of Animal Sciences.

Sogbesan OA, Ajuonu ND, Ugwumba AAA, Madu CT. 2005. Cost benefits of maggot meal as supplemented feed in the diets of *Clarias gariepinus* and *heterobranchus longifilis* hybrid fingerlings in outdoor concrete tanks. Journal of Scientific and Industrial Studies **3(2).**

Sumantri A. 2010. Environmental Health 3rd edition. Jakarta: KENCANA.

Ukanwoko AI, Olalekan OA. 2015. Effects of Source and Time of Harvest on the Proximate Composition of Maggot (*Musca domestica*) Larva Meal. International Journal of Livestock Research **5(7),** 1-7.

Viroje W, Malin S. 1988. Preliminary study on producing of fly larva meal from pig feces as protein source in animal diets. King Mongkuts Agricultural Journal **6,** 25–31.

Zhu FX, Wang WP, Hong CL, Feng MG, Xue ZY, Chen XY, Yao YL, Yu M. 2012. Rapid production of maggots as feed supplement and organic fertilizer by the two-stage composting of pig manure. Bioresource Technology **116,** 485–491.