EFFECT OF FEEDING BLACK SOLDIER FLY (*HERMETIA ILLUCENS*) LARVAE MEAL ON THE GROWTH PERFORMANCE AND ORGAN WEIGHT OF THE VILLAGE CHICKENS, AYAM KAMPUNG KACUK (AKK)

By

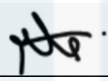
ALWAFI BIN NORDIN
(D18B0034)

A RESEARCH PAPER SUBMITTED TO THE FACULTY OF VETERINARY MEDICINE, UNIVERSITI MALAYSIA KELANTAN
IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR
THE DEGREE OF
DOCTOR OF VETERINARY MEDICINE

2023

CERTIFICATION

This is to certify that we have read this research paper entitled 'Effect of Feeding Black Soldier Fly (BSF) Larvae Meal on The Growth Performance Ayam Kampung Kacuk (AKK)" by Alwafi Bin Nordin. In our opinion, it is satisfactory in terms of scope, quality and presentation as partial fulfilment of the course DVT 55204 – Research Project requirements.



Dr Mohd Farhan Hanif Bin Reduan
DVM (UMK), PhD Clinical Pathology (UPM)
Senior Lecturer
Faculty of Veterinary Medicine
Universiti Malaysia Kelantan
(Supervisor)

Dr Abd Rahman Bin Aziz
Senior Fellow
DVM (UoF), MSc (University of Melbourne, Australia),
Faculty of Veterinary Medicine
Universiti Malaysia Kelantan
(Co-supervisor)

Mr Amirul Faiz Bin Mohd Azmi
Master in Animal Nutrition (Universiti Putra Malaysia)
Lecturer,
Faculty of Veterinary Medicine
Universiti Malaysia Kelantan
(Co-supervisor)

ACKNOWLEDGEMENT

Special thanks to those who have given their support, guidance, advice and aid for the completion of this project paper:

i. Dr Mohd Farhan Hanif Bin Reduan

ii. Dr Abd Rahman Bin Aziz

iii. Lab assistants of FPV UMK

iv. Family

v. DVM 5 Class of 2018/2023

Thank You

DEDICATIONS

I dedicated my dissertation work to my family and many friends. Special gratitude to my loving parents, Nordin Abdul Malek and Zamnah Binti Khalil, whose encouragement and push for tenacity ring in my ears. My sister, Aliyah Binti Nordin, has never left my side and is very special.

I also dedicated this dissertation to many lecturers and seniors who have supported me throughout the process. I will always appreciate everything they have done, especially Dr Mohd Farhan Hanif bin Reduan, Dr Abd Rahman bin Aziz, Amirul Faiz Bin Mohd Azmi
and the laboratory assistants for helping me develop my skills as a veterinary student.

I also dedicated this spadework to Animal Laboratory Supervisor Dr Roslina Binti Rashid for helping me throughout the project.

I also dedicated this work and give special thanks to my classmates, Mohammad Taufiq bin Tarmuzi and Muhammad Kasyfi bin Mohd Yazid for being there for me throughout the entire program of Doctor Veterinary Medicine. All of them have been my best strong supporters.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

BSFL	Black Soldier Flies Larvae
AKK	Ayam Kampung Kacuk
CP	Crude Protein
G	Gram

ABSTRACT

An abstract of the research paper presented to the Faculty of Veterinary Medicine, Universiti Malaysia Kelantan, in partial requirement of the course DVT 5504 – Research Project.

Interest in animal-based food protein would increase quickly with the worldwide population expansion and high demand. This research project aims to investigate the potential for feeding Black Soldier Fly (BSF) Larvae Meal on the growth performance of village chicken. This experiment was conducted for 21 days using two weeks old chickens (n=10). All chickens were divided into two dietary groups consisting of 5 chickens of each; (A) restricted commercial pellets (100 g per chicken per day) served as control, and (B) limited feed with a ratio 3: of 5; commercial pellets: Black Soldier Flies Larvae meal (BSFL). The growth performance of Village Chicken was assessed for a period of 21 days. During the experimentation, the body weight of the chickens was recorded weekly. The amount of feed given (kg) was recorded daily to monitor the feed intake. After 21 days, the final weight of the chickens was recorded. At the end of this experiment, the chickens were euthanised by the exsanguination method, where each part of the chicken was measured and weighed. Results showed that the average body weights and organ weights were not affected ($p>0.05$) by the type of diet given. However, a significant($p<0.05$) result was observed in the gastrointestinal organs. The present study revealed chickens fed with a commercial diet had a similar increase in body weight compared to chickens fed with a combination of feed. In conclusion, replacing the commercial diet positively affects body weight performance and organ weight.

Keywords : Black Soldier Fly, Black Soldier Fly Larvae, chicken, growth performance and organs weight.

ABSTRAK

Abstrak kertas penyelidikan yang dibentangkan kepada Fakulti Perubatan Veterinar, Universiti Malaysia Kelantan, sebagai keperluan sebahagian daripada kursus DVT 5504 – Projek Penyelidikan.

Minat terhadap protein makanan berasaskan haiwan akan meningkat dengan cepat dengan pertambahan populasi di seluruh dunia dan permintaan yang tinggi. Projek penyelidikan ini bertujuan untuk menyiasat potensi pemakanan. Hidangan Larva Black Soldier Fly (BSF) terhadap prestasi pertumbuhan ayam kampung. Eksperimen ini dijalankan selama 21 hari menggunakan ayam berumur dua minggu (n=10). Semua ayam dibahagikan kepada dua kumpulan pemakanan yang terdiri daripada 5 ekor ayam setiap satu; (A) pelet komersial terhad (100 g setiap ayam sehari) berfungsi sebagai kawalan, dan (B) makanan terhad dengan nisbah 3: 5; pelet komersial: Hidangan Larva Black Soldier Flies (BSFL). Prestasi pertumbuhan Ayam Kampung dinilai untuk tempoh 21 hari. Semasa eksperimen, berat badan ayam direkodkan setiap minggu. Jumlah makanan yang diberi (kg) direkodkan setiap hari untuk memantau pengambilan makanan. Selepas 21 hari, berat akhir ayam direkodkan. Pada penghujung eksperimen ini, ayam-ayam telah di euthanised dengan kaedah exsanguination, di mana setiap bahagian ayam disukat dan ditimbang. Keputusan menunjukkan bahawa purata berat badan dan berat organ tidak terjejas ($p>0.05$) oleh jenis diet yang diberikan. Walau bagaimanapun, keputusan yang ketara ($p<0.05$) diperhatikan dalam organ gastrousus. Kajian ini mendedahkan ayam yang diberi makan dengan diet komersial mempunyai peningkatan berat badan yang sama berbanding dengan ayam yang diberi makan dengan gabungan makanan. Kesimpulannya, menggantikan diet komersial memberi kesan positif terhadap prestasi berat badan dan berat organ.

Kata kunci : Lalat Askar Hitam, Larva Lalat Askar Hitam, ayam, prestasi tumbesaran dan berat organ.

1.0 INTRODUCTION

In the past, when the global population was projected to reach 9 billion by 2050, the demand for animal-based protein would expand dramatically (Caparros Megido *et al*., 2016; Yen, 2015). To fulfil the rising demand, food production must increase, which will lead to the loss of resources such as land, water, and forests, as well as a significant burden on the global environment (Van Huis *et al*., 2013). Feed accounts for roughly 70% of grill production costs (Spranghers *et al*., 2017). To lessen reliance on traditional poultry management, there has been an ongoing hunt for more contemporary chickens to care for on a global scale. Insects, a normal part of a chicken's diet, have excellent potential as alternative chicken food. Insects are gaining popularity as an alternative protein source in poultry and pig feed. The Black Soldier Fly (BSF; Hermetia illucens) developed in tropical and temperate climates from Argentina to the central United States (Sheppard *et al*., 1994). BSF has been started in Australia, India, Africa, and Europe due to human initiative (Gujarathi & Pejaver, 2013). Furthermore, BSF is not considered a pest, thus the production of these flies requires careful management to prevent the spread of hazardous bacteria. In contrast to other dipteran species, such as the house fly M. Domestica, BSF is not a pest; hence, no additional steps are necessary for its cultivation, and it decreases the number of hazardous microbes (Liu *et al*., 2008; Erickson *et al*., 2004). Among the 'services' developed is the conversion of liquid manure and other household and agro-industrial wastes into a source of animal proteins (Caruso *et al.,* 2014). Due to their high nutrient content, BSF larvae can be used as the foundation of a new technology to support a circular economy, which is an economy that generates no waste and reduces the consumption of raw resources and energy by maximising their use (Barragan *et al.,* 2017).

Through natural breeding and selection, the ancestor of the Malayan fowl was the southeast Asian jungle fowl (*GaIlus bankiva*). They are referred to as village fowls, and their plumage

colour patterns are separated into four distinct types (Ramlah & Shukor, 1987): The colours are light brown, black, white, and dark brown. Since they are the most common, the light brown and dark brown varieties of village chicken have been utilised in the majority of published study. The traditional method of keeping village poultry is to let them roam freely. According to Ramlah and Shukor (1987), 82.1% of farmers used the free-range system, followed by the semi-intensive system (15.4%) and the intensive system, which consisted primarily of cages (1 per cent). The popularity of semi-intensive, larger-scale village fowl farming has increased in response to the demand of a niche market (Engku Azahan & Noraziah, 1992) (Performance of Village Fowl in Malaysia, 2019).

1.1 Research Problem

Village chicken, particularly Ayam Kampung Kacuk (AKK) industry in Malaysia, has grown in popularity among local farms as an alternative to standard broilers chicken breeds such as Ross and Cobb. Due to its resistance to many diseases and it's well adapted, many small-scale farmers prefer to use the Ayam Kampung Kacuk breed as a meat type of chicken. Nevertheless, An increase in the cost of commercial feed and raw materials raises manufacturing costs. Black Soldier Fly Pupa can provide as an alternative source of protein and fat when fed to Black Soldier Flies. The chickens can achieve similar growth performance, which helps farmers reduce reliance on commercial feed and be cost-effective.

1.2 Research Questions

I. What is the effect of feeding Black Soldier Flies pupa meals on the growth performance of Ayam Kampung Kacuk?
II. What is the effect of feeding Black Soldier Flies pupa meals on intestinal health?

1.3 Research Hypothesis

H_0: Black Soldier Flies larvae cannot substitute commercial feed on the growth performance of local village chicken, AKK.

H_1: Black Soldier Flies larvae partially substitute commercial feed on growth performance of local village chicken, AKK.

1.4 Research Objectives

This research design investigates the effect of Black Soldier Flies pupa meal feeding to village chicken, Ayam Kampung Kacuk. The specific objectives of this study are:

I. To compare the growth performances of Ayam Kampung Kacuk fed with Black Soldier Flies larvae

II. To evaluate the intestinal changes of Ayam kampung Kacuk fed with Black Soldier Flies and commercial feed.

2.0 LITERATURE REVIEW

2.1 Chemical composition and nutritive value of larval meal from Black soldier flies.

According to the amino acid profile, BSF larval protein contains a relatively high proportion of lysine (6-8% of protein) (Sheppard *et al.,* 2008), It compares favourably to published animal feed values (Newton *et al.,* 1977). Comparable quantities of lysine, leucine, phenylalanine, and threonine are present in swine manure-fed larvae and soybean meal (Newton *et al.,* 2005b). Comparing the amounts of alanine, methionine, histidine, and tryptophan in BSF larvae and soybean meal (based on g/16 g N), larvae have a higher concentration of alanine, methionine, histidine, and tryptophan, and a lower concentration of arginine.

2.2 Ayam Kampung Kacuk Chicken as Animal Model

Ayam Kampung (village) chickens, with the brown broiler, silkie, and original kampung chickens rounding out the list (Azlina Azma & Engku Azahan, 2021). Despite exceeding the original kampung chickens in terms of growth, these crossbreds retain many of the phenotypic characteristics of the original kampung chickens. Malaysians purchase crossbred kampung

chickens primarily for their body weight, in contrast to commercial white broilers offered to consumers as eviscerated dressed carcasses and cut-up parts as opposed to fully feathered live birds. Buyers of kampung chicken must ensure that the birds they acquire are authentic kampung chickens and not spent layer hens or immature broilers (Azlina Azma & Engku Azahan, 2021). Although feeding BSF larvae to chickens is well-suited to conventional poultry 283 production methods, research on the influence of BSF larvae on chicken growth rates and fatty acid profiles of BSF larvae and chicken meat has not yet been published. (Moula *et al*., 2018).

2.3 Growth Performance

This study demonstrated that replacing a portion of corn and soybean meal with BSF prepupae meal could increase broiler chicken growth. It offers a higher concentration of protein than many vegetable protein sources and a sufficient amino acid profile, making it an appetising meal. However, its nutritional makeup varies depending on the substrate's composition. (Wang & Shelomi, 2017). Due to the fact that these larvae were reared on various substrates, such as Among organic waste streams, fruits and vegetable wastes, poultry manure, and kitchen wastes, a broad range of nutrient composition was discovered, including crude protein (CP) (33–55%), ether extract (EE) (18–32%), Ca (2.4–5.8%), lysine (1.9–2.7%), and methionine (0.5–0.8%) (Craig Sheppard *et al.,* 1994; Finke, 2013). According to DeMarco *et al.* (2015), BSF meals included fewer amino acids than those of other insects. The nutritional discrepancies are mostly owing to the insect-rearing medium and the defatting procedure, both of which can impact the ether extract concentrations (Elangovan *et al.,* 2021; Wang & Shelomi, 2017).

2.4 Palatability of Black Soldier Flies

Fat content has a substantial impact on the Palatability and flavour of meat, even modest levels of oxidised fatty acids, such as those identified in the BSFL, may have drastically altered the flavour of meat (Belitz *et al*., 2009; Min & Ahn, 2014). With increasing dietary BSFL meal levels, protein and lipid digestibility, protein efficiency ratio, and lipid retention decreased linearly. In contrast, increasing BSFL paste in the diet decreased linearly protein digestibility, protein efficiency ratio, and phosphorus absorption (Weththasinghe *et al*., 2021).

Black soldier fly larvae (BSFL) are high in fat, calcium, and protein, and their profile of amino acids is good for pigs. Their palatability and high moisture content (55–65%) may increase feeding in piglets just weaned from a liquid milk diet. Their consistency may allow larvae to serve as a bridge between milk and concentrate (Ipema *et al*.,2021).

2.5 Digestibility of Black Soldier Flies

Comparable to other animal proteins, insect protein is more digestible than plant-based protein (Traksele *et al*., 2021). Researchers have found that softer-bodied insects, such as silkworm larvae, contain less chitin. Consequently, they are more digestible than larval species with chitin-based shells (Frye & Calvert, 1989; Finke, 2007). Despite its low protein digestibility, chitin possesses various benefits. For instance, it is acknowledged that the prebiotic potential of this structural polysaccharide is beneficial to gastrointestinal health (Selenius *et al.,* 2018).

3.0 MATERIALS AND METHODS

3.1 Production of black soldier fly pupa

The Black Soldier fly pupa meals were harvested from the fly's eggs. Once the flies are mated, they produce eggs at around 500-900 that take about four days to hatch. After hatching, the larvae started to feed on any waste food for 13 to 18 days and turned into the prepupal and pupal stages. During the pupal stage, the pupa underwent hibernation and turned into flies. This is the most suitable stage for the pupa to be collected as animal feed as they contain the optimum nutrient. The pupae were collected and dried using a sand-roasting method. The pupae were cooked in hot sand and filtered to collect the cooked pupa. Later, the pupa was dried under the sunlight, collected and ready to feed the chickens.

3.2 Experimental animal

The chickens were divided into two (2) groups of 5 chickens each. Group A consisted of the chicken fed with commercial feed pellets only. In contrast, Group B consisted of the chickens fed with Black Soldier Fly pupa meal and commercial feed at the ratio of 5:3. Before starting the feeding process, the initial weight of the chickens was recorded. The chickens were fed with two different types of feed for 21 days. During the experimentation, the body weight of the chickens was recorded weekly. The amount of feed given (kg) was recorded daily to monitor the feed intake. After 21 days, the final weight of the chickens was recorded. At the end of this experiment, the chickens were euthanised by the exsanguination method. Each part of the chicken was measured and weighed.

4.0 RESULTS

4.1 Evaluation of growth performance of local village chicken, Ayam Kampung Kacuk (AKK)

The growth performances of the chickens, including initial weight, day 21st and day 28th, were recorded in Table 1. Results showed no significant differences ($p>0.05$) in all parameters in both groups. However, higher final body weight was observed in the chickens of group A compared to group B.

Table 1: Initial Body Weight, Week 3 Body Weight, Week 4 Body Weight, and Final Body Weight of Group A and Group B

Parameter	**Group**		***p*-value**
	A	B	
Initial body weight (g)	255.40	250.2	0.32
Week 3 body weight (g)	377.4	381.6	0.40
Week 4 body weight (g)	685.4	643.0	0.20
Final body weight (g)	1052	936.2	0.14

Note: Group A: 60% BSFL 40% commercial pellet, Group B: 100% commercial pellet

4.2 Evaluation of the growth of chicken organs.

Results showed no significant differences ($p>0.05$) in all parameters of organ weights in both groups except in the gastrointestinal parameter. However, there was a significant difference ($p<0.05$) in gastrointestinal (GIT) weight between Group A and Group B. In comparison, chickens in Group A demonstrated higher organ weights than Group B's.

Table 2: The parameter of group A and group B's organs

Parameter	**Group**		***P* - value**
	A	B	
Final live (g)	1052	936.2	0.14
Kill-out weight (g)	1052	1052	0.14
Deskinned weight (g)	915.4	845.44	0.07
Carcasses weight (g)	748	681.2	0.12
Breast (g)	161.66	150.52	0.64
Drumstick (g)	187.8	170.6	0.30
Wings (g)	79.64	73.5	0.94
Neck (g)	33.62	46.96	0.12
Shanks (g)	53.84	47.04	0.33
Full Gizzard (g)	43.52	27.96	0.57
Empty Gizzard (g)	29.04	18.12	0.86
Gastrointestinal (g)	126.4	107.74	0.01
Liver (g)	30.42	36.7	0.95
Dressing percentage	Mild	Highly fat	

Note: Group A: 60% BSFL 40% commercial pellet, Group B: 100% commercial pellet

5.0 DISCUSSION

Diet type had no effect on the average body weight of the chickens ($p>0.05$), according to the results. However, Group A chickens had a larger initial body weight, week 3 body weight, week 5 body weight, and ultimate body weight than Group B chickens. This conclusion may be attributed to the absence of a significant influence of diet on the dry matter (DM) intake of hens. In addition, compared to the body weight of part of the organs, chickens in group A also demonstrated higher weight, especially in gastrointestinal where the ($p<0.05$) compared to group B. In Malaysia, the market weight for five weeks old of the chicken village, Ayam Kampung Kacuk (AKK) breed was about 1.0 -1.4 kg. However, lower body weight was determined for both groups of chickens in the project. This might be due to the limited feed given during the growing phase. Furthermore, Other research demonstrated that BSF larvae could successfully thrive on horse manure under certain rearing conditions. Lauric acid and palmitic acid made up the majority of the fatty acid profiles in larvae (28.1% and 22.0%, respectively). In previous research using Ardennaise chickens, a commercial feed containing 8% defrosted entire larvae resulted in greater weekly body weights compared to control chickens. Other data, including fatty acid profiles and protein levels, statistically indistinguishable between birds fed larvae and the control group (Moula *et al*., 2018).

In addition, the average weight of the chickens' necks was not altered ($p>0.05$) by the type of diet provided. However, the values were greater in the neck of group B. The fat mass may contribute to this condition, since group B birds exhibited a larger fat dressing % than group A chickens. Moreover, The high carbohydrate content of the commercial diet compared to the food given to group A may also contribute to the development of this condition. In contrast, The substitution of HI larva fat for soybean oil in developing broiler diets showed no affect on growth performance, feed preference, or carcass traits, according to Schiavone *et al.* (2017). In the same context, Cullere et al. (2016) No adverse impacts on productivity, mortality, or carcass

features were seen when 10% and 15% defatted HI larva meal was introduced to the meals of developing broiler quails (Schiavone *et al*., 2018). As a consequence of that, the preparation of the Black Soldier Fly larvae might affect the content of fats in Black Soldier Fly larvae in comparison with other studies.

Moreover, the average weight of the gastrointestinal tract was changed ($p<0.05$) by the type of food administered. Furthermore, the average weight of group A's Gizzard was higher than group B. This could be due to Black Soldier Flies Larvae meal taking a longer time to be digested than group B; hence the feeds were available longer in the gastrointestinal tract. Another part of an organ, such as the small intestine, might get affected as the chickens in group A showed liquid faecal form during the first week of feeding but came out the solid form and consistent towards the end. In another study was done, Small intestine mass increased ($p< 0.01$) in birds fed Black Soldier Flies larval meal at doses of 12.5 and 100 (Facey *et al*., 2023). On the other side, it has been established that increased microbial diversity in the stomach influences the microbiome by modifying the protein source in poultry diets, namely vegetable versus animal sources (Bean-Hodgins & Kiarie, 2021). Animal proteins are rich in crude protein and can cause the digestive tract to ferment extra crude protein, so nourishing pathogenic bacteria such as C. perfringens (Drew *et al*., 2004; Wilkie *et al.,* 2005; Bean-Hodgins & Kiarie, 2021). It has been demonstrated that a significant A portion of the protein in insect meal is bonded to chitin, and the quantity of chitin hinders protein digestion (Marono *et al*., 2015). Therefore, BSFL can enhance bacterial populations in the gut, which would thicken the gut wall by boosting the mucosa or muscularis synthesis and increase total body mass (Facey *et al*., 2023).

6.0 CONCLUSION

In conclusion, feeding the chickens with a commercial diet and combining Black Soldier Flies larvae showed similar results. Replacing 60% of the commercial diet with Black Soldier Flies larvae meals does not adversely affect the growth performance. Hence, Black Soldier Flies larvae meals can be alternative feeding meals for the village chickens.

7.0 RECOMMENDATIONS AND FUTURE WORK

Several restrictions were identified during the course of this study. For future research, it is recommended to prepare Black Soldier Fly larvae stocks for feeding chickens in advance, as feeding chickens requires a considerable quantity of larvae meals. Secondly, this study can be improved by increasing the number of animals used (n=20) to produce significant results on the growth performance. Besides that, a few batches of chicken need to be used to produce meaningful results on growth performance based on the given diet. Lastly, a few groups can be added which consist of different treatment percentages.

REFERENCES

1. Moula, N., Scippo, M.-L., Douny, C., Degand, G., Dawans, E., Cabaraux, J.-F., Hornick, J.-L., Medigo, R. C., Leroy, P., Francis, F., & Detilleux, J. (2018). Performances of local poultry breed fed black soldier fly larvae reared on horse manure. *Animal Nutrition*, *4*(1), 73–78. https://doi.org/10.1016/j.aninu.2017.10.002
2. Biasato, Ilaria, Manuela Renna, Francesco Gai, Sihem Dabbou, Marco Meneguz, Giovanni Perona, Silvia Martinez et al. "Partially defatted black soldier fly larva meal inclusion in piglet diets: effects on the growth performance, nutrient digestibility, blood profile, gut morphology and histological features." *Journal of animal science and biotechnology* 10, no. 1 (2019): 1–11.
3. Moula, N., Scippo, M.-L., Douny, C., Degand, G., Dawans, E., Cabaraux, J.-F., Hornick, J.-L., Medigo, R. C., Leroy, P., Francis, F., & Detilleux, J. (2018). Performances of local poultry breed fed black soldier fly larvae reared on horse manure. *Animal Nutrition*, *4*(1), 73–78. https://doi.org/10.1016/j.aninu.2017.10.002
4. Facey, H., Kithama, M., Mohammadigheisar, M., Huber, L.-A., Shoveller, A. K., & Kiarie, E. G. (2023). Complete replacement of soybean meal with black soldier fly larvae meal in a feeding program for broiler chickens from placement through to 49 days of age reduced growth performance and altered organ morphology. *Poultry Science*, *102*(1), 102293. https://doi.org/10.1016/j.psj.2022.102293
5. Guo, Y., Ali, R. A., & Qureshi, M. A. (2003). The influence of β-glucan on immune responses in broiler chicks. *Immunopharmacology and immunotoxicology*, *25*(3), 461–472.
6. He, W., Li, P., & Wu, G. (2021). Amino acid nutrition and metabolism in chickens. In *Amino Acids in Nutrition and Health* (pp. 109-131). Springer, Cham.

7. Kim, Y. B., Kim, D. H., Jeong, S. B., Lee, J. W., Kim, T. H., Lee, H. G., & Lee, K. W. (2020). Black soldier fly larvae oil as an alternative fat source in broiler nutrition. *Poultry Science*, *99*(6), 3133–3143.
8. Krás, R. V., Kessler, A. D. M., Ribeiro, A. M. L., Henn, J. D., Bockor, L., & Sbrissia, A. F. (2013). Effect of dietary fibre, genetic strain and age on the digestive metabolism of broiler chickens. *Brazilian Journal of Poultry Science*, *15*, 83-90.
9. Murawska, D., Daszkiewicz, T., Sobotka, W., Gesek, M., Witkowska, D., Matusevičius, P., & Bakuła, T. (2021). Partial and Total Replacement of Soybean Meal with Full-Fat Black Soldier Fly (Hermetia illucens L.) Larvae Meal in Broiler Chicken Diets: Impact on Growth Performance, Carcass Quality and Meat Quality. *Animals*, *11*(9), 2715.
10. Onsongo, V. O., Osuga, I. M., Gachuiri, C. K., Wachira, A. M., Miano, D. M., Tanga, C. M., … & Fiaboe, K. K. M. (2018). Insects for income generation through the animal feed: effect of dietary replacement of soybean and fish meal with black soldier fly meal on broiler growth and economic performance. *Journal of economic entomology*, *111*(4), 1966-1973.
11. Mengesha, M., Tamir, B., & Dessie, T. (2011). Village chicken constraints and traditional management practices in Jamma District, South Wollo, Ethiopia. *Livestock Research for Rural Development*, *23*(2), 30-37.
12. Azlina Azma, I.A, & Engku Azahan, E.A. (2021). *Dressed yield and edible parts of crossbred village (kampung) chickens are affected by feed restrictions*. Malaysian Journal of Animal Science (Malaysia); https://agris.fao.org/agris-search/search.do?recordID=MY2021000901
13. Myers, H. M., Tomberlin, J. K., Lambert, B. D., & Kates, D. (2014). Development of black soldier fly (Diptera: Stratiomyidae) larvae fed dairy manure. *Environmental entomology*, *37*(1), 11–15.
14. Dabbou, S., Gai, F., Biasato, I., Capucchio, M. T., Biasibetti, E., Dezzutto, D., Meneguz, M., Plachà, I., Gasco, L., & Schiavone, A. (2018). Black soldier flies defatted meal as a dietary protein source for broiler chickens: Effects on growth

performance, blood traits, gut morphology and histological features. *Journal of Animal Science and Biotechnology*, *9*(1). https://doi.org/10.1186/s40104-018-0266-9

15. Barragan, K. B., Dicke, M., & Loon. (2017, June 29). *Nutritional value of the black soldier fly (Hermetia illucens L.) and its suitability as animal feed*. ResearchGate; Wageningen Academic Publishers.https://www.researchgate.net/publication/317221082_Nutritional_value_of_the_black_soldier_fly_Hermetia_illucens_L_and_its_suitability_as_animal_feed#:~:text=...%20Black%20soldier%20fly%20(meal%2DSBM%20%5B4%5D%20.
16. Elangovan, A. V., Udayakumar, A., Saravanakumar, M., Awachat, V. B., Mohan, M., Yandigeri, M. S., Krishnan, S., Mech, A., Rao, S. B. N., Giridhar, K., & Bhatta, R. (2021). Effect of black soldier fly, Hermetia illucens (Linnaeus) prepupae meal on growth performance and gut development in broiler chicken. *International Journal of Tropical Insect Science*, *41*(3), 2077–2082. https://doi.org/10.1007/s42690-020-00377-4
17. Schiavone, A., Dabbou, S., De Marco, M., Cullere, M., Biasato, I., Biasibetti, E., Capucchio, M. T., Bergagna, S., Dezzutto, D., Meneguz, M., Gai, F., Dalle Zotte, A., & Gasco, L. (2018). Black soldier fly larva fat inclusion in finisher broiler chicken diet as an alternative fat source. *Animal*, *12*(10), 2032–2039. https://doi.org/10.1017/s1751731117003743
18. Newton, L., D. Craig Sheppard, Watson, D. W., & Thelen, E. E. (2005). *The black soldier fly, Hermetia illucens, as a manure management/resource recovery tool*. ResearchGate; unknown. https://www.researchgate.net/publication/237345975_The_black_soldier_fly_Hermetia_illucens_as_a_manure_managementresource_recovery_tool
19. Weththasinghe, P., Hansen, J. Ø., Nøkland, D., Lagos, L., Rawski, M., & Øverland, M. (2021). Full-fat black soldier fly larvae (Hermetia illucens) meal and paste in extruded diets for Atlantic salmon (Salmo salar): Effect on physical pellet quality, nutrient digestibility, nutrient utilisation and growth performances. *Aquaculture*, *530*, 735785. https://doi.org/10.1016/j.aquaculture.2020.735785

20. Ipema, A. F., Bokkers, E. A. M., Gerrits, W. J. J., Kemp, B., & Bolhuis, J. E. (2021). Providing live black soldier fly larvae (Hermetia illucens) improves welfare while maintaining the performance of piglets post-weaning. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-86765-3

Appendices

Figure 1: The chicken's parts and organs are separated for weighing

Figure 2: Each dorsal of the chicken neck was labelled using a marker

Figure 3: Commercial pellet

Figure 4: Black Soldier Flies Larvae (BSFL)

Figure 5: Two groups of chickens are separated into different cages