EFFECT OF FEEDING BLACK SOLDIER FLY (*HERMETIA ILLUCENS)* LARVAE MEAL ON THE HAEMATOLOGICAL, SERUM BIOCHEMICAL, AND MEAT QUALITY OF LOCAL VILLAGE CHICKENS

By

MUHAMMAD TAUFIQ BIN TARMUZI

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CERTIFICATION

This is to certify that we have read this research paper entitled 'Effect of Feeding Black Soldier Fly (*Hermetia Illucens*) Larvae Meal on The Haematological, Serum Biochemical, And Meat Quality of Local Village Chickens' by Muhammad Taufiq Bin Tarmuzi, and in our opinion, it is satisfactory in terms of scope, quality and presentation as partial fulfilment of the requirements for the course DVT 55204 – Research Project.

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
MSc Animal Nutrition (UPM)
Faculty of Veterinary Medicine,
Universiti Malaysia Kelantan

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ABBREVIATION

BSFL	-	Black Soldier Fly Larvae
BSF	-	Black Soldier Fly
AKK	-	Ayam Kampung Kacuk
DM	-	Dry Matter
EE	-	Ether extract
Ca	-	Calcium
P	-	Phosphorus
Na	-	Sodium
W1	-	Initial Weight
W2	-	Final Weight
ALT	-	Alanine Aminotransferase
GGT	-	Gamma-Glutamyl transferase
BUN	-	Urea
CREA	-	Creatinine

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.

Nowadays, one factor contributing to the rise in poultry production expenses and the subsequent increase in chicken prices is the rise in the price of chicken feed. Therefore, finding a substitute for poultry feedstuff due to this circumstance is crucial. This research aimed to determine the effect of feeding local village chicken meals consisting of Black Soldier Fly Larvae (BSFL) on the meat quality, haematological and biochemical profiles of the local village chicken. The chickens were divided into 2 groups: the treatment group (group A) and the control group (Group B). The treatment group was fed with a combination of 60% BSFL and 40% commercial feed meanwhile, the control group was fed with 100% commercial feed. The chickens were slaughtered for meat quality and blood analysis at 35 days of age. For meat quality analysis, parameters such as pH, cooking loss, and drip loss were evaluated. Meanwhile, for the haematological and serum biochemical profiles, parameters such as erythrocytes count, leukocytes count, alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT), Urea (BUN), and creatinine (CREA) were analyzed. The data shows no significant differences ($p>0.05$) between both groups' meat quality and haematological parameters analysis. The BSFL in the local village chicken diet did not affect the meat quality compared to the complete commercial feed diet. The results suggest replacing 60% of Black Soldier Fly Larvae in the local village chicken diet gave similar results on haematological and serum biochemical profile and meat quality properties compared to a fully commercial feed diet.

Keywords: Black Soldier fly, haematological, serum biochemical, meat quality parameters

ABSTRAK

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

Pada masa kini, salah satu faktor yang menyumbang kepada kenaikan perbelanjaan pengeluaran ayam dan kenaikan harga ayam seterusnya ialah kenaikan harga makanan ayam. Oleh itu, mencari pengganti bahan makanan ayam kerana keadaan ini adalah penting. Kajian ini bertujuan untuk mengetahui kesan pemberian makanan ayam kampung tempatan yang terdiri daripada Larva Lalat Askar Hitam (BSFL) terhadap kualiti daging, profil hematologi dan biokimia ayam kampung tempatan. Ayam dibahagikan kepada 2 kumpulan: kumpulan rawatan (kumpulan A) dan kumpulan kawalan (Kumpulan B). Kumpulan rawatan diberi makan dengan kombinasi 60% BSFL dan 40% makanan komersial sementara itu, kumpulan kawalan diberi makan dengan 100% makanan komersial. Ayam-ayam tersebut disembelih untuk kualiti daging dan analisis darah pada umur 35 hari. Untuk analisis kualiti daging, parameter seperti pH, kehilangan masak, dan kehilangan titisan dinilai. Sementara itu, bagi profil biokimia hematologi dan serum, parameter seperti kiraan eritrosit, kiraan leukosit, alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT), Urea (BUN), dan kreatinin (CREA) telah dianalisis. Data menunjukkan tiada perbezaan yang signifikan ($p>0.05$) antara kualiti daging kedua-dua kumpulan dan analisis parameter hematologi. BSFL dalam diet ayam kampung tempatan tidak menjejaskan kualiti daging berbanding diet makanan komersial lengkap. Keputusan mencadangkan menggantikan 60% Larva Lalat Askar Hitam dalam diet ayam kampung tempatan memberikan hasil yang sama pada profil biokimia hematologi dan serum dan sifat kualiti daging berbanding diet makanan komersial sepenuhnya.

Kata kunci: Lalat Askar Hitam, hematologi, biokimia serum, parameter kualiti daging

1.0 INTRODUCTION

Nowadays, grain maize and soybean meal prices, the two primary ingredients for chicken feeds, have risen by 13% and 11%, respectively (The Star Online, 2022). The increase in chicken feed prices is one of the causes that contributed to the rise in poultry production costs, causing chicken prices to re-escalate (The Star Online, 2022). Due to this situation, finding an alternative source of poultry feedstuff has become essential and critical in many countries, including Malaysia. Therefore, the present study aimed to evaluate the effects of feeding black soldier fly (*Hermetia illucens* L.) larvae meal in chicken diets on the haematological, serum biochemical and meat quality parameters.

The black soldier fly (BSF), *Hermetia illucens* Linnaeus, is a large Stratiomyidae fly that is widespread but is assumed to have originated in the Americas. Its size ranges from 13 to 20 mm. The tropics and temperate regions of the planet both contain it. Although adapted primarily to these regions, it can tolerate wide temperature extremes except when ovipositing. They are typically considered non-pest and beneficial bugs. Adult flies lack mouth parts, stingers, and digestive organs. Therefore, they do not bite or sting and do not feed during their brief existence. They are also not involved with disease transmission because they only eat as larvae (Maglangit *et al*., 2021). BSF larvae (BSFL) devour various organic wastes and decompose them, returning nutrients to the soil. BSFL is also a good source of protein for aquaculture, pet food, cattle feed, poultry feed, and human nutrition (Maglangit *et al*., 2021). The five stages of the black soldier fly's life cycle are egg, larva, prepupa, pupa, and adult. Its life cycle is divided into three stages: the egg, the larva, and the pupa, which are the two that survive the longest. Females lay between 500 and 900 eggs (Maglangit *et al*., 2021).

In order to create edible biomass, black soldier fly larvae (BSFL) transform organic waste into proteins, lipids, peptides, amino acids, chitin, vitamins, and polypides. Proteins and amino acids, the nutritional value of which changes substantially depending on the type of substrates the larvae are given, have been used to make animal feed, fish meal alternatives, and feedstuffs with excellent digestibility. Protein and oil buildup in BSF are encouraged by protein and oil-rich substrates. The protein content is 30-40%, and the oil content is 28-35 As a result, in the face of growing prices for commercial feed, these insects provide an alternative protein source (Maglangit *et al*., 2021).

Black soldier fly larvae (BSFL) have already been utilised in several nations' chicken feed as a partial substitute for meals based on soy or corn. The organism spontaneously colonises and decomposes chicken faeces. For the purpose of managing waste and reducing pollution, poultry farms frequently keep populations (Wang & Shelomi, 2017For monogastric animals, insects are currently thought to be a special and promising source of dietary protein (Makkar et al., 2014). Insects have a high ratio of feed to protein and contain a lot of high-quality protein (Makkar *et al.,* 2014).

In many rural regions, village chickens are the most popular livestock. Ayam kampung kacuk (AKK) is a common breed used in village chicken farming. They comprise local genetic stock, which is interbred with improved stock. According to various writers, semi-intensive management method-raised animals had lower live weights than intensive system-raised animals at all ages (Choy, 1958; Engku Azahan and Zainab, 1980; Jalaludin *et al*., 1985; Engku Azahan and Noraziah, 1992).

The research intends to assess the effects of feeding BSFL on the haematological, serum biochemistry, and meat quality parameters of the local village chickens based on the aforementioned factors and to offer trustworthy data on the prospective use of insect meal in a local village chickens' nutrition.

2.0 RESEARCH PROBLEM STATEMENT

The most important aspect of poultry production is poultry feeding. High prices in purchasing commercial feed or concentrate diets result in a high cost of poultry production. Due to this condition, farmers seek feed alternatives to reduce their reliance on commercial feed while cost-effective. Alternatively, the Black Soldier Fly larvae (BSFL) can be suggested as a protein meal substitution in poultry feeding, including village chicken farming. There are limited findings on feeding BSFL on the haematological, serum biochemical, and meat quality parameters of local village chickens, Ayam Kampung Kacuk (AKK).

3.0 RESEARCH QUESTIONS

i. What are the hematological and serum biochemical changes of village chickens (AKK) after being fed with Black Soldier Fly Larvae?
ii. Does the Black Soldier Fly Larvae (BSFL) improve the meat quality of village chicken (AKK)?

4.0 RESEARCH HYPOTHESIS

H_0: The Black Soldier Fly Larvae does not improve the meat quality of village chickens (AKK).

H_1: The Black Soldier Fly Larvae improves the meat quality of village chickens (AKK).

H_0: Feeding Black Soldier Fly Larvae does not cause haematological and serum biochemical changes in village chickens (AKK).

H_1: Feeding Black Soldier Fly Larvae causes haematological and serum biochemical changes in village chickens (AKK).

5.0 RESEARCH OBJECTIVES

This research investigates the effect of Black Soldier Fly larvae (BSFL) feeding on the local village chicken. The specific objectives of this study are:

i. To determine the meat quality of village chickens fed with BSFL.
ii. To evaluate the haematological and serum biochemical parameters of village chickens provided with BSFL.
iii. To verify the Black Soldier Fly Larvae as an alternative source of protein for the livestock industry

6.0 LITERATURE REVIEW

6.1 Nutritional Profile of Black Soldier Fly Larvae

Numerous papers have discussed the nutritional qualities of BSF larvae as sources for animal feed. Fresh larvae have a relatively high dry matter (DM) content (35–45%), making them easier and less expensive to dehydrate than other fresh by-products (Newton *et al.*, 2008). Maurer *et al*. (2016) reported that dried full-fat BSF larvae meal contained 41.5% crude protein (CP), 26.5% ether extract (EE), 4.3% ash, 0.80% calcium (Ca), 0.50% phosphorus (P), 0.08% sodium (Na), and 0.33% chloride while dried partly defatted BSF larvae meal consisted of 59.0% CP, 11.0% EE, 5.0% ash, 0.98% Ca, 0.63% P, 0.08% Na and 0.28% chloride.

The BSF larva's amino acid profile is superior to or on par with that of soybean meal (SBM) (Tran *et al.*, 2015). Lysine and methionine concentrations in BSF larval proteins are comparable to those in meat feed (Ravindran *et al.*, 1999). Valine and leucine were the most common necessary amino acids in defatted BSF larvae feed, but alanine and glutamic acid were also present in significant amounts, according to Cullere *et al*. (2016). BSF's amino acid composition changes throughout time. Since the greatest level of amino acid content was predominantly expressed in the early stages of larval development before gradually declining, it appears to be related to its CP content. The adult stage of larvae has the highest concentration of amino acids (g/kg) in dry matter (DM) (Liu *et al.*, 2017).

In comparison to soybeans, bran meal, and other regularly used plant proteins in feed, including rapeseed, cottonseed, and sunflower meal, the protein found in BSF larvae (BSFL Proteins) has a substantially higher value at the same level of dryness. The protein content of BSF larvae ranges from 31.2% to 45.7%; when we feed them manure, the protein level is higher. Compared to only giving them plant-derived agricultural waste. However, this protein percentage is alleged to be superior to other conventional animal feed.

Calcium and phosphorus are abundant in BSF larvae (Newton et al., 2005). Depending on the feed substrate, the ash level of different BSF pre-pupae samples varied. Ash content varied between 14.6% when BSF pre-pupae were reared on chicken manure and 16.6% when they were fed pig manure, according to the previous report (Newton *et al.*, 2005).

6.2 Meat Quality Analysis of Chicken

There are several definitions of quality, but the most commonly used is: "Quality is the composite of those characteristics that differentiate individual units of a product and which have significance in determining the degree of acceptability of that unit to the user" (Groom 1990). The flesh quality of a broiler chicken is assessed using a number of factors, including colour, texture, flavour, pH, water holding capacity, cooking loss, drip loss, and others. In this study, only pH, drip loss, and cooking loss will be covered.

The pH of meat has an impact on its softness, ability to hold water, colour, juiciness, and shelf life. Meat with a higher pH has a greater chance of absorbing water than meat with a lower pH. The pH of broiler meat is determined by the amount of glycogen in the muscle before slaughter and the rate of glycogen conversion to lactic acid after slaughter. Meat's colour can be used to quickly identify its pH. If the meat is very dark, the pH will be high; if it is very light, the pH will be low (Anadon, 2002). A pH meter can also be used to check the pH of the meat.

Low pH is assumed to be the origin of the bright colour because it causes the proteins in the muscle to spread out and alters how light reflects off the surface. Breast meat colour changes have an impact on shelf life, smell development, moisture pickup during marinating, drip loss, water holding capacity, and cooking loss. These changes are mostly brought on by pH effects (Allen *et al. 1998*). Lighter-than-average fillets had an initial pH of 5.8, 6% marination pickup, 5.88% drip loss, and 34.4% cook loss. The initial pH of fillets that were darker than usual was 6.02; the percentages of marination pickup, drip loss, and cooking loss were 7.67%, 3.34%, and 32.9%, respectively. Low water-holding capacity (WHC) has been associated with low pH in poultry meat, which leads to increased cook-loss, drip loss, shelf life, and decreased softness (Barbut 1993).

The broiler chicken's meat quality criteria can be impacted by a variety of circumstances. Nutrition, management, biochemical adjustments, carcass temperature, pre-slaughter, carcass processing, and genetics for broilers are all included (Mir *et al.*, 2017).

6.3 Haematological Profiles of Chickens Feed With BSFL

Blood is essential for carrying nutrients, metabolic waste products, and gases throughout the body (Zhou *et al*. 1999). Blood can also be used to assess an animal's nutritional and clinical status (Olorode and Longe 2000). In studies on chicken feeding, haemato-biochemical profiles are most usually used (Adeyemi *et al.* 2000)

The haematological profiles of livestock blood profiles can be used to determine how the immune system in poultry is configured. Hematological testing is utilised not only for medical diagnosis but also for tracking the effectiveness of treatment.

Diets are designed to deliver certain dietary levels that are required for peak performance. Because food components have observable impacts on blood composition, blood analysis has been suggested as a quick and easy way to examine the nutritional health status of animals in feeding experiments (Etim, 2014). According to research, chickens supplemented with Black Soldier Fly Larvae will have various mean haematological blood values depending on the ratio used (Andri Cahya Irawan *et al*., 2020).

7.0 METHODOLOGY

7.1 Study Design

The chickens were divided into two groups, with 5 chickens per group. Firstly, the day-old chicks were fed commercial starter feed for 14 days. Then the chickens were separated into two groups which are Group A (treatment) and Group B (control). Chicken in Group A will be fed with a combination of 60% Black Soldier Fly larvae and 40% commercial feed for 21 days, while chickens in Group B were fed with commercial feed only. After that, on the 35th day, the chickens were slaughtered and sampling was done. Then further analyses were conducted.

7.2 Meat Quality Analysis

The pH of the meat, drip loss, and cooking loss were the three factors that were extracted from the meat quality analysis. The procedure was followed method by Lim *et al*., (2019). The right pectoralis major (breast muscle) was removed and kept cold (80°C) to preserve the meat's pH characteristics for the pH measurement. The samples were broken up and homogenised with a homogenizer after 24 hours. A portable pH meter was then used to measure the pH.

A sample of 25 g of breast flesh from each group's samples was weighed and recorded as the initial weight for the drip loss assessment (W1). The weighed breast meat was then placed in a plastic bag that had been vacuum-sealed and kept at 4°C. The samples were removed from the vacuum-sealed bag and gently blotted with tissue to dry them after 48 hours. After then, the final weight of the breast meat was determined by weighing it once more (W2). The formula (W1-W2)/W1 x 100 was then applied to the reported weight to get the drip loss percentage. This process will determine whether the meat can retain water while being stored.

Twenty grams of breast meat were taken from the samples for cooking loss measurement. Then it was weighed and recorded as initial weight (W1). After that, the breast meat was placed in a vacuum-packed plastic bag. After that, it was immersed in a water bath at 80°C for 20 minutes. After 20 minutes, the cooked samples were taken out from that water bath to let rest and cool down to room temperature for 15 minutes. Next, the samples were taken out from the vacuum-packed plastic bag and blotted with tissue paper to dry them. After that, the breast meat was weighed again and recorded as the final weight (W2). This procedure is used to determine the ability of the meat to hold water during cooking, and the percentage of the cooking loss were calculated using the formula (W1-W2)/ W1 x 100.

7.3 Haematological and Serum Biochemical Profiles

The haematology analysis aims to determine haematological and serum biochemical changes of chickens fed with BSFL compared to those fed with a commercial diet. Blood samples will be collected from the chicken on the 35th day of experimentation to perform the haematology analysis (erythrocytes and leukocytes count). Two sets of blood samples were taken from each bird via the jugular or brachial vein. In 5ml lavender-capped vacutainer tubes with anticoagulant (EDTA) for haematology, one set of blood was drawn. For serum biochemistry (alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT), urea (BUN), and creatinine (CREA) measurements, additional blood samples were taken in 5 ml vacutainer tubes without anticoagulant. The coagulated blood samples were then centrifuged at 3000 rpm for 15 minutes. After that, it was kept at -20°C for haematology analyzer analysis.

7.4 Data Analysis

An independent-sample t-test was used to compare the meat quality analysis parameters mean among group A (fed with BSFL) and Group B (fed with commercial feed). The test was performed using SPSS Version 27 software.

8.0 RESULTS

8.1 Evaluation of Meat Quality Analysis of Local Village Chicken, Ayam Kacuk Kampung (AKK).

The evaluation of the meat quality analysis was done after the 35th day. The parameters taken were the pH of the meat, the cooking loss, and the drip loss (Table 1). Results showed no significant difference (p>0.05) in all parameters for the meat quality of the chickens in both groups, A and B. Lower pH of meat was observed in chickens in Group A, meanwhile lower percentage of drip loss was also observed in chickens in Group A compared to Group B.

Table 1: Evaluation of Meat Quality Analysis

Parameter	**Group**		***p*-value**
	A (Treatment)	**B (Control)**	
pH	6.000	6.204	0.37
Cooking Loss (%)	22.6	22.4	1.00
Drip Loss (%)	5	9	0.40

8.2 Evaluation of Hematology and Serum Biochemical Profiles of Local Village Chicken, Ayam Kacuk Kampung (AKK).

The results of haematological and serum biochemical profiles are shown in Table 2. There were no significant differences (*p*>0.05) were observed in all parameters for haematological and serum biochemical profiles of the chickens in both groups A and B.

Table 2: Evaluation of Haematological & Serum Biochemical Profiles

Parameter	**Groups**		***p*-value**	**Normal ranges**
	A (Treatment)	**B (Control)**		
Erythrocyte (10^6 cell/µL)	3.416	3.506	0.72	2.5 - 3.5
Leukocyte (10 cell/µL)	13.654	13.650	0.86	
ALT (U/L)	5.9600	6.0240	0.11	5 - 20
GGT (U/L)	243.40	238.80	0.33	0 - 900
CREA (mg/dL)	2.8420	2.6780	0.89	0.6 -124.0
BUN (mg/dL)	0.3120	0.3080	0.32	0.10 - 0.40

9.0 DISCUSSION

The pH value of the meat is an essential parameter regarding the transformation of muscle tissue in meat. It depends on the rate of decomposition of glycogen deposits in the muscles. Results show no significant difference (*p*>0.05) in the pH values of village chickens between group A and group B after being fed with BSFL meals. This finding suggests the usage of BSFL for local village chicken has the same effect on the pH of the chicken meat compared to chicken feed with 100% commercial feed. Although there were no significant differences between both groups, we can observe a slightly lower pH value in chickens of group A compared to group B. It is known that BSF larvae are rich in lauric acid and hence the products derived by them would have considerable levels, of this fatty acid (Popova *et al*., 2020). Besides, it is possible to assume that the BSFL meal increased lauric acid content causes the meat of broilers to have lower pH values. Zeiger et al (2017) observed that chickens consuming lauric acid in the food had considerably lower pH in the breast muscles depending on the chicken strain.

Cooking loss is an indicator to evaluate the water-holding capacity of cooked meat. It is related to the levels of meat juice which is the amount of water bound in and between the muscle fibers of the meat (Robyn Dorothy Warner, 2017). The meat juice is one of the factors that determine the tenderness of the meat. However, both groups A and B had no significant differences in the cooking loss (*p*>0.05) which suggested cooking loss of the local village chicken was not affected by the type of diet given to chickens. In comparison, the normal cooking loss for chicken breast meat ranged between 22% and 28% on average (Albrecht *et al*., 2019). The present findings showed lower cooking loss values in both groups of chickens. This might be attributed to other factors, such as the size of the small meat breast sample, which is 20g. Besides that, the type of animal, cutting technique, latitude type, fat content, pH value, muscle fibre sarcomere length, myofibril contraction status, size and sample weight, the crosssection of meat, warming, meat fat, age, and energy consumed in the feed are among the variables that affect cooking loss values (Nurwanto *et al*., 2003).

Drip loss was measured to characterise the meat samples' water-binding capacity when stored (Guo & Dalrymple, 2017). The average drip loss of the breast meat was 5% for group A and 9% for group B. Results showed that Group B had a higher drip loss average than group A. However, there was no significant difference between the two groups ($p>0.05$). This indicates that BSFL does not affect the drip loss of the chicken meat breast. The results obtained in this study agree with those reported by (Schiavone *et al.*, 2019).

For the haematological parameter, the erythrocyte and the leukocyte are the parameters measured in this research. For the average of erythrocytes, chickens in group A had 3.416 x 10^6 cell/µL while group B had 3.506 x 10^6 cell/µL. There was no significant difference ($p>0.05$) related to BSFL meal utilization toward the erythrocytes count of the chicken. For the leukocyte count, the average for group A was 13.654, while for group B was 13.650. There was no significant effect ($p>0.05$) of BSFL usage as feed on the leukocyte count. These findings revealed that partially BSF larva in a chicken diet did not appear to have any negative effects on the health of the animals. The findings differ from a previous study which indicated changes in blood profiles after inducing with dietary BSF larva feed (Marono *et al*., 2017). However, other investigations involving different insect food species did not demonstrate any appreciable difference in the blood characteristics of the animals, thus supporting our findings (Bovera *et al*., 2015; Biasato *et al*., 2017; Dabbou *et al.*, 2018;). Additionally, the current investigation showed that all blood values found were within the chicken reference ranges (Lumeij, 1997).

For the serum biochemical profiles, the parameters evaluated were alanine aminotransferase (ALT), gamma-glutamyltransferase (GGT), Urea (BUN), and creatinine (CREA). The ALT average (U/L) was 5.96 for group A and 6.02 for group B. The GGT average (U/L) for group A was 243.4, while for group B was 238.8. Meanwhile, the CREA average(mg/dL) for group A was 2.84, while for group B was 2.67. The BUN average(mg/dL) for group A was 0.312, while for group B was 0.308. There was no significant difference ($p>0.05$) was found for ALT and GGT, thus implying that BSFL meal has a similar effect on the liver function compared to the commercial feed. In addition, there were also no significant differences ($p>0.05$) of BUN and CREA. Thus, both chicken groups in the current study showed no toxicity on renal parameters. The results from this study were aligned with a study which claims that BSF meal does not have significant finding to the serum biochemical profiles parameters such as ALT, GGT, BUN, and CREA (Dabbou *et al.*, 2021).

10. CONCLUSION

In conclusion, feeding the local village chicken with commercial feed and commercial feed combined with Black Soldier Fly larvae does not significantly differ regarding the meat quality parameters such as pH, cooking loss, and drip loss. Apart from that, there were also no significant differences in haematological and serum biochemicals through the combination of Black Soldier Fly Larvae with commercial feed for the local village chicken. Thus, replacing 60% of commercial feed with Black Soldier Fly larvae have a similar effect on the meat quality, haematological, and serum biochemical profile of local village chickens.

11.0 RECOMMENDATIONS AND FUTURE WORK

The study can be improved by increasing the number of animals per group of experiments. Secondly, more parameters for the meat quality analysis, hormonal blood profiles related to growth performance, haematological, and serum biochemical should be included. Other than that, more treatment groups with different percentages of BSFL and commercial feed should be included.

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13.0 APPENDICES

Figure 1: Black Soldier Fly Larvae

Figure 2: Commercial Feed

Figure 3: Blood collection via the jugular vein

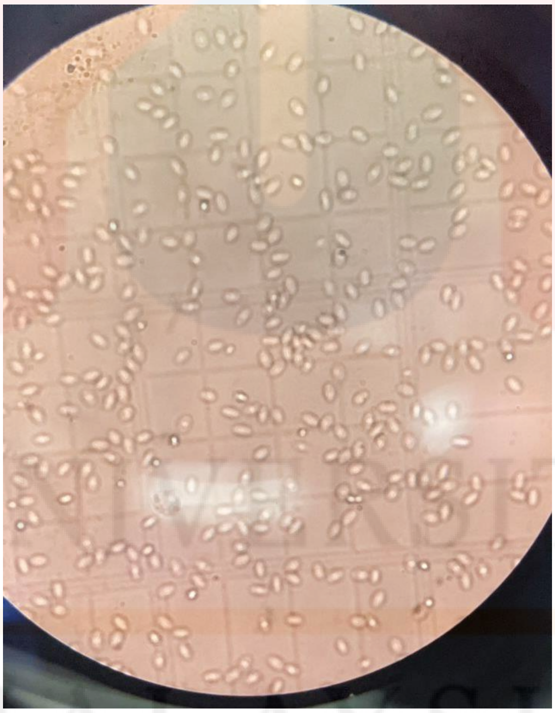

Figure 4: Erythrocyte count via microscope.

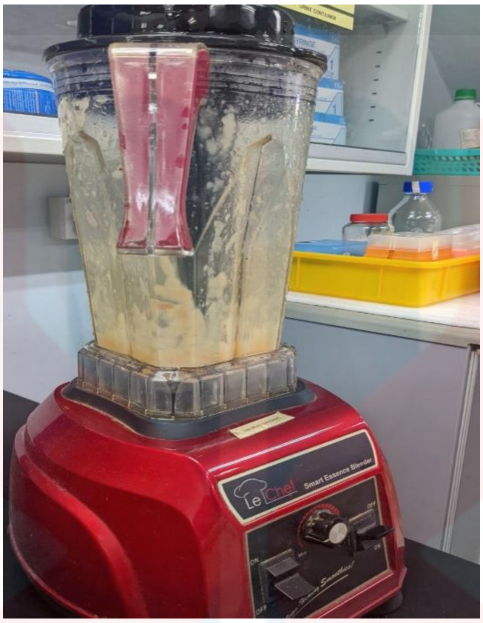

Figure 5: Chicken breast meat homogenised using in a homogenizer

Figure 6: pH determination of the chicken breast meat using a portable pH machine