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Comparative analysis of *Hermetia illucens* L. mixed chicken feed and commercial chicken feed to growth performance, carcass weight, and meat proximate content of *Gallus domesticus* L.

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ABSTRACT: The development of the broiler farming industry to meet the needs of chicken meat in Indonesia has problems including the availability and high prices of commercial feed. This is due to the use of high-priced protein sources from a fish meal as a commercial feed composition. One option that can replace a fish meal as a composition of broiler feed is *Hermetia illucens* L. larvae flour. This study aims to determine the difference between *H. illucens* mixed chicken feed (HiMCF) and commercial chicken feed (CCF) on growth performance of *Gallus domesticus* L. with parameters Final Body Weight (FBW), Daily Feed Intake (DFI), Daily Weight Gain (DWG), Feed Conversion Ratio (FCR), Approximate Digestibility (AD), Efficiency of Conversion Digestibility (ECD), carcass weight with 3-joint wings, forequarter, and leg quarter, and the meat proximate content. In this study, *G. domesticus* were cultivated for 33 days with HiMCF and CCF treatment. The complete proximate content of feed and meat was analyzed descriptively, while growth and carcass weight were analyzed by statistical SPSS T-test (T-test, = 0.05). The feeding of HiMCF and CCF treatment on the growth of broiler chickens to DFI, DWG, FCR, AD, and ECD was the same except for FBW. While the feeding of HiMCF and CCF treatment to the carcass weight was not the same except for 3-joint wings. The feeding of HiMCF and CCF treatment gave the same proximate content of broiler chicken meat. Based on this research, the HiMCF can be an alternative feed for broiler chickens.

Keywords: Carcass; *G. domesticus*; Growth; *H. illucens*; Meat; Proximate content

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INTRODUCTION

Production of broiler chicken (*Gallus domesticus* L.) in Indonesia in 2019 was 3,495,090 tons, an increase of 85,532 tons from the previous year, followed by an increase in broiler meat consumption per capita by 1.87% from 5,579 tons to 5,683 kg (Directorate General of Livestock and Animal Health, 2020). The increase in production and consumption of chicken meat indicates the development of the livestock industry in Indonesia. However, the development of this industry has not been followed by the availability and price of commercial broiler feed, which is more affordable, but the availability of feed is limited, and the price of broiler chicken feed is relatively expensive because it has a high crude protein content derived from the expensive fish meal (Wardhana, 2016; Henry et al., 2015).

In developing countries such as Indonesia, fish meal is used as one of the compositions of animal feed as the main source of crude protein (Wardhana, 2016), while in European countries the use of fish meal as a mixture of animal feed composition is no longer allowed so that soy flour is used as a source of crude protein for feed livestock (Schiavone et al., 2017). In Indonesia, the cost of feed for broiler production is 70 % of operational costs (Nasruddin, 2010).

The high cost of broiler chicken feed makes chicken farmers get not enough profit. One of the efforts to reduce the cost of broiler feed is by substituting the composition of a fish meal using insects because proteins derived from insects are more economical, environmentally friendly, and have an important role in nature. Insects are reported to have high feed conversion efficiency and can be reared, and mass-produced (Gasco et al., 2013; Henry et al., 2015; Huis, 2013).

Insects that contain a crude protein content of 40 – 50 % with lipids content ranging from 29 – 32 % are *Hermetia illucens* L (Diptera: Stratiomyidae) (Barragán-Fonseca, 2018; Doberman et al., 2017; Cullere et al., 2016; Bosch et al., 2014). Utilization of *H. illucens*, namely leftover cultivation media, can be used as solid organic fertilizer, liquid organic fertilizer, and hydroponic nutrient solution from leachate, and the larvae become one of the compositions of animal feed such as broiler chicken feed (Abduh et al., 2020; Diener et al., 2009). Similar applications have been made with the substitution of soy flour by *H. illucens* larvae flour giving satisfactory growth performance, carcass weight, and overall meat quality of broiler chickens (Schiavone et al., 2017; Renna et al., 2017). Based on this research, *H. illucens* larvae flour can also substitute expensive fish meal, and no research has been done.

This study aims to determine the difference between *H. illucens* mixed chicken feed (HiMCF) and commercial chicken feed (CCF) on growth performance of *Gallus domesticus* L. with parameters Final Body Weight (FBW), Daily Feed Intake (DFI), Daily Weight Gain (DWG), Feed Conversion Ratio (FCR), Approximate Digestibility (AD), Efficiency of Conversion Digestibility (ECD) and carcass weight with 3-joint wings, forequarter, and leg quarter, and the meat proximate content.

MATERIALS AND METHODS

Location and time of research

The *H. illucens* cultivation and making HiMCF was conducted in Technology Laboratory XI School of Life Sciences and Technology ITB Ganesha. The broiler farming research was conducted in Malang Village, Majalaya District, Bandung Regency (7°04'56.9"S 107°47'48.9"E) at an altitude of 1,183 masl with 1-day-old-chicken (DOC) under a partitioned cage. Chicken is then harvested on the following day by fasting for one night. Testing of HiMCF and CCF proximate content and meat proximate content at Laboratory of the Faculty of Animal Husbandry, Padjadjaran University.

Statistical model

The type of cage used was a partitioned cage with a length of 60 cm x width 60 cm x height 60 cm for each partition. Each partition is not only equipped with a base of husks to keep the chicken mat dry but also 15-watt yellow LED lamps which is equivalent to 40 lux to keep the chickens warm. This study used a Randomized Block Design (RBD) in the form of two treatments of feed with six replications using *G. domesticus* 1-DOC with a weight of 74-75 g and commercial chicken feed (BR1) from CV. Missouri Poultry Bandung City, and without water restriction. Each partition was filled with four chickens so the total used was 48 chickens.

Feed

The type of feed used was commercial chicken feed (CCF) from feed mill production and *H. illucens* mixed chicken feed (HiMCF). Larvae and prepupae of *H. illucens* were fed with fruit waste and palm kernel meal for 18-21 days and harvested directly put in the refrigerator for one day, after that it is dried in direct sunlight until the water content is about 10% and mashed using a blender. Larvae and prepupae of *H. illucens* flour will substitute fish meal for 20% of the composition of commercial chicken feed in HiMCF feed treatment. The composition of HiMCF feed is 400 g commercial chicken feed, 270 g cornflour, 180 g bran, 91.2 g fish meal, 36 g *H. illucens* larvae flour, 3.6 g *H. illucens* prepupa flour, 7.2 g papaya leaf, 6 g gelatin, and 6 g premix for one kilogram of feed (Schiavone *et al.*, 2017; Renna et al.,2017). Testing of BSF mixed chicken feed and commercial chicken feed proximate content at Laboratory of the Faculty of Animal Husbandry, Padjadjaran University. Feeding was given two times a day at 08.00 am and 04.00 pm and each feeding in the week 1^{st} of 50 g, the week 2^{nd} of 70 g, and the week $3\text{-}5^{th}$ of 100 g for one chicken (Cobb, 2018; Schiavone et al., 2017). Feed and drink containers are cleaned every day, while the rice husk is replaced twice a week.

Data observations and statistical analysis

Microclimate condition as temperature, relative humidity, and light intensity was recorded using Data Logger HOGO U12-012. Observation of *G. domesticus* weight data was carried out every day and tried to avoid chicken stress and leftover feed weighed every time they are given feed. Whole chicken every treatment and leftover feed were weighed using a digital scale with an accuracy of 1 g and a weight limit of 25 kg.

Chicken carcass analysis used one chicken from each replicate which was taken randomly to be slaughtered and cut into three parts into 3-joint wings, forequarter, and leg quarter then each part is weighed. Analysis of the proximate content of chicken meat in the Laboratory of the Faculty of Animal Husbandry, Padjadjaran University by taking 100 g of chicken meat from each part. Data was compiled using Microsoft Excel 365 64-bit software.

The data is then processed to obtain Initial Body Weight (IBW), Final Body Weight (FBW), Daily Feed Intake (DFI), Daily Weight Gain (DWG), Feed Conversion Ratio (FCR), Approximate Digestibility (AD), Efficiency Conversion Digestibility (ECD) (Schiavone et al., 2017), dan percentage of the carcass, 3-joint wings, forequarter, leg quarter data (Bell and Weaver, 2002). The results of the processed data were then analyzed using IBM SPSS Statistics 25 64-bit. The test used is the T-test ($\alpha = 0.05$), followed by the requirements of normality test and validity test.

RESULT AND DISCUSSION

Microclimate

During the conducted experiment, the microclimate condition (Table 1) as the temperature was strongly supporting optimal growth performance of broiler chicken as asserted by (Cobb, 2018; Schiavone et al., 2017; Renna et al.,2017) that the critical temperature for broiler chicken is 30 ºC and optimum temperature conditions at 24 ºC (Wardhana, 2016; Cobb, 2018) and the lower the temperature will increase the consumption of broiler chicken feed (Ximenes et al., 2018). because relative humidity and light intensity did not give a real effect on growth chicken. If the environment temperature exceeds the broiler chicken limit, the chicken will tend to consume more water than their feed. This phenomenon was broiler chickens as homeothermy are warm-blooded animals with thermoregulatory capabilities to maintain their body temperature (Cobb, 2018).

In addition, water is not limited due to focus research is feed treatment effect toward broiler chicken biomass growth performance.

Table 1. Microclimate condition

Microclimate	Unit	Maximum	Minimum	Average
Temperature	°C	27.22 ± 0.41	22.32 ± 0.33	24.87 ± 0.37
Relative humidity	%	86.58 ± 0.31	82.86 ± 0.23	83.72 ± 0.27
Light intensity	Lux	35.72 ± 0.36	33.79 ± 0.41	35.07 ± 0.35

Feed proximate content

The growth of broiler chickens is determined by the quality of feed, the quality, in this case, is related to the nutritional content, such as protein, lipids, carbohydrates, and fiber. In addition to quality, quantity also determines the acceleration of chicken growth. According to the requirements of SNI 8173.3:2015 starter feed for broilers aged 1 to 14 days and finisher feed for broilers aged 15 until harvest (National Standardization, 2015). The proximate content of HiMCF and CCF (Table 2) after being analyzed showed results by the Indonesian National Standard but the ash content was still above the standard. This is because the high ash content of H. illucens is 9.71% while the fish meal is 6.64% (Barragán-Fonseca, 2018; Raksakantong et al., 2010).

Table 2. Feed proximate content CCF and HiMCF

Proximate content	Unit	SNI starter	SNI finisher	Treatment	
				CCF	HiMCF
Water	%	Maximum 14	Maximum 14	7.94	8.17
Ash	%	Maximum 8	Maximum 8	5.82	8.65*
Crude protein	%	Minimum 19	Minimum 18	23.8	22.3
Crude fiber	%	Maximum 6	Maximum 8	5.97	6.12*
Crude lipids	%	Maximum 7.4	Maximum 8	8.18*	6.65
Carbohydrate	%	Minimum 50	Minimum 50	56.2	54.8
Metabolism energy	kcal/kg	Minimum 2,900	Minimum 2,900	4,066	3,993

*Not according to Indonesian National Standard (SNI)

Broiler chicken growth performance

The Day-Old Chicken (DOC) used had an Initial Body Weight (IBW) treatment with CCF and HiMCF there was no significant difference (T-test, $P > 0.05$). DOC weight of broiler chickens is 73 - 78 g per head (Cobb, 2018). Daily Feed Intake (DFI) is the weight of feed consumed by broiler chickens to meet daily needs (Schiavone et al., 2017; Renna et al., 2017). There was no significant difference in the DFI of the Cobb strain of broiler chickens treated with CCF and HiMCF (Table 3) (T-test, $P > 0.05$). This indicates that broiler chickens consume HiMCF feed. But in the first week, there was a big difference. The average daily feed consumption requirement in the first week of CCF and HiMCF treatment was 21.64 g and 15.55 g, respectively. According to Cobb (2018) stated that the average daily feed consumption of Cobb strain broiler chickens in the first week was 20 g. The HiMCF treatment chicken feed consisted of 40%

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commercial chicken feed which was crumbling type, while the rest was mashed which caused broiler feed preference to prefer to crumble feed. According to Azis et al. (2011) stated that broiler chickens aged 0-7 days have a very high risk of dying, it can reach 50% if the adaptation process to new feed and environment is very long. So that the daily feed consumption of the HiMCF treatment was lower than the CCF treatment.

Daily Weight Gain (DWG) is the daily weight gain of broiler chickens due to consuming feed (Schiavone et al., 2017). DWG broiler chicken CCF and HiMCF treatment (Table 3) there was no significant difference (T-test, $P > 0.05$). This shows that HiMCF feed is willing to be consumed by broiler chickens. Daily chicken weight gain has experienced a difference from the beginning of the second week due to low feed consumption in the first week. The difference in weight difference between CCF and HiMCF treatments at each week which was not significantly different resulted in the accumulation of different final weights of broilers.

The average chicken weight in the fifth week of CCF and HiMCF treatment was 1,388.80 ± 5.45 g and 1.113.30 ± 6.32 g, respectively. Harvesting at the final weight is around 1.3 kg per head due to consumer preferences in Indonesia (Nasruddin, 2010), but the final weight of broilers treated with HiMCF does not reach it.

Feed Conversion Ratio (FCR) is the amount of feed consumed to make broiler chickens weigh one kilo (Schiavone et al., 2017). There was no significant difference between the FCR values of CCF and HiMCF treatment (T-test, $P > 0.05$). According to Cobb (2018), the FCR value for the Cobb strain broiler chicken is 1.6. The FCR value shows the conversion of consumed feed into biomass for broilers. The FCR value of the HiMCF treatment was very high (Table 3) indicating that the HIMCF treatment feed was not good enough to produce high chicken biomass.

Approximate Digestibility (AD) is the ability of broilers to digest the feed given (Bosch et al., 2014). The AD value of CCF and HiMCF treatment had no significant difference (T-test, $P > 0.05$). Different crude fiber and protein will make a big difference in digestibility. Increased levels of crude protein in the feed will increase the digestibility of the feed. The digestibility of crude fiber is very different from the digestibility of other food substances. Crude fiber that cannot be digested will block the action of enzymes that digest other food substances (Nasruddin, 2010).

Table 3. Growth performance broiler chicken with CCF and HiMCF

Parameter	Unit	Treatment		p-value
		CCF	HiCMCF	(5%)
Initial Body Weight (IBW)	g	74.60 ± 0.79	74.80 ± 0.29	0.88
Final Body Weight (FBW)	g	1,388.80 ± 5.45	1,113.30 ± 6.32	0.01*
Daily Feed Intake (DFI)	g	68.85 ± 2.67	63.78 ± 2.91	0.50
Daily Weight Gain (DWG)	g	42.09 ± 3.42	33.73 ± 5.73	0.11
Feed Conversion Ratio (FCR)	-	1.64 ± 0.21	1.92 ± 0.56	0.98
Approximate Digestibility (AD)	%	82.62 ± 0.51	76.53 ± 0.66	0.22
Efficiency Conversion Digestibility (ECD)	%	57.83 ± 1.42	49.33 ± 2.38	0.68

*Significant level at 5% ($P < 0.05$)

The efficiency of Conversion Digestibility (ECD) is the efficiency value of feed consumption which is converted into broiler chicken biomass (Bosch et al., 2014). There was no significant difference between the ECD values of CCF and HiMCF treatments (T-test, $P > 0.05$). The ECD value of CCF treatment is very good because it is close to 58% (Cobb, 2018). However, the HiMCF treatment resulted in an ECD value of 49.33% which indicated that the HiMCF treatment feed was not efficient enough for chicken digestion so that the final weight conversion was less than optimal.

The final weight of the Cobb strain broilers was measured one day before harvesting. This is done with the aim that when harvesting chickens for 12-24 hours the chickens are not fed so that the chickens do not experience stress, make it easier for blood to flow when slaughtered, and empty the digestive system of the chickens to facilitate the process of cleaning the organs in broiler chickens (Pratama et al., 2015). Final Body Weight (FBW) of CCF and HiMCF treatment had a significant difference (T-test, $P < 0.05$).

The fifth week of FBW of broiler chickens is 1.4 kg (Cobb, 2018). This difference occurred because the results of the accumulation of DWG in CCF and HiMCF treatments were different but not significant so the final weight of HiMCF treatment could not be the same as the CCF treatment. The use of HiMCF will reduce production costs by 12.5% when compared to CCF productivity is only reduced by 10%. So that HiMCF can be used as an alternative feed and can produce other products such as organic fertilizer from *H. illucens* cultivation.

Broiler chicken carcass

Meat from broiler carcasses is a highly nutritious food ingredient, has a delicious taste and aroma, soft texture, and relatively cheap price, so it is liked by many people (Nasruddin, 2010). In addition, chicken carcass meat has high market demand. The carcass weight of broiler chickens is used as a benchmark for estimating profits in a broiler slaughterhouse business (Pratama et al., 2015).

Profit estimation is seen from live weight, carcass, 3-joint wings, forequarter, and leg quarter (Table 4). Live weight of broiler chickens before slaughter had a significant difference in chicken weight (T-test, $P < 0.05$) which showed a significant difference in live weight of broiler chickens. The carcass weight of broilers treated with CCF and HiMCF had a very significant difference (T-test, $P < 0.05$). This is because the live weight of broiler chickens before slaughter is significant. The carcass percentage of broilers varied between 65 - 75 % of live weight for 35-day-old broilers (Bell and Weaver, 2002).

Wing weights or 3-joint wings of broiler chickens between CCF and HiMCF treatments were not significantly different (T-test, $P > 0.05$). The percentage of the weight of 3-joint wings of broiler chickens with HiMCF treatment is 11.57 %, which means that according to Bell and Weaver's (2002) research, it is 9 - 12%.

The weight of the 3-joint wings of the HiMCF treatment was greater than the CCF treatment because crude lipids in broiler meat accumulated on the wings of broiler chickens that were rarely used and the behavior of the HiMCF treated chickens was more active than the CCF treatment. The forequarter weights (chest and back) of CCF and HiMCF treatments showed a very significant difference (T-test, $P < 0.05$). The percentage of forequarter weight of broilers treated with HiMCF was still in normal condition because according to [9] stated that the percentage of forequarter weight was 41 – 47 %. Leg quarter weights (upper and lower thighs) CCF and HiMCF treatments showed significant differences (T-test, $P < 0.05$).

According to Bell and Weaver (2002) stated that the percentage of leg quarter weights is 41 - 47%. The percentage of leg quarter weights in the HiMCF treatment was greater than the CCF treatment. This is because the crude lipids content of HiMCF treatment is greater than CCF so that crude lipids accumulate in the upper thighs, lower thighs, and wings (Pratama et al., 2015).

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Table 4. Broiler chicken carcass weight with CCF and HiMCF

Parameter	CCF		HiMCF		p-value (5%)
	g	%	g	%	
Live weight	1,423.67 ± 5.36	100	1,242.67 ± 4.16	100	0.01*
Carcass weight	994.33 ± 4.21	69.80	816.50 ± 3.25	65.74	0.01*
3-joint wings	89.50 ± 4.39	9.02	94.33 ± 3.42	11.57	0.21
Forequarter	452.17 ± 3.97	45.46	338.17 ± 4.89	41.35	0.01*
Leg quarter	438.17 ± 3.10	44.06	369.33 ± 2.15	45.39	0.01*

*Significant level at 5% ($P < 0.05$)

Meat proximate content

Provision of broiler chicken feed containing balanced proximate according to SNI for broiler chickens will produce good quality chicken meat. One of the parameters of chicken meat that has good quality and quality is that it has a balanced proximate content. The results of the proximate analysis of broiler meat on CCF and HiMCF treatments (Table 5) showed the same results based on descriptive analysis. This indicates that the HiMCF treatment feed was able to produce the same proximate content as the CCF treatment.

The proximate content of CCF and HiMCF treated chicken meat was approximately the same as that of (Oliveira et al., 2016). So that the results of the study of proximate content with CCF and HiMCF treatments were very good.

Table 5. Meat proximate content CCF and HiMCF

Proximate content	Unit	Treatment		Oliveira et al. (2016)
		CCF	HiMCF	
Water	%	55.02	59.78	70.12
Ash	%	4.10	4.37	2.67
Crude protein	%	20.39	19.33	20.40
Crude lipids	%	6.83	9.15	6.65
Carbohydrate	%	68.69	67.15	-
Metabolism energy	kcal / kg	3,273	3.107	-

CONCLUSIONS

The feeding of HiMCF and CCF treatment on the growth of broiler chickens to DFI, DWG, FCR, AD, and ECD was the same except for FBW. While the feeding of HiMCF and CCF treatment to the carcass weight was not the same except for 3-joint wings. The feeding of HiMCF and CCF treatment gave the same proximate content of broiler chicken meat.

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