Influence of Diet Inclusion of Black Soldier Fly larvae (*Hermetia illucen spp*) (BSFL) Meal on Growth Performance and Carcass Characteristic of Broiler Chicken

By

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DECLARATION

I hereby declare that the work embodied in here is the result of my own research except for the excerpt as cited in the references.

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BSFL	Black Soldier Fly Larvae
FCR	Feed Conversion Ratio
ADG	Average Daily gain
Kg	Kilogram
G	Gram
BW	Body weight
WHC	Water Holding Capacity
ME	Metabolizable Energy
CP	Crude Protein
CF	Crude Fat
Na	Sodium
Ca	Calcium
Meth	Methionine
Cys	Cysteine
N	Nitrogen
EE	Ether Extract
NFE	Nitrogen Free Extract
MC	Moisture Content
DM	Dry Matter
STE	Standard Error

ABSTRACT

Influence of diet inclusion of Black Soldier Fly larvae (Hermetia illucen spp) (BSFL) meal on growth performance and carcass characteristic of broiler chicken

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A study was conducted to determine the effects of bsfl meal on growth performance and carcass characteristics of broiler chicken. Black soldier fly larvae is known as insect that contain a good quality of crude protein and various amounts of aminoacid. The diets were formulated into four different types of inclusion treatments. Each treatment received different amount of bsfl which are 0% of bsfl, 20% of bsfl, 40% of bsfl and 60% of bsfl. Thirty two (32) male broilers were tested throughout the production period, 42 days. Each treatments received eight replicates. Proximate analysis were conducted to determine the nutrient content of broiler meats. Feed intake, weight gains, dry matter weight (DM) , crude protein content (CP) and crude fat content (CF) were collected. The results showed that 20% has the highest intake and average live weight for the three phases. However 60% of the bsfl showed a positive result in average daily gain and feed conversion ration. In terms of carcass quality, overall, 20% of showed excellent result in dry matter and crude fat content in broiler meat. To conclude, the maximum number of bsfl can be used in feed formulation is 20% of bsfl inclusion. 20% of bsfl has the greatest result in growth performance and carcass characteristic without any adverse effect so that it can be replaced other expensive protein source with that particular inclusion

Keywords: Black Soldier Fly Larvae, Growth performance, Carcass characteristic

ABSTRAK

Kesan pemasukan diet Larva Terbang Askar Hitam (Hermetia illucen spp) (BSFL) pada prestasi pertumbuhan ayam pedaging dan kualiti daging ayam pedaging

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Satu kajian telah dijalankan untuk menentukan kesan serbuk bsfl pada prestasi pertumbuhan dan ciri-ciri karkas ayam pedaging. Larva terbang askar hitam telah dikenali sebagai serangga yang mengandungi protin mentah yang baik dan mempunyai pelbagai jumlah asid amino. Diet digubal menjadi empat jenis rawatan inklusi yang berlainan. Setiap kumpulan makanan menerima jumlah bsfl yang berbeza iaitu 0% bsfl, 20% bsfl, 40% bsfl dan 60% bsfl. 32 ekor ayam pedaging jantan telah diuji melalui tempoh pengeluaran, 42 hari. Setiap kumpulan makanan menerima lapan ekor replika. Analisis proksimat dilakukan untuk menentukan kandungan nutrien daging broiler. Pengambilan makanan, kenaikan berat badan, berat bahan kering (DM), kandungan protin mentah (CP) dan kandungan lemak mentah (CF) dikumpulkan. Keputusan menunjukkan bahawa 20% Bsfl mempunyai pengambilan makanan tertinggi dan berat hidup purata tertinggi bagi tiga fasa. Walau bagaimanapun, 60%bsfl menunjukkan hasil positif dalam purata keuntungan harian dan rizab penukaran makanan. Dari segi kualiti karkas, secara keseluruhannya, 20% Bsfl menunjukkan hasil yang sangat baik dalam bahan kering dan kandungan lemak mentah dalam daging broiler. Untuk membuat kesimpulan, bilangan maksimum bsfl boleh digunakan dalam formulasi suapan adalah 20% daripada kemasukan bsfl. 20%bsfl mempunyai hasil yang paling bagus dalam prestasi pertumbuhan dan kualiti daging ayam tanpa sebarang kesan buruk supaya ia boleh digantikan sumber protin mahal lain dengan jumlah jumlah yang tertentu

Kata kunci: Larva Terbang Askar Hitam, Prestasi pertumbuhan, Kualiti daging ayam

CHAPTER 1

Introduction

1.1 Research background

Over the last few decades, consumer desirability has changed from red meat (beef) to white meat (poultry). There are many factors that cause changes preferences including the growth of population, low price, an increasing number of processed products, religious preference (Magdelaine, Spiess, and Valceschini, 2008). Malaysia is a country with diverse culture, religion and ethnic. Muslims cannot consume pork while Hindus cannot consume beef. The demand for broiler meat as the main protein source in their daily diet is increased year by year. In 2011, Malaysia is one of the countries that have the highest consumption of poultry in the world with per-capita consumption of 35.3kg. Malaysia has experienced high self-sufficient level for poultry production which was 128% and decreased to 103% in 2018 (Ministry of agriculture, 2018). In general, Malaysia's broiler production cycle is 5.33 times in a year. Only a few big companies especially from multinational companies able to produce broiler six times in a year. Meanwhile, the average of Malaysia's feed conversion ratio (FCR) is 1.67, which indicates the effectiveness of broiler that turns feed into animal weight. However, that FCR is still in competitive level among the world's top broiler production. Common market size of broiler meat in Malaysia is 2.2kg (MARDI 2015)

Broiler meats produce a high amount of energy because it contains a high amount of glycogen and lipids (Overland, Borge, Voght, Schoyen, Skrede, 2011). Lipids in broiler meat can affect the colour and texture of meat and flavor. (Overland et al.,2011). Nevertheless, the quality of chicken meat is worrying because lipids in broiler especially cholesterol and saturated fatty acid are highly related to the risk of cardiovascular diseases. This problem demands awareness and solution from researchers to fulfill the market requirement including alternative sources of feed ingredients (Oliveiera, Avanco, Gracia-Neto, Pansano, 2016). The aim of this study is to determine the new protein larvae source which has ability turn waste as their feed, Black Soldier Fly Larvae meal (BSFL) on growth performance and quality of carcass of broiler chicken.

BSFL larvae originated from native America (Sheppard, Newton, Thompson, Savage ,1994). It can live in temperate and tropical season. Black soldier flies naturally consume decompose matter such as manure and biomass, they also have been exploited to minimize animal dung in the animal farm (Newton, Sheppard, Watson, Burtle, Dove, 2005) From that moment, it is helpful to improve the waste management industry. Although they are not considered as a disease's carrier, matured soldier flies show the possibility to carry pathogens. It is not recommended for human and animal consumption (Goddard, 2003). The female black soldier fly can produce about 500 eggs in cracks and crevices in a decomposed matter such as kitchen waste, dung, garbage, and other organic waste. The eggs will hatch and turn into larvae in about four days (NCIPMI 1998). These larvae are often used in animal feed research purposes.

It is showed many positives reviews from many kinds of research claimed that BSFL can be a good nutritional source for layer hen (Jansen, 2018), broiler chicken (Cockroft, 2018), fish Xiao, Jin, Zheng, Cai, Jeffrey, Jibin and Zhangand, 2018) and pig (Nekrasov, Pravdin, Kravtsova, Bastrakov, Pashkova and Ushakova, 2018). This is because of Black soldier Larvae (Hermetia illucens sp.) rich with high protein and sources. According to Schiavone, defatted BSFL meal has a magnificent source of apparent metabolized energy and digestible of amino acid for broilers with highly efficient nutrient digestion (Schiavone et al., 2015)

1.2 Problem statement

The most common problem that farmers face is the expensive feed price. Soybean meal, corn meal, fish meal is quite expensive but it contained high-quality protein which is recommended to use in poultry feed formulation, yet researcher is still looking alternative sources that could provide high-quality protein with low price.

BSFL or *Hermetia illucens* is an edible insect that can be replaced as animal feed because of high protein content. The insect has the ability to convert from waste into nutritious protein which helps to cut the cost of feed, reduce the amount of waste and environmental friendly. Black soldier larvae is an insect that easily grows in the farm, can be either fed directly to the animal or process the insect and turn into conventional feed and market it. This thing could improve our local economic production. Chicken also naturally consume insect as their feed. Insect contained a good quality amount of protein which can reach 64% for the highest (Hwangbo et al., 2009) and 39.16% for the lowest (Atteh and Ologbenla, 1993).

Black soldier larvae also contain high essential amino acids such as lysine which help to boost the growth of animals and other protein content (Koethe, 2018).Compared to other protein sources from plant-based such as soybean meal, corn meal, maize, it requires high maintenance, care, workers, space(field or land), water, and good condition of the environment (soil and weather). These things are causes more money needed to raise the animal and people start thinking about whether it is necessary for them to start up the business.The fish meal also one of excellent protein source and have the highest amount of protein compared to other sources that could supply to broiler but it is the most expensive protein

1.3 Objectives

1. To evaluate the effects of BSFL meal on growth performance of broiler chicken
2. To determine the chemical composition of broiler carcass fed with

1.5 Hypothesis

1.5.1 Hypothesis of growth performance of broiler chicken

1. H null = the diet inclusion of BSFL has no significant on the growths performance of broiler chicken
2. H alternative = the diet inclusion of BSFL can enhance the growth performances of broiler chicken

1.5.2 Hypothesis of carcass characteristic of broiler meat

1. H null = the diet inclusion of BSFL has no significant on the carcass characteristic of broiler meat.
2. H alternative = the diet inclusion of BSFL can enhance the carcass characteristics of broiler meat.

1.6 Scope of the study

The study required animal nutrition knowledge, farm management basic, poultry industry knowledge and feed technology formulation.

The effectiveness of BSFL meal with different inclusion rate was measured by evaluating the growth performance as well as carcass characteristics of broiler meat chicken from the colour of meat, texture, tenderness, and pH.

1.7 Significance of the study

The demand for broiler meat chicken in Malaysia is really high yet the cost of production of Broiler chicken is also expensive. This is because, the use of soybean meal, fish meal, maize as their primary protein source in feed formulation and most of these ingredients are imported. Black soldier fly larvae are a good alternative protein source that can be used in feed formulation (Schiavone et al., 2017). Larvae or maggot also knew as a natural feed of chicken due to high palatability. The purpose of this study is to determine the potential of BSFL meal as a primary protein source that can replace other expensive feed ingredients in Malaysia. Other than that, to determine the ability of BSFL meal to improve the growth rate of broiler and produce high quality of carcass broiler meat.

1.8 Limitation of study

However, the weather in the experimental area fluctuates whichreduced the performance and growth of broiler chickens by manupulated the feed intake and water intake of the broiler. Too much heat caused stress, cannibalism, weight loss and back pecking which can ruin the experimental data of carcass characteristics. Too much heat also can contribute the increases of the pale, soft and exudative (PSE) of broiler meat which make us difficult to determine the effectiveness of nutrients inside BSFL meal.

The experiment was located at UMK Jeli far away from the city, it was hard to find BSFL meal supplier in nearby thus, the BSFL was shipped. During shipment, the quality of the product could reduced, so the result might be inaccurate.

CHAPTER 2

Literature Review

2.1 Introduction

The production of broiler chicken in Malaysia plays a significant role in Malaysia economic and serve the demand of the Malaysian consumer by providing cheap protein source to its multi-ethnic population (Abdurofi et al., 2017). Chicken meat is the most famous meat protein because there is no dietary prohibition from other religion against chicken meat consumption (DVS 2012). In 2012, the percentage of broiler meat consumption reached 96% in Peninsular Malaysia, compared to other poultry meat such as duck and other, they only reached 1% to 3% of consumption in Malaysia (Agrofood Statistic,2013). Thus, the production of broiler meat should be concomitant to the demand for broiler meat, the broiler industry should be continuously produced and maintain profit and reasonable price of the chicken meat (Abdurofi et al., 2017). The amount of broiler meat in 2012 was 637.00 million birds and 673.87 million for day old chick (DOC). In 2013, an increasing number of broiler production happened which was 770.22 million DOC and 720.11 million broilers (Department of Veterinary Service 2012)

Nonetheless, the main problem in the agriculture industry that interfere the performance well and due to relying upon the price trends of feedstuff which was often mentioned by many researchers is feed cost (Elsedig et al., 2015; Chanjula & Pattamarakha, 2002). This problem causes the unreasonable price of chicken meat. 70% of broiler production cost comes from feed cost and newly hatched chicks contribute about 22% and the rest is from labor, supplements, and equipment jointly contribute not more than 9% (Ravindran, 2013). Most of the feedstuff used in feed formulation for monogastric (poultry and swine) are imported. Soybean and maize are widely used in the animal farm in Malaysia. Only 30% of raw material available in Malaysia to make feed formulation. Palm kernel cake is an abundant by-product that is produced from the oil palm industry. The average of crude protein and crude fat in palm kernel cake 15-17% and 16%. However, it is less palatability, lack of amino acid and lysine. (Loh n.d) Meanwhile, the quality of the local fish meal is much lower than the imported fish meal, the protein content of the local fish meal is lower than ash content which is usually not bigger than 55% (Raghavan, 2000). Moreover, local fish meal is made from a by-product fish but the fish industry is not that large to support that production of fish meal as well as human consumption. (Loh n.d)

2.2 Black soldier fly larvae

Wild birds to free-range chicken eat insect as their natural feed without health problems experienced as a result of this (Miao, Glatz, & Ru, 2005). The insect is known as organisms that turn organic waste as a food source (detritivore). This species commonly found in compost heaps. From these traits, it would help to reduce waste. The insect can absorb the nutrients from that waste (Cockroft 2018). Linder (1919) was the first to provide details regarding the production of larvae as a protein source by using waste for agricultural purposes. However, this study was not concluded. The insect is poikilotherm means that does not need the energy to regulate body heat. Hence, the insect able to store energy in their body mass and be a good feed converter (Nijdam, Rood, & Westhoek, 2012). Essential amino acids inside the insect could help reduce the cost of feed and improve the profit for animal producers (Newton, Sheppard, Wes Watson, Burtle, & Dove, 2005).

The Black Soldier fly larvae that were reported to consist of 42% crude protein, with a respectively higher crude fat content of 38% (Newton, Booram, Barker, & Hale, 1977). The black soldier fly (BSF) is known to reduce the predominance and rearing of the housefly, which can lessen the conceivable spreading of diseases by the housefly (Bradley and Sheppard, 1984). It is likewise trusted that the BSF larvae can devour and process natural waste faster and more effective rate than the housefly larvae (Kim, Bae, Park, Choi, Han, and Koh, 2011). Normally, the BSF can be discovered all over South America and Asia, yet is local to Colombia (Canary and Gonzalez, 2012).

They can endure and adjust to a wide exhibit of ecological temperatures (McCallan, 1974). These flies fall under the Stratiomyidae family and, in the wild, are usually found in environments appropriate for larval development, for example, marshlands and moist place with animal waste, spoiled fruits or any organic decomposed (Rozkošný, 1982; Li, Zheng, Qiu, Cai, Tomberlin, & Yu, 2011). The BSF is not considered as a vermin animal groups (Sheppard et al., 1994; Newton et al., 2005b) since the grown-up fly does not eat or search for food and hence does not enter a place where human lives (Sheppard, Newton, Thompson, & Savage, 1994). The adult fly depends just on the energy stores collected during the larval stage.

2.3 The life cycle of black soldier fly

According to Newton et al., (2005) BSF going through five phases in their life cycle: egg, larvae, pre-pupae, pupae, and adult. This life cycle is somewhere in the range of 40 and 44 days (Fok, 2014). The fertilized egg take between 102 and 105 hours to hatch, at 24°C. The color of newly hatched BSF larvae is white creamy and energetic crawl towards mixture where they eat heavily in this stage. Good environment conditions can take the larvae to reach maturity in two weeks and if the condition is just optimal, it takes more than several months to reach maturity. (Sheppard Sheppard, Tomberlin, Joyce, Kiser, and Sumner, 2002; Myers, Tomberlin, Lambert, and Kattes, 2008).

At the stage of larvae and pupae where the BSF able to change organic waste into good protein and high-fat biomass. During the degradation, waste is lessened and pathogens are reduced (Erickson, Islam, Sheppard, Liao, and Doyle, 2004), and also nitrogen and phosphorus are decreases as well (Sheppard, 1983; Sheppard et al., 1994; Newton et al., 2005b; Diener, Zurbrügg, & Tockner, 2009;Diener, Zurbrügg, Gutiérrez, Nguyen, Morel, Koottatep, & Tockner, 2011). The number of organic matters in some cases such as manure can be lessened significantly to 60% and get high energy and protein body composition. (Newton et al., 2005b and Kim et al., 2011). BSFL can be first larvae that utilize organic matters to fertilizers (Erickson et al., 2004).

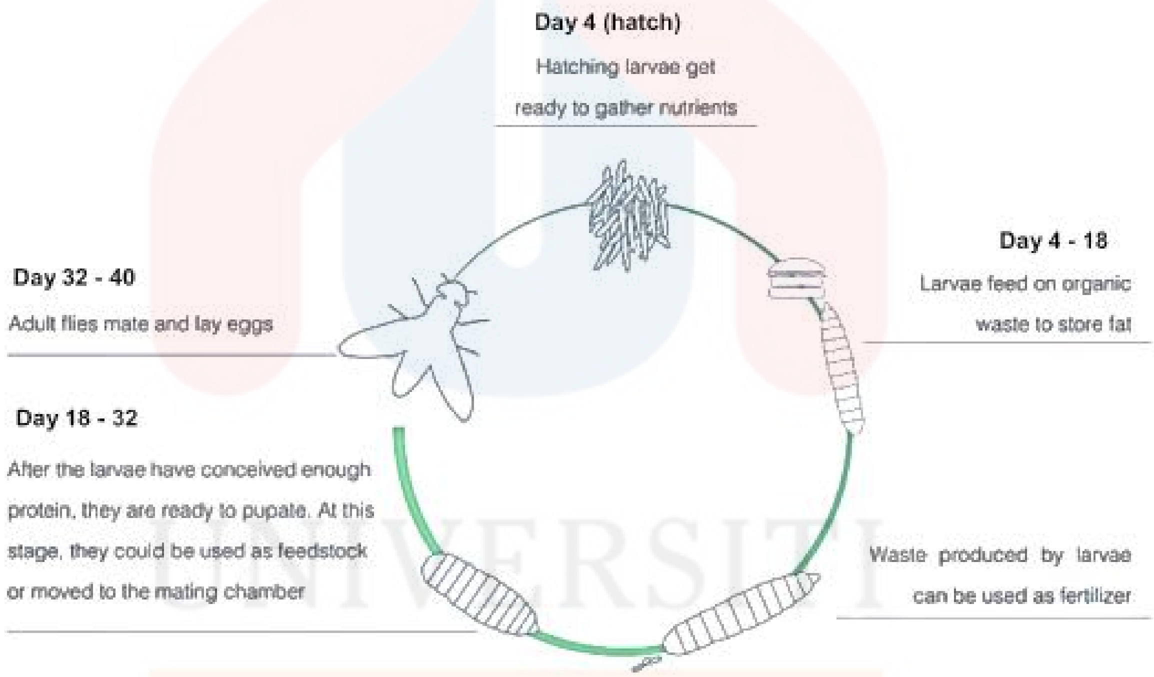

Figure 2. 1 shows the life cycle Black Soldier Fly (Fok, 2014)

2.4 The chemical composition of BSFL

Many factors that affect the chemical composition of BSFL, one of it is deffating the BSFL. The purpose of deffating BSF larvae and pre-pupae is because to reduce the amount of fat content (38%) and increase the amount of crude protein from 46% to (Surendra et al., 2016), by using solvent extraction and around 50% crude protein after pressing larvae (Table 2.1). Other than that, the age of larvae also influences the protein content (larvae versus pre-pupae versus pupae) (Calvert, Martin, and Morgan, 1969; Newton et al., 2005b; Aniebo, Erondu, and Owen, 2009). Labotary method type of analyses prefer by each author for the different nutrients, especially for the amino acid and fat determinations also influence the chemical composition of BSFL (Cockroft, 2018).

The amount of crude protein inside the BSF around 35% (Haasbroek, 2016) to 44% (Surendra et al., 2016) for dried full-fat BSF larvae and pre-pupae (Newton, Booram, Barker, and Hale, 1977; Bondari & Sheppard, 1981; St-Hilaire, Sheppard, Tomberlin, Irving, Newton, McGuire, Mosley, Hardy, and Sealey, 2007b; Diener et al., 2009, 2011; Kroeckel, Harjes, Roth, Katz, Wuertz, Susenbeth, and Schulz, 2012). A little part of the protein in the BSF larvae and pre-pupae shows the chitinous cuticle, however, this may be reduced by additional fractionation in order to increase the amino acid profile (Newton, Sheppard, Watson, Burtle, Dove, Tomberlin, and Thelen, 2005).

The amount of crude fiber for pre-pupae are 10% for both the full-fat solvent extracted (Kroeckel et al., 2012; Surendra et al., 2016). Newton et al. (2005a) discovered BSFL had essentially higher levels of manganese, iron, and calcium than soybean meal, even though lower potassium levels. Kroeckel et al., (2012) revealed BSFL contain 0.7% phosphorus and 6.5% calcium which was different than (Newton et al.1977) claimed that BSFL contains 5% for calcium and 1.5% for phosphorus.

What makes BSFL unique is the content of amino acids. Neither fish meal nor soybean meal able to supply completely for broiler chicken with all the amino acids it needed. (Cockroft 2018). However, it might be perfect to mix the BSFL with other protein sources together to accomplish the ideal amino acid profile for the particular animal being fed. The amino acid (AA) profile of BSFL is nearer to the optimal AA profile of broilers. This is because not all AA inside the BSFL reaches the AA broiler requirement. (Cockroft 2018) (table 2.2).

Table 2. 1: Nutrient content of Black Soldier Fly on a dry matter basis (%) (Cockroft, 2018)

	Tschirner & Simon, 2015	St Hilaire, 2007	Barroso, 2014	Bondari & Sheppard, 1981	Newton, 2005	Haasbroek, 2016	Surendra, 2016	Haasbroek, 2016	Kroeckel, 2012	Tschirner & Simon, 2015	Surendra, 2016	Surendra, 2016
Form	Full fat	Full fat	Full fat	Full fat	Full fat	Full fat	Full fat	Pressed	Pressed	Pressed	Pressed	Solvent extracted
Age of BSF	Young larvae	Pre-pupae	Larvae	Larvae	Mixed age	Larvae	Pre-pupae	Larvae	Pre-pupae	Young Larvae	Pre-pupae	Pre-pupae
Crude protein (%)	37.2	43.6	36.2	38-40	43.2	35.10	43.7	38.05	47.6	49.2	53.1	63.9
Crude fat (%)	30.8	33.1	18.0	18-28*	28.0	-	31.8	11.8	16.6	19.7	3.4	-
Crude fibre (%)	-	-	-	-	-	-	10.1	-	9.6	-	10.9	13.2
Ash (%)	13.5	15.5	9.3	-	16.6	8.03	6.0	13.15	15.9	18.2	8.5	10.7

Table 2. 2 Amino acid content on each raw material in comparison to the ideal amino acid profile for broiler chickens (Cockroft, 2018)

Amino Acid	Black soldier fly larvae[3]	Soybean meal[1]	Fish meal[1]	Ideal amino acid profile for broilers[2]
Lysine	100.00	100.00	100.00	100.00
Methionine + Cysteine	-	47.54	48.00	*38.00
Threonine	62.66	63.93	54.67	74.00
Isoleucine	67.22	75.41	57.33	73.00
Valine	84.23	78.69	65.33	82.00

(1) – Food and Agricultural Organisation (FAO) 2004

(2) – National Research Council (NRC) 2004

(3) – Pieterse et al., 2015

(*) – Only methionine

2.5 Broiler nutrient requirement

The essential nutrient for birds depends on the age of the birds (starter, grower, finisher), type of breeds and type of production (meat or egg producer),. There are two things that influence the broiler performance which is the amount of metabolize energy and crude protein that supplies from their diet (Zaman et al., 2008). The presence of arginine and lysine help to improve growth rate (Chamruspollert et al., 2002). However, too much amino acids require more energy on catabolizing the amino acids for excretion, which reduce the body weight depending on the level of oversupply (Kidd, 2004). So, the ratio of energy and protein in chicken diets is the main concern during formulation to prevent loss weight (Aletor et al., 2000; Nalle et al., 2012).

Chicken that grows for meat purpose is called as broiler or broiler chicken. This breed originated from the jungle red fowl of the Indian Subcontinent. Its traits have been modified turn into high nutrition content, increase the weight of the breast-muscle and fast grower. The life of broiler chicken production consists of two stages. First, they are hatched and moved out to the broiler house at first day-old from the hatchery. Then, they will stay on the farm until they reach a market size to be slaughtered. After hens produce eggs, the eggs will store inside the incubator. The chicks will readily hatch and break the shell by using egg tooth on day 21. A chick called a 'day-old chick' is up to 72 hours old. The range ambient for newly temperatures hatched chicks are 32°C to 35°C and for relative humidity are 60% to 70% (Leeson & Summers, 2005).

The purpose of the yolk is to provide energy for embryo during the incubation process. 19 days before its hatched, the yolk turns into the abdominal cavity and continue supply energy until it hatched (Uni, Ganot, and Sklan, 1998). The high nutritional feed on the starter phase (first to second weeks) is very important to develop the gastrointestinal tract and other vital organs (Uni et al., 1998). The diets that increase feed intake would help for newly hatched chick would provide benefit for production. (Cockroft, 2018). BSFL contain natural antibiotics that help boost passive immunity to active immunity in the early days of life, cheaper than chemical antibiotic and also provide antibiotic-free meat product (Sheppard, Newton, and Burtle, 2007)

2.6 Growth performance of broiler

Growth performance is one of the parameters that are used in broiler feed industry to measure the effectiveness of diets. This growth rate is affected by feed intake. There are many factors that influence feed intakes such as temperature, stocking density, age, breed purposes, and the most important thing is the ingredient of the formulation. Providing low nutrients, low energy diets helps to reduce feed cost and increase feed intake. However, giving less energy feed will do not contribute to the growth of animals performance. The goal of this study is to reach market size in a short time. Ideal metabolized energy (ME) in broiler feed is 3300 to 2700 Kcal ME/ Kg. From this suggested ME does not affect the energy requirement. However, It just increases their protein uptake to meet the energy requirement. The birds that were provided 2700 kcal ME/kg has the highest feed intake but has the lowest the weight gain compared to other diet ME. When the birds are provided high energy feed, it will devour less because they will regulate their intake according to their energy consumption (Leeson & Summers, 1997; de Albuquerque et al., 2003). Based on the previous study from (Cockroft, 2018) it is said that fat content in full-fat BSFL is the highest compared to soybean meal which causes higher liveweight on the first and second week of-of growth trial. This is because of full-fat BSFL store more energy from the high amount of crude fat. (Cockroft, 2018). In this case, energy, fat, and protein is a vital source required for animal growth. (Cockroft, 2018). Further studies needed to determine the effects of insect's fat on broiler chicken.

Broiler's in the intensive system is design to be fast growing and productivity chicken. However, there are some side effects on this modified species where the bone development is not as fast as meat gain that lead to bone and leg problems (Hocking et al., 2009; Garcia et al., 2013). It gives bad sequences to the farmers because of discoloration of meat that causes by bone fracture and leads to consumer rejection (Rubin et al., 2007; Gregory & Wilkins, 1989; Rath et al., 2000; Garcia et al., 2013). Osteoporosis happens when a reduction of mineral content and bone mass which produce the micro hole of the bone that makes it more fragile and causes fracturing (Gregory & Wilkins, 1989; Peck et al., 1993; Bishop et al., 2000; Rubin et al., 2007). This problem can prevent it by supplying a sufficient amount of phosphorus and calcium to the broiler (Leeson & Summers, 1997).

A right ratio for calcium to phosphorus is 2:1 and it was suggested by the National Research Council (2004). According to Makkar., Tran, Heuzé, & Ankers, (2014) calcium and phosphorus content in BSFL meal is quite high than other insect protein candidates. It is true that the full-fatted 5% Ca content was found by (Newton et al., 2005) and the full-fatted 3% Ca content found by Haasbroek (2016), the FF treatment Ca content (4%) was recorded by (Cockroft, 2018). FF treatment from (Cockroft, 2018) was the most superior in all terms from Average daily gain (ADG), Feed conversion ratio (FCR), live weight to European protein efficiency.

To determine efficient broiler growth,the ADG must reach 50g (Butcher & Nilipour, 2009). According to Cockroft, 2018, the ADG of FF treatment (60.20g), is higher than control treatment with (47.37g). Compared to housefly larvae that contain high crude protein, house fly larvae ADG also cannot reach as high as FF treatment which is 55.47g for 10% housefly larvae inclusion and 51.21g for 25% housefly inclusion in the broiler. Uushona (2015) also found that an ADG for 15% BSF pre-pupae inclusion in broiler diets is higher than BSFL which is 65.8g.

Butcher and Nilipour (2009) revealed that an FCR of 1.85 or less were needed for effective broiler chicken production. FCR allow us to measure feed intake and total average live weight gain simultaneously. Basically, it was used to measure the amount of feed that transfer into meat weigh. From that, we can calculate the efficiency of diet to convert from feed into body weight. The cost of production of the broiler is one of the biggest concern for broiler producers. Thus, the purpose would be to find a diet which has the highest efficiency in growth. Pretreatment of soybeans such as processing and toasting would help to increase the FCR in broiler chicken (Marsman, Gruppen, Poel, Kwakkel, Verstegen, and Voragen 1997). According to Cockroft (2018), FF treatment of BSFL meal has better FCR than other treatment (Dry rendered and Extruded BSFL) which is below than 1.41. which is also much better than control treatment, or industrial standard with FCR 1.69. Control treatment that contains soybean meal as their major ingredient is the worst FCR than other treatment. Even though the pre-pupae contain a high amount of crude protein (table 1), but from the previous study of Uushona (2015) found that the FCR for 15% BSF pre-pupae can only get 1.5 not high as high FF BSFL treatment (Cockroft, 2018). This is a very positive finding in support of the viability of BSFL protein inclusion.

According to Cockroft (2018), it is said that dry rendered BSFL treatment had the highest feed intake which makes the meat discoloration. This is because broiler consume more feed to fulfill their energy requirement. Extruded BSFL treatment was the highest feed intake in the first week but it has good results on PER, ADG, EPEF, and FCR because of sufficient nutrient to fulfill the requirement. The FF treatment yielded had the best result in all parameters in the current trial. FF treatment earned the highest live weights at slaughter, the excellent ADG and the best FCR, PER, and EPEF amongst treatments. These are very good finding on BSFL protein inclusion growth performance.

2.7 Carcass Characteristic on Broiler chicken

Animal protein markets encounter wide demands from consumers regarding meat quality, meat preferences, and ethical awareness. Health conscious and animal production welfare conscious becomes a major concern of consumers (Mcilveen, 1995). If this demand was not fulfilled by the broiler industry, people will change their preferences yet the industry would suffer big losses (Biehal & Chakravarti, 1983).

The limitations of household food budgets are also one of the factors that affect the demand for broiler meat chicken. Usually, people tend to choose a chicken carcass that suits their budget, less budget only could afford a small chicken budget (Cockroft, 2018). Although the budget is less, the consumer applied the concept where the product should be 'value for money' which only applies to heavier whole carcasses (Sproles & Kendall, 1986). Based on (Fisher, 2013) study claimed that, the heavier the carcasses the more protein content, which means that heavier carcasses are meatier and bone tissue yield than a small carcass. (Shahin & Abd Elazeem, 2005).

Over the past few years, chicken genetic has been invented, improved and designated into broiler meat producer (Rostagno et al., 2007). These genetic make protein deposition into meat carcass faster, meatier to reach slaughter weight sooner; this technology could help to reduce the production costs and give a good quality value of the product to consumers. Higher dressing rates mean the higher meat yield. The lower dressing percentage shows the higher is mass of the visceral organs and the fat percentage. To measure the dressing percentage, the cold carcass weight divided by the live weight (Cockroft, 2018). Different carcass component has a different price, this thing gives economic importance to broiler producer than others. Breast component contains the highest meat yield than other component and these reasons make it to the highest price by consumers (Husak, Sebranek, and Bregendahl, 2017).

Another meat quality indicator is by observing meat appearance and physical characteristics (Allen, Fletcher, Northcutt and Russell, 1998; van Laack, Liu, Smith, and Loveday, 2000; Qiao, Fletcher, Northcutt, and Smith, 2002; Swatland, 2004; Huff-lonergan & Lonergan, 2005). The first thing that has been observing by the customer is the meat color, tenderness, and juiciness. (Allen et al., 1998; Qiao et al., 2002; Huff lonergan et al., 2014). pH influence the color of the meat. If the pH of meat reaches an isoelectric point (pH 5.3) of major proteins, the water molecule binds together and absorb the light which causes paleness (van Laack et al., 2000). So that pH parameter is very important to measure the meat quality (Cockroft, 2018). According to Risvik (1994), consumers desire juicier meat, and Barbut (1997) found that tenderness is also important in the determination of meat quality by consumers. The temperature in self-store and post-slaughter effects the water holding capacity of meat which is also influence the tenderness and juiciness of meat (Huff-lonergan et al., 2014; van Laack et al., 2000)

The flavor and muscle tissue firmness of the meat is influenced by the fat content of the meat itself (Mottram, 1998). But, too much fat content can reduce the shelf life of the meat, this is because, fat cause excessive and turn meat into rancid (Song, Lin, Zhang, Hayat, Chen, Liu, Xiao and Niu, 2013). However, this problem can be prevented by giving sufficient antioxidants in animals' feed (Wood & Enser, 1997; Bou, Guardiola, Tres, Barroeta, and Codony, 2017). The good thing is BSFL has rich antioxidants in their composition (Makkar et al., 2014). This would come in as an extraordinary advantage in the prevention of rancidity while still being able to give flavor-filled and tender meat products (Cockroft, 2018).Although defatted BSFL has less fat, it should be high of antioxidant than full-fat BSFL. Introducing various type of fatty acids also could improve meat quality (Kroeckel et al., 2012). This is because, monogastric animals able to adapt and mimic the fatty acid that has been provided from feed itself (O'neill O'neill, Galvin, Morrissey, and Buckley, 1998; Barroeta & Barroeta, 2015; Cao Cao, F. L., Zhang, Yu, Zhao, and Wang, 2017).

The nutrient content of the meat also can be a good indicator to measuring meat quality especially for a people that worried about health. Based on the Cockroft (2018) high amount of crude proteincan be essential to the nutrient attractiveness of meat by consumers. He found that extruded BSFL (EX) has the highest crude protein in meat other than treatment (Cockroft, 2018). Surprising FF BSFL crude protein not as high as EX BSFL. This reasons could be from their treatment given (defatted process). This finding shows a good sign about BSFL that could give a high quality of protein sources, not just only give more fat than protein. Things that should be highlighted in this study is how much amount of crude protein and crude fat should be applied to improve the quality of meat.

Table 2. 3 the average nutrient content on each treatment (Cockroft, 2018)

	Treatment				
Parameters	**FF**	**DR**	**EX**	**Control**	**P-Value**
Dry Matter (%)	24.58^{a} ± 0.89	24.08^{ab} ± 0.96	24.81^{a} ± 0.65	23.46^{b} ± 0.87	0.06
Protein (%)	21.03^{ab} ± 0.53	19.37^{c} ± 0.88	22.03^{a} ± 1.13	20.09^{bc} ± 1.04	<0.01
Fat (%)	9.62 ± 1.93	11.53 ± 3.24	8.64 ± 1.77	10.31 ± 2.33	0.23
Ash (%)	4.48 ± 2.06	4.20 ± 1.50	5.39 ± 2.62	4.21 ± 1.50	0.70
Mineral					
Phosphorus (%)	3.14 ± 0.17	3.08 ± 0.17	3.04 ± 0.15	3.13 ± 0.37	0.86
Potassium (%)	3.41^{ab} ± 0.20	3.26^{b} ± 0.22	3.72^{a} ± 0.49	3.67^{a} ± 0.32	0.08
Calcium (%)	0.11^{ab} ± 0.02	0.09^{b} ± 0.02	0.09^{b} ± 0.02	0.12^{a} ± 0.02	0.04
Magnesium (%)	0.53 ± 0.03	0.53 ± 0.07	0.55 ± 0.04	0.53 ± 0.05	0.81
Iron (mg/kg)	226.07 ± 32.12	243.87 ± 39.99	231.01 ± 46.26	253.02 ± 18.98	0.59
Copper (mg/kg)	2.99 ± 1.76	2.95 ± 1.36	2.30 ± 0.54	3.83 ± 1.75	0.36
Zinc (mg/kg)	119.71 ± 10.39	117.57 ± 12.52	113.08 ± 9.74	126.99 ± 19.92	0.38
Manganese (mg/kg)	5.75 ± 1.36	5.71 ± 1.70	4.82 ± 0.91	6.48 ± 2.15	0.38
Boron (mg/kg)	3.70 ± 0.85	3.56 ± 0.72	3.41 ± 0.71	4.47 ± 1.77	0.37
Aluminium (mg/kg)	98.98 ± 78.12	67.07 ± 15.01	102.90 ± 45.11	88.84 ± 35.04	0.60

(^{a,b}) – Means with different superscripts within the same row differ significantly (P <0.05)
EX – Extruded black soldier fly larvae
DR – Dry rendered black soldier fly larvae
FF – Full fat black soldier fly larvae

CHAPTER 3

Methodology

3.1 Experimental Design

Defatted black soldier fly larvae meal *(Hermetia illucens)* is used as the main ingredient in this experiment. There were four formulated feeds that contain different BSFL meal inclusions which are 0%,20%,40%and 60% in broiler chicken diets on growth parameter and carcass quality. 32male broilers are tested andeight broilers for each group. Each group had different diets ad-libitum. The control treatment included maize, soybean meal and fish meal as a protein source. Others raw material to fulfill the broiler requirement is DCP, limestone, lysine, methionine, antioxidants, premix and vegetable oil were used to formulate the broiler feed. The experiment was carried out at the broiler house at Agrotechnology Park. Standard management practices of commercial broiler production were applied. Chicks were vaccinated against Newcastle disease (ND) and Infectious Bronchitis (IB) in mix vaccine at 7 and 21 of age and against Infectious Bursal disease (IBD) at 13 d of age. Anticoccidial compounds will be used as a preventive dose from 22 - 29 days of age. The chicks housed in floor pens (1.25 x 2 m) each. There were4 cages allocated in the same size to separate each treatment.

The weight of day old chicks (DOC) until broilers reach market size, the broiler were weighed and recorded at the first day of the experiment. The broilers chickens were observed three times a day including feeding routine on morning and evening. Every two weeks, the feed were changed from starter to grower, from grower to finisher as the chickens grow. Lastly, the broilers were slaughtered by incision after they reach market size range from 29 to 42 days old, the carcass were weight and proximate analysis were performed to determine the nutrient composition in broiler meat.

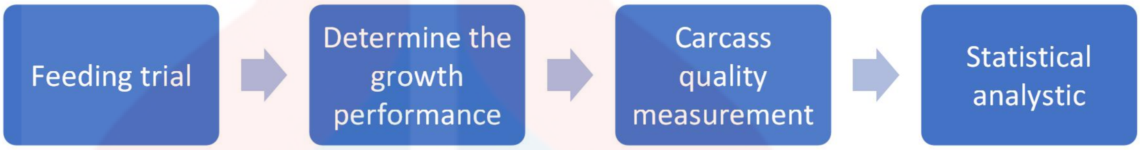

Figure 3. 1 shows the flowchart of the study

Table 3.1 shows the total feed requirement for eight male broilers by the stages for every treatment. All treatments received same amount of feed. Each one of the broiler consume 0.5kg for the stater phase, 1.5kg for the grower phase and 2.31kg for finisher phase. The amount of feed were reduced if the any mortality happened in that groups of treatment.

3.2 Materials

Table 3. 1 shows the total feed requirement for eight male broilers by the stages for every treatment

Stages (day)	Cumulative feed intake(kg/head)	Total feed requirement for eight broilers (kg/treatment)	Round off for feed formulation (kg)
Starter (0-14)	0.479	3.832	4
Grower (15-28)	1.498	11.984	12
Finisher (29-42)	2.311	18.488	18.5

Treatment.

The broiler house was clean up and sprayed antiseptic to kill the microbes. The brooder guard, hoover and thermometer, bedding will be set up before accepting the newly hatched chick. At the first and second week, the newly hatched chick will be placed on the brooder guard. After two weeks, the chickens will be transferred into the proper partition for the rest of the experiment

3.3 Feeding trial

One of the *In vivo* methodologies was used in this experiment is Feeding trial , which is directly feed the animal with tested feed. The method was performed in the farm. Each of the eight tested broilers were separated in a cage from other animals with different percentage BSFL inclusion. The purpose of feeding trial was to measure the growth of broilers and the quality of carcass characteristic of broilers. (FAO, n.d.)

3.4 Measuring growth performance

Eight tested broilers were measured their weight in the second (starter), fourth (grower) and sixth (finisher) week of the experiment after feeding the diets. The weights were recorded every week until week six to determine the growth of broiler by using the weighing balance.

3.5 Average daily gain (ADG)

This method is different than body weight measurement, Average daily gain (ADG) determines the performance by measuring daily gain by the animals over a given period. (Boling-Frankenbach et al., 2001)

Formula: Total Pounds Gained / number of Days

(End Weight - Beginning Weight) / (End Date - Begin Date)

3.6 Feed conversion ratio (FCR)

The feed conversion ratio is the amount of feed that needed to grow the animals. The lower FCR, the higher the quality of feed (Boling-Frankenbach et al., 2001)

FCR = (amount of fed / amount weight gain)

3.7 Carcass quality measurement

3.7.1 Proximate analysis

The proximate analysis was performed to determine the amount of chemical composition inside the broiler meats. These experiments were determining the amount of crude protein, crude fibre, dry matter, moisture content, and crude fat. These experiments were tested on four groups of meat from a different treatment. The chest part of broiler meat will be analyzed to justify the nutrient content with three replicates.

3.7.2 Dry matter (DM)

The dry matters of broiler meat were analyzed by removing the moisture of the meat. 2 g of samples were placed in aluminium foil and put in the furnace to remove the moisture for 24 hours at 100°C. The samples were taken out and weighed to determine the dry matter of meat. Association of Official Analytical Chemists (AOAC) International (2002), Official Method 934.01

Moisture content can be obtained by dry matter (DM) analysis by subtracting the live weight of broiler meat with dry broiler meat. Here is the step for measuring moisture content. Here is the step to measure the moisture and dry matter content

$$\% \text{ Moisture} = \frac{(\text{weight of sample} + \text{empty crucible}) - (\text{weight of dry sample} + \text{empty crucible})}{\text{weight of sample}} \times 100$$

$$\% \text{ Dry Matter} = 100 - \% \text{ Moisture}$$

3.7.3 Crude protein determination (CP)

Based on AOAC official, Kjeldahl method was used to determine the crude protein content of broiler meat by measuring the amount of nitrogen content. The Kjeldahl method involves three major steps which are digestion, distillation and titration methods. After titration, the result will time by 6.25

VA: volume of acid used

W: weight sample

$$\%N = \{\frac{14 \times VA \times 0.1}{1000 \times 100}\}^{W} \times 100$$

Crude Protein (%) = Nitrogen (%) x 6.25

3.7.5 Ether extract determination (EE)

Ether extract analysis is a method the measure the number of fats and oils inside of them. Soxtec method was used to detemine crude fat inside the broiler meat samples. In this experiment, Soxtec apparatus that includes three major components which are an extractor, condenser and 250ml flask. (AOAC, 2002) Method 954.02

To measure Crude fat (%):

Crude Fat (%) = (Mass of Beaker + Fat) - (Mass of beaker) Sample Mass x 1001

3.8 Data collection and Statistical analysis

Analysis of variance (ANOVA) methods were applied for measuring the live weight of the broiler, the weight of broiler carcass and proximate analysis of meat carcass on different treatment group. All data were analyzed by using the IBM SPSS Statistics 23 software with significance different (P<0.05)

CHAPTER 4

Result and discussion

4.1 Average feed intake

According to the table 4.1, the highest feed intake after 14 days in the trial was 60% Bsfl at 201.36g but there is no significant different between those groups. Compared to other research, it was slightly lower than 15% full-fat BSF pre-pupae treatment that consumes 210g per chick in the 11 days (Uushona, 2015). In Cockroft (2018) research, he found the highest significantly different in treatment with extruded bsfl at 173.4g per chick. From observation, it could be the palatability of feed with bsfl treatment that influence the feed intake of chicks.

Table 4. 1 : Average feed intake for each treatments

	Control	20% BSFL	40% BSFL	60% BSFL	P-value
Starter stage	174.51 ± 15.13	154.91 ± 11.23	159.29 ± 12.72	201.36 ± 15.17	0.082
Grower stage	460.43 ± 26.28^{bc}	476.64 ± 12.49^{c}	388.43 ± 24.47^{b}	250.21 ± 17.16^{a}	0.000
Finisher stage	704.14 ± 48.29^{a}	754.86 ± 51.14^{a}	409.79 ± 28.25^{b}	367.71 ± 26.19^{b}	0.00

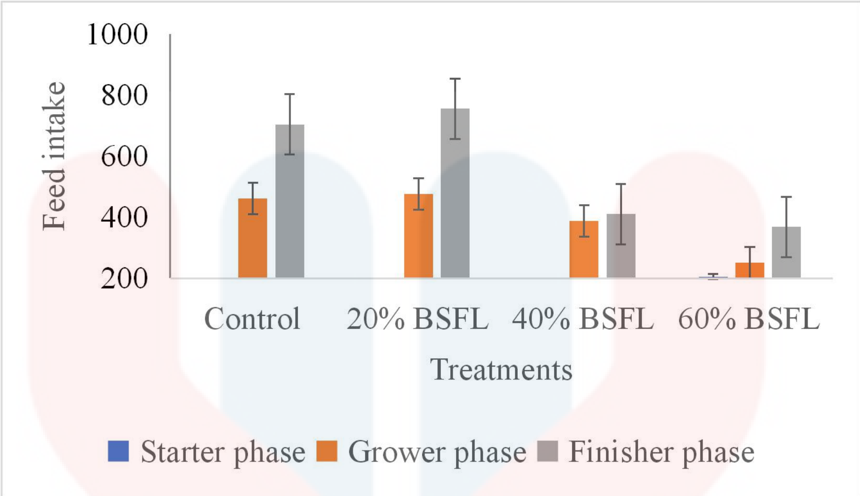

Figure 4. 1 Average feed intake for each treatment in starter, grower an finisher phase

The chicks should consume more feed in order to develop their digestive system and increase the enzymes secretion in the body (Noy & Sklan, 1997). It also helps to improve the performance of the broilers (Pretorius, 2011). The high nutritional feed on the starter phase (first to second weeks) is very important to develop the gastrointestinal tract and other vital organs (Uni et al., 1998). The diets that increase feed intake would help for newly hatched chick would provide benefit for production (Cockroft, 2018).

In the fourth weeks of the trial, there was a significant differences between these groups. The 20% of bsfl consume significantly higher than the others groups that consume 476.64g per broilers. 60% of bsfl consume significantly lowest at 250.21g per broilers which is lower than 40% of bsfl 388.43g per broilers. However, above all these treatments they consume lesser than Extruded bsfl treatment groups that consumed 575.9g by Cockroft (2018).

In the sixth and final weeks of the trial, 20% of bsfl intake (754.86g per chick) was the significantly higher than all the other groups. Overall, the average of the feed intake in 20% of bsfl is the highest compared to other groups based on the figure 4.1.1. This is because the feed that contains bsfl has more palatibility than 0% of bsfl of and the feed itself has brighter colour than 40% of Bsfl and 60% of bsfl. But, 0% of bsfl intake is much higher than 40% of bsfl and 60% of bsfl.

This is could be the excessive amount of the bsfl content reduces the feed intake of broiler chicks in 40% of bsfl group and 60% of bsfl group. The palatibility, flavour and colour of the feed influence the feed intake of the broiler. The feed of 40% of Bsfl and 60%of bsfl has darker colour and strong smell compare to the other treatments. Based on the journal from Capretta (1969), newly hatched chicks tend to choose green colour than red colour. The feed of 40% of bsfl and 60% of bsfl has dark brown colour compared to 20% and 0% which has bright yellowish colour.

The causes of dark feed colour are from pre-pupae bsfl meal that has black colour of feed. Pre- pupae larvae have dark black exoskeleton which can influence the colour of feed. It also has a strong smell which can reduce the feed intake of chicks.

The study is corroborated by Risha (unpublish), the intake from group 40% of bsfl and 60% bsfl with treated enzyme protease is lesser than without treated enzyme protease because the colour of feed is less attractive and has strong smell. This statements is supported by the study from Gillette et al., (1983) claimed that the chicks tend to responsive more on less flavoured feed than strong flavoured feed.

4.2 Average live weight

Table 4.2 shows the results from the broiler production parameter trial undertaken, from this result there are some significant differences in the average body weight from different growth stage. The live weights of broiler chicken were recorded every two weeks of six weeks rearing. From this result, 40% Bsfl inclusion group performed significantly different P (<0.05) in stater stage. The rest of the other groups do not performed significantly different. However, the body weight from treatment extruded bsfl (Cockroft, 2018) weigh higher than 40% of Bsfl (632.1g per chicks) in the second weeks of trial. The body weight these chicks from all of these treatments can considered as the worst body weight. The body weight of the chicks in the second week's trial should be weighing more than 500g per chicks. Based on Aizan (unpublish), the metabolize energy inside of all the feed contain low energy which is below than 3000 kcal ME/kg. Each of metabolize energy for starter feed are 2373.41 for control, 2754.61 for 20% of bsfl, 2928.07 for 40% of bsfl and 2827.15 for 60% of bsfl. The energy requirement of the broiler chicks should be above 3000 kcal ME/kg for the starter phase.

Table 4. 2: Average live weight for each treatments

Average body weight	Control	20% BSFL	40% BSFL	60% BSFL	P-Value
Starter stage	127 ± 8.83^{a}	122.875 ± 10.80^{a}	186.375 ± 8.14^{b}	126.38 ± 9.83^{a}	0.000
Grower stage	428.00 ± 42.43^{c}	373.75 ± 29.83^{ab}	219.25 ± 19.91^{ab}	294.50 ± 9.87^{a}	0.000
Finisher stage	796.50 ± 47.22^{b}	1033.75 ± 65.87^{c}	520.00 ± 37.82^{a}	713.75 ± 44.72^{b}	0.012

According to Leeson (2005), the metabolize energy requirement should be 3023 (starter phase), 3166 (grower phase) and 3202 (finisher phase). Energy requirement is needed for maintenance, growth and reproduction and it depends on the animals. (Ferket & Gernat, 2006)

In the grower stage, 0% Bsfl inclusion shows the better result compared to other Bsfl inclusion groups with significantly different P (<0.05) followed by the chicks in group 20% of Bsfl and 60% Bsfl. The 60% of Bsfl has the worst average body weight in that group. Both 40% of bsfl and 60% of bsfl does not show the efficiency of the feed for growth performance. Although 20% of bsfl has lower average body weight (373.75g per chicks) than 0% of the bsfl inclusion (428g per chicks), it show the positive progress in the second week of grower phase. The average of body weight from 40% of bsfl to 60% of bsfl group show drastically worst results after they reached a few days of the first week of grower phase because their intake was drastically poorer than other treatments (Table 4.1.1). There were about four chicks died after they started to consume the feed because of leg paralysis from 60% of bsfl group and one died from 40% of bsfl . The rest of the chicks survived and eat less. There was a research that claimed that after the birds were adapted with the current feed they will avoid the feed if the feed makes them feel illness and unpleasant post-ingestion effects (Gillette et al., 1983).

After broilers reached at the first week of finisher phase, again, the chicks from the group 20% of Bsfl showed the positive result that reached more than 1kg than all the other treatment groups receiving different percentage of bsfl meals. The result revealed that 20% of Bsfl has significantly different in finisher stage followed by 60% of Bsfl and 0% of Bsfl. The 40% of Bsfl does not show the significant different in the result.

This finding can be validated by the research from Anankware et. al (2018) claimed that 15% of bsfl treatment with replacement of soybean meal and partial replacement of fish meal has the highest significance difference in the growth of broilers against control group. Overall the range from 10-20% of bsfl for replacement of other protein sources is suitable for the growth performance of broiler chicken.

4.3 Average daily gain

Table 4.3 shows 60% Bsfl has the highest (significantly highest than all the treatments) average daily gain in stater stage which is 10g per day followed by 40% of Bsfl with 5.95g per day. Meanwhile, 20% of Bsfl has the lowest weight gain compared to other group which is 5.52g. Although, the feed intake of 60% of bsfl was slightly higher than 0% of bsfl but the adg of 40% of bsfl and 60% of bsfl is much higher than 0% of bsfl. This is because the 60% of bsfl contained the highest crude fat at 6% with crude fibre at 4% followed by 40% of bsfl that has crude fat at 5.9% and crude fibre at 3.6% (Aizan, unpublish) This indicate that bsfl is suitable for growth performance in starter phase due to the high crude fat and crude fibre.

Table 4. 3: Average daily gain for each groups

	Control	20% BSFL	40% BSFL	60% BSFL	P- value
Starter stage	$5.79^{a} \pm 0.59$	$5.52^{a} \pm 0.70$	$5.95^{a} \pm 0.63$	$10^{b} \pm 0.53$	0.00
Grower stage	$24.32^{c} \pm 1.89$	$16.41^{bc} \pm 3.02$	$8.87^{ab} \pm 1.96$	$6.52^{a} \pm 0.48$	0.00
Finisher stage	$30.29^{a} \pm 0.93$	$49.50^{c} \pm 1.04$	$17.70^{a} \pm 2.36$	$29.95^{b} \pm 2.58$	0.00

After 21 days, 0% of bsfl has the highest average daily gain which is 24.32g compared to other treatment with bsfl inclusion and 60% of Bsfl has the worst result after they reach grower phase. This is because their intake was drastically decrease by days (table 4.2). So that their average daily gain is lesser than other treatment as their intake is less.

In the end of the finisher phase, 20% of Bsfl has the highest weight gain with 47.63g followed by 0% of Bsfl that gain 30.29g per day for 14 days. This finding is quite similar with Uushona (2015) that gained an ADG of 65.8g for 15% BSF pre-pupae inclusion in broiler diets for 35 days. However there was no significant difference between 0% of bsfl and 60% of bsfl (29.95g per chick per day) even their feed intake was obviously significantly different which is 704.14g for 0% of bsfl and 367.71g for 60% of bsfl. This result showed that 60% of bsfl is very good in terms of average daily gain in the finisher phase. However, above than 20% of bsfl inclusion need pre-treatment to increase their efficiency of feed intake in order to improve their daily gain weight. This statement is corroborated by the research from Cockroft (2018) The higher intake of feed is related to lower body weight in the Dry rendered (DR) treatment which is a big drawback when using this treatment for broiler growth production. Chickens alter their intake to fulfill their energy requirements (Leeson & Summers, 1997). It might be the energy inside the DR treatment was not as bioavailable, and thus DR' fats are less digestible than that of the extruded and full fat treatments. Thus the bsfl inclusion needs a treatment in order to improve the feed efficiency for growth performance.

4.4 Feed Conversion ration

Table 4.4 show result for feed conversion ratio for each group with different amount of Bsfl meal. 60% Bsfl has the lowest fcr , which is less than 2.00 compared to other groups that has fcr more than 2. The group that has the worst fcr in the starter stage is from 0% of Bsfl which is 2.31. This is because the broilers in the groups consume more feed than other chicken due to the high palatibility of feed. Nandeesha et al. (1989) said that the fat content inside the insect of larvae contains high palatability stimulants which would encourage the chicks devoured at a higher rate. Other claimed that house fly larvae meal inclusion in a three-phase feeding system improved average broiler total feed intake, total feed intake, and average daily gain instead by using commercial corn-soy oil cake meal diet.(Pretorius, 2011).

Table 4. 4: Feed conversion ratio for each treatments

	Control	20% BSFL	40% BSFL	60% BSFL	P- value
Starter stage	2.31 ± 0.22	2.28 ± 0.32	2.11 ± 0.28	1.47 ± 0.09	0.076
Grower stage	1.38 ± 0.11	2.30 ± 0.41	4.00 ± 1.37	2.79 ± 0.23	0.133
Finisher stage	1.67^{b} ± 0.05	1.09^{a} ± 0.02	1.78^{b} ± 0.32	0.90^{a} ± 0.07	0.006

After 21 days, the group with 0% of Bsfl has the lowest fcr compared to other groups. Meanwhile, 40% has the worst fcr in the result which is 4.00. Even the intake per chick of the 40% of bsfl and 60% of bsfl was drastically lesser than other groups. The average weight gain of 60% of bsfl is higher than 40% of bsfl. This is because the feed of 40% of bsfl and 60% of bsfl is less attractive, has darker colour of feed and strong smell which make the chicks in that groups eat lesser.

In the finisher stage, 60% Bsfl has shown the positive result (0.90) which is the result is ideal fcr for broiler production that is lower than 2. 40% of bsfl has the highest fcr number at 1.78 and slightly higher than 0% of bsfl inclusion at 1.69. This is because the intake per chick of 60 of bsfl is partially lesser than all the other treatments and had great average live weight per chick. The average live weight per chick in 60% of bsfl is higher than 40% of bsfl and slight lower than 0% of bsfl which is no significance difference between those two groups. But, body weight of broiler in 20% of bsfl can reach more than one kilogram even their fcr is little bit higher than 0% of bsfl. Feed intake of the broiler chicken is influence by the metabolize energy in the feed, the higher the metabolize energy content, the lesser intake of chicks. Metabolize energy helps to increase the performance of live weight and quality of carcass meat (Leeson, 2005). This finding is supported by the research from Aizan (unpublish) where the metabolize energy content inside of 20% of bsfl inclusion is the most highest at 3548.363 kcal ME/kg followed by 60% of bsfl at 3524.14 kcal ME/kg and the lowest metabolize energy in the finisher stage feed formulation is 40% of bsfl which is 3426.14 kcal ME/kg. It conclude that, above 20% to 60% of bsfl inclusion is suitable for fcr in the finisher stage but it need to alter the formulation and pre- treatment to improve the quality of feed in order to increase the body weight and reach market size in short time.

4.5 Carcass quality measurement (chest part): proximate analysis

4.5.1 Dry matter

In the table 4.5 summarize the percentage of the dry matter of broiler meat for each treatment. In this table showed that 20% of bsfl has the highest percentage of dry matter from all the other treatments. However, there was no significance difference between these groups. but dry matter (%) in 0% of bsfl is the most lowest than all other groups and 40% of bsfl is higher than 60% of bsfl. This is because the carbohydrates content in the feed that influence the dry matter of broiler meat (Abang et al., 2015). This is true that the average of crude fiber inside the feed in 20% of bsfl is the highest among the other feed.

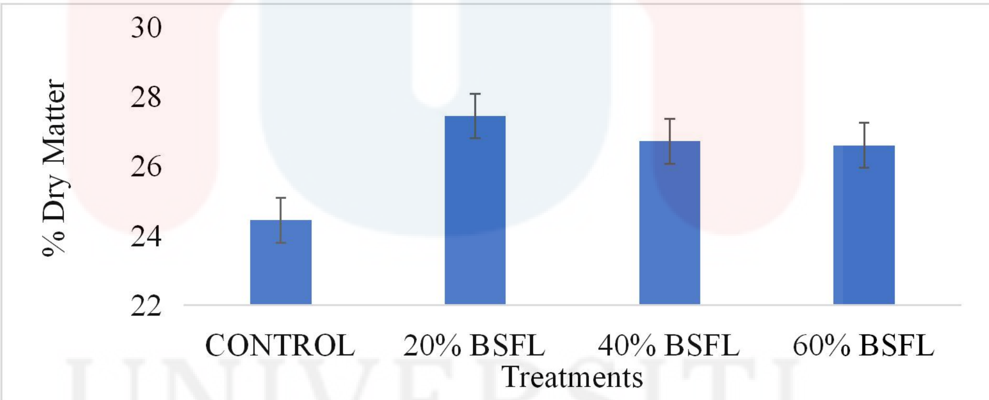

Figure 4. 2 The percentage of Dry matter in broiler meat for each treatment

Table 4. 5 : The percentage of nutritional composition in broiler meat for each treatment

	Treatment				
Nutritional content (%)	CONTROL	20% BSFL	40% BSFL	60% BSFL	P-Value
Dry Matter	24.44±0.45	27.44±0.64	26.711±1.04	1.29±26.60	0.258
Crude protein	92.65±3.63	97.14±3.40	74.49±6.14	68.26±1.93	0.003
Crude Fat	3.43±0.37	8.41±1.21	5.08±1.39	6.18±2.10	0.167

4.5 Crude protein

In the table 4.5 showed that 20% of bsfl has the significantly highest in %CP versus all of the treatments (97.13%). The control group has the second highest (92.65%) followed by 40% of bsfl (74.49%) and the worst was 60% of bsfl with 68.25% of %CP. This research is supported by Cockroft (2018) which is extruded treatment of bsfl has the highest significance compare to full fat and dry rendered treatment of bsfl which is 22.03. In this experiment, extruded pre pupae were used in broiler feed.

However, the %CP of all the samples in this experiment is invalid because the range of the %CP for broiler meat is around 20-24% (Panreac, n.d). This is because there was a human error in this experiment, the digestion time should take more than four hours to digest the samples, however, in this experiment the samples only digest from three to four hours to digest. Since the kjeldhal machine is used in every day, the efficiency of machine itself is reduced.

4.5.3 Crude fat

In the table 4.1 showed 20% of bsfl has the highest crude fat but there is no significant difference between those groups. However, the crude fat in the 20% of bsfl is quite similar with extruded bsfl at 8.64 (Cockroft, 2018) and the rest of the sample has lower crude fat.

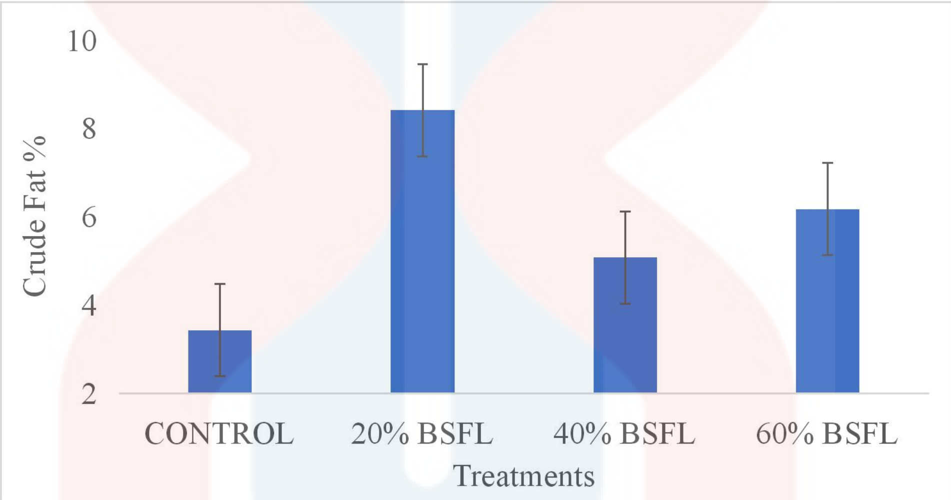

Figure 4. 3 the percentages of the crude fat in broiler meat for each treatment

Before this, there was mentioned, fat in meats influence of the flavour and so it may be necessary for consumer preferences. The flavor and muscle tissue firmness of the meat is effected by the fat content of the meat itself (Mottram, 1998). But, too much fat content can decrease the shelf life of the meat. This is because excessive fat can turn meat into rancid (Song, Lin, Zhang, Hayat, Chen, Liu, Xiao and Niu, 2013). Rancidity of meat is less preferable of consumer.

CHAPTER 5

Conclusion and recommendation

The study has indicate that the maximum inclusion bsfl can be used in feed formulation is 20% of bsfl inclusion. Overall, 20% of bsfl has the greatest result in growth performance and carcass characteristic without any adverse effect. It can be recommended for replacement of other expensive protein feedstuff such as fish meal and soybean meal. However, the inclusion from 40% to 60% of bsfl can be improve in terms of increasing their feed intake, palatibility and colour of feed by pre-treatment. This is because it also had a great result in improving average daily gain and feed conversion ratio. Further study need to do determined motility rate of bsfl inclusion because the broiler keep dying after they consumed high content of bsfl.

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APPENDIX A

Table A 1: Raw data of body weight of treatments for starter phase

Average body weight	Control	20% BSFL	40% BSFL	60% BSFL
Starter Stage	96.00	170.00	212.00	82.00
	116.00	82.00	167.00	172.00
	152.00	127.00	188.00	102.00
	108.00	97.00	211.00	113.00
	113.00	143.00	180.00	142.00
	167.00	143.00	143.00	122.00
	147.00	90.00	194.00	139.00
	117.00	131.00	196.00	139.00
Mean	127.00	122.88	186.38	126.38
Standard deviation	24.97	30.55	23.03	27.79
Standard error	8.83	10.80	8.14	9.83

Table A 2: Raw data of feed intake of treatments for starter phase

Average Feed Intake	Treatment			
	Control	20% BSFL	40% BSFL	60% BSFL
Starter stage	41.42	75	51	66
	91.71	94.71	107	114
	126	131	120	143
	147	131	131	184
	186	131	132	199
	214	178	149	222
	192	160	189	227
	209	171	191	243
	219	153	214	251
	223	180	183	250
	224	165	188	242
	230	216	213	203
	149	151	152	225
	191	232	210	250
Mean	174.5092857	154.9078571	159.2857143	201.3571429
SE	15.12720228	11.2337221	12.71687836	15.17176641

APPENDIX B

Figure B 1: The mixture of broiler feed, 20% of bsfl inclusion

Figure B 2: Feeding trial (starter phase)

Figure B 3: Pellet sun drying process

APPENDIX C

Figure C 1: sample preparation for crude fat analysis

Figure C 2: Soxtec machine