Feed and animal nutrition: insect as animal feed

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Abstract. In the last ten years, insects have been widely recognized for food and feed. Many studies using insects (Black soldier fly, cricket and silkworm pupae) as feed to explore their nutritional value and apply it in some animal rations as an alternative source of protein and fat. Data showed that Black soldier fly (BSF) has high protein and fat, especially lauric acid which potential as an antibacterial pathogen. In vitro study showed that BSF extracted could phagocyte 99% of pathogen bacteria such as E coli and S aureus. Meanwhile, cricket has also high fat and protein, including glutamic acid for brain development, and mineral Fe has to support hemoglobin synthesis. Silkworm pupae contain 67.48% of unsaturated fatty acid with linoleic acid (omega 6) and linolenic acid (omega 3) which very good as a steroid hormone precursor. Application insects to substitute imported ingredients (Casein, fish, meat bone, and soybean meal) in poultry diets resulted in a good performance and the animal still healthy with low mortality. The BSF and cricket meal as part of milk replacer could produce ADG of pre-weaning goat/sheep around 100 -120 g/h/d, meanwhile if those ingredients are used as part of creep feed, the daily gain of post-weaning goat/sheep could be more than 150 g/h/d. Application of silkworm meal as a substitute for the fish meal could improve egg quality and quantity of laying quail. It was concluded that insects have the potential to be used as a protein source in the poultry and pre-weaning small ruminant rations without any negative effect on the animal.

Keywords: insect, black soldier fly, cricket, feed, and silkworm pupae

1. Introduction
The demand for food from animal origin has been increasing every year. This trend goes following the increasing of human population and the increase of public awareness about the importance of animal protein consumption. According to the Food and Agricultural Organization (FAO), in 2050 the production of food from animal origin should be increased 60-70% to fulfill the need of the worldwide population [1]. The increase in consumption would eventually increase the production of livestock.

The feed cost of the livestock industry is around 60% up to 75% of the total budget, and the proportion of protein accounts for over 15% of total feed cost [2]. Many kinds of protein feed sources such as legumes, grains, and animal waste usually are used as part of good rations. For the eco-friendly industry, there is a growing interest in the use of insects as a protein source in livestock [3]. Therefore, it is practical on insect production on the scale of the amount and uses them as an alternative ingredient for a sustainable environment in the livestock industry [4]. The insect is one of the potential commodity alternatives as a new protein source for animal feedstuff [5, 1]. It can be used to substitute or reduce some other expensive and high quality feeds such as casein, soybean meal, meat bone meal, fish meal, and oil utilization. Black soldier fly (BSF, Hermetia illucens),
bombyx mori and cricket (Gryllus bimaculatus) larvae are potential insects that can be used as feed or food.

2. The nutrients composition of Black Soldier Fly (BSF), Cricket and Silkworm meal.

2.1 Black soldier fly (BSF)
Black soldier fly (Hermetia illucens), a potential insect, commonly use as sources of animal protein and contained 4.4 – 8.4% of moisture, 42 – 54.09% of crude protein, 11.8 – 34.8% of fat, 7-9% crude fiber and 14.6 – 15.9% of ash, based on dry matter basis [6, 7]. The BSF has different compositions depend on age harvesting, medium rearing, and technology processing. The data showed that the proportion of crude protein and crude fat increased by the change of physiological status, age and pressing treatment. BSF at different ages with palm kernel waste medium has higher protein (52.34%) and fat (36.92%) in prepupae compared to protein (43.22%) and fat (19.51%) in the larvae stage. Meanwhile, the pressing and defatted treatments could decrease fat content, from 37% (original) to be 27.36% (steamed), 17.05% (methanol extracted), 17.95% (normal pressing) and 13.05% with heated pressing (Astuti et al. 2018). The results showed that there was a fat decrease until more than half a lower concentration compared to full fat, on the other hand, crude protein increased to be 43.9%. The composition of fatty acids and amino acids in BSF samples with palm kernel waste medium shows that the highest concentration of fatty acids in BSF is lauric acid (40.29%) meanwhile oleic acid, linoleic acid also palmitic acid is 7.99%, 4.02%, and 9.99%, respectively. Concerning amino acids composition, BSF was particularly high in glutamic acid (3.49%), following by aspartic acid (2.70%), alanine (2.47%) and leucine (2.15), but low in methionine (0.47%), lysine (1.67%) and histidine (0.70%), as reported by [8]. BSF with the organic waste medium has lower quality compared to palm kernel meal medium.

2.2 Cricket
Crickets (Gryllus bimaculatus) meal contain 54.10% crude protein, 6.90% crude fiber, and 26.90% crude fat and they also have essential amino acids such as 1.80% methionine, 6.28% valine, 11.10% histidine, 6.59% lysine, 7.49% leucine and nonessential amino acids as 13.00% glutamine, 8.13% alanine, 6.90% arginine, and 6.36% glycine [9]. Meanwhile, the fatty acids consist of 50.32% palmitic acid (C16:0), 32.06% stearic acid (C18:0), 9.77% oleic acid (C18:1) and 2.34% linoleic acid (C18:2) [10]. Cricket meal has high mineral iron, so it is good for hemoglobin precursors. [11] indicated that in 100 g of cricket meal contained 8.7g of chitin which could disturb the nutrient absorption by animals. There are several ways to reduce the proportion of chitin in insects such as through mechanical methods by removing heads, wings, and legs or chemical treatment. Treatment with methanol extraction could reduce the fat content to be 11.99%, compared to originally (26.94%) and also the crude fiber and chitin decrease to be 1.64% and 0%, meanwhile some amino acids such methionine, lysine, tyrosine, leucine, and alanine are increase [9]. The high proportion of glutamic acid in cricket protein was in agreement with other studies that characterized amino acid profiles of cricket [12]. The low proportion of methionine in cricket was also observed in [13] research. According to previous research, in comparison to fish meal, insects including cricket generally contain a lower concentration of methionine that needs to be considered when formulating ration based on insect protein[14].

2.3 Silkworm pupae
It is reported that the silkworm pupae meal contains 51.1% of crude protein and 34.4% of crude fat[15]. The fatty acids composition of silkworm pupae contains 32.52% of saturated fatty acids and 67.48% of unsaturated fatty acids with linoleic acid (omega 6) 8.57% and linolenic acid (omega 3) 24.4% [15]. Both types of unsaturated fatty acids have been a lot of concern for people considering the benefits for the body.
3. The application of BSF, cricket and silkworm in the ration

Various insects have been tried to be the protein or fat alternatives and test for growth performance, blood traits, carcass traits, in livestock [16, 9, 17, 7]. Before applied the insect to the poultry and small ruminant kids ration, there were some in vitro experiments to find out the antibacterial trial. The amino acid in the insect has potential as antimicrobial protein (AMP) which could inhibit pathogen bacteria activity [18]. It is reported that the AMP from the insect is a group of antibacterials such as ceropins, defensins attacin, lysozymes, and dipteracins. The antibacterial test using BSF larvae and cricket meal methanol extracted showed that with dose of 2560 mg/100ml concentration of BSF meal extraction challenged by 5.9 x 10^9 CFU/ml of Staphylococcus aureus (gram-positive) could kill 99.96% of the pathogen bacteria, meanwhile, if the same dose is contacted with 2.1 x 10^9 CFU/ml of Escherichia coli (gram-negative) result showed almost 99.99% of the pathogen bacteria died. Furthermore, it was reported by using cricket meal extraction, the percent of killed S. aureus and E. coli bacteria were around 99.94% and 98.76%, respectively. Table 1. showed the in vitro clearance test by using a blood goat kid challenged by E. coli.

| Treatments       | Total final bacteria (CFU/ml) | Total death bacteria (Δ) | Bacteria death (%) |
|------------------|------------------------------|--------------------------|--------------------|
| E. coli          | 2.70 x 10^14                 | -                        | -                  |
| Fed goat milk    | 2.60 x 10^7                  | 2.69 x 10^14             | 99.99              |
| Fed MR com.      | 5.70 x 10^7                  | 2.69 x 10^14             | 99.99              |
| Fed BSF MR       | 7.20 x 10^7                  | 2.69 x 10^14             | 99.99              |
| Fed cricket MR   | 5.80 x 10^7                  | 2.69 x 10^14             | 99.99              |

MR=milk replacer; MR com= milk replacer commercial

Table 2. The % activity and Phagocytosis capacity of blood goat kids challenged S. aureus

| Treatments       | (% activity) | Phagocytosis capacity (per 50 active cells) |
|------------------|--------------|---------------------------------------------|
| Fed goat milk    | 63.33 ± 9.71 a| 120 ± 18.61 a                               |
| Fed MR com.      | 75.33 ± 8.41 ab| 151 ± 46.32 a                              |
| Fed BSF MR       | 79.89 ± 2.71 b| 240 ± 31.66 b                              |
| Fed cricket MR   | 76.00 ± 4.26 ab| 179 ± 67.49 ab                             |

MR=milk replacer; MR com= milk replacer commercial. Different superscripts following the mean in the same row indicate a significant difference (P<0.05).

3.1 BSF dan cricket meal for poultry and goat kids

The utilization of BSF in the quail ration showed that feed consumption seemed to be in line with the egg production and egg mass. Control group was found to show the lowest feed consumption, and in turn, also showed a lower egg production and egg mass in comparison with 50% BSF and 100%BSF substitutes of fish meal. The highest fat concentration in 100% BSF substitution caused the high fat intake in this group which relates to the highest egg production. Fat, especially cholesterol is a precursor of steroid hormone that induced egg production.

| Variables                        | Control         | 50% BSF of FM | 100% BSF |
|----------------------------------|-----------------|---------------|----------|
| Macrofag phagocytic activity (%) | 60.17 ± 7.91 a  | 77.00 ± 4.34 b| 89.83 ± 3.32 a |
| Macrofag phagocytic capacity (per cell macrophage) | 2.18 ± 0.66 c | 5.42 ± 1.39 b | 9.13 ± 3.07 a |
| Antibody titer                   | 1 ± 0b          | 105.6 ± 93.02 ab| 192 ± 110.85 a |
| Feed consumption (g quail⁻¹ day⁻¹) | 19.10±1.51     | 19.38±1.41   | 19.85±1.14   |
For laying hens, there are several studies evaluated the impact of black soldier fly on laying performance, egg quality and gut health [19, 20, 21, 22]. These studies have shown that the uses of black soldier fly do not appear to be as good as applied to broilers [19, 20, 21]. Feeding 7.5% of defatted black soldier fly larva meal had similar egg production and poor FCR relative to corn-soybean meal diet [20]. Moreover, 5% inclusion of black soldier fly larva meal decreased egg mass [20]. Only limited results show that black soldier fly meals can increase the content of lutein, γ-tocopherol, β-carotene and total carotenoids in egg yolk and reduce cholesterol in egg yolk [22]. Therefore, the effects of fress black soldier fly on laying hens better than dry or pellet one [23]. Different inclusion levels of defatted black soldier fly larva meal can improve growth performance, blood parameters and gut morphology of broiler, whereas 15% inclusion have no positive effects [24]. Interestingly, 15% of defatted black soldier fly larva meal inclusion can improved carcass traits and meat quality [25]. Schiavone's group also have investigated the inclusion of insect fat in finishing broiler which indicated that 50% or 100% replacement of soybean oil with larva fat has no adverse effects on growth performance, blood parameters and gut health [25]. Furthermore, black soldier fly larva meal has microbiota regulatory function which tested by two diverse substrates, chicken feed and/or vegetable waste [26]. Although cricket has no extensive applications like Tenebrio molitor and Hermetia illucens, there is also a positive effect that promotes animal growth performance. Chicks were given a basal diet with a 0.5g/kg diet of cricket chitin and chitosan can have improved growth performance and carcass quality and its regulatory mechanism may via enhanced expression of nutrients transporters [27, 28].

Application of BSF and cricket meal as part of milk replacer and creep feed in animal kids are presented in Table 4.

**Tabel 4.** Feed consumption of goat kids fed milk replacer containing insects

| Consumption       | Treatments          | GM       | MRC      | MRB      | MRCR     |
|-------------------|---------------------|----------|----------|----------|----------|
|                   | g h⁻¹ d⁻¹            |          |          |          |          |
| Week 1-4:         | Milk Replacer       | 151,00±3,62a | 208,00±31,64b | 169,83±7,98a | 160,85±22,32a |
| Week 5-8:         | Milk Replacer       | 160,36±0,00a | 210,40±26,85b | 172,00±11,29a | 175,86±15,45a |
|                   | Creep Feed          | 93,67±56,28 | 121,06±66,11 | 84,87±2,76  | 121,37±0,00 |

GM=goat milk; MRC=milk replacer commercial; MRB= milk replacer BSF; MRCR= milk replacer cricket
Figure 1. Goat kids performance fed milk replacer and creep feed containing insects

The goat milk treatment (yellow line) still has the highest growth rate compared to commercial milk replacer (grey line), BSF milk replacer (red line) and cricket meal (blue line). Colostrum from mother milk is one of the reasons why the kids grow better. Goat kids with cricket milk replacers have better gain compared to BSF one.

Dry matter and Ca intake of MR containing cricket meal was higher as compared to Cow Milk treatment and the Cow Milk treatment was higher than that of Goat milk. The highest protein and fat intake were observed in goat kids fed with MR containing cricket. The phosphorus intake was similar across all treatments. The ADG and final body weight of kids fed with Goat Milk and MR containing cricket were similar and higher that of Cow Milk treatment.

Table 5. Nutrient intake of goat kids during 8 weeks experiment

| Nutrient intake | Treatments | GM  | CM  | CMR |
|-----------------|------------|-----|-----|-----|
| Dry matter      | 98.20±7.79<sup>a</sup> | 120.05±5.24<sup>b</sup> | 203.87±3.07<sup>a</sup> |
| Protein         | 30.97±2.46<sup>b</sup> | 30.88±1.35<sup>b</sup> | 43.97±0.66<sup>a</sup> |
| Fat             | 31.73±2.52<sup>b</sup> | 18.72±0.82<sup>c</sup> | 51.40±0.77<sup>a</sup> |
| Calcium         | 0.90±0.07<sup>c</sup> | 1.50±0.07<sup>b</sup> | 3.30±0.05<sup>a</sup> |
| Phosphorus      | 1.82±0.14  | 1.97±0.09  | 1.77±0.03  |
| Initial BW (kg) | 3.75±0.34  | 3.70±0.32  | 3.88±0.33  |
| Final BW (kg)   | 9.65±0.54<sup>a</sup> | 8.53±0.51<sup>b</sup> | 9.23±0.53<sup>a</sup> |
| ADG (g/h/d)     | 120.41±10.00<sup>a</sup> | 98.47±20.96<sup>b</sup> | 109.18±12.37<sup>a</sup> |

Different superscript within the same row is significantly different at P<0.05.
GM = goat milk, CM = cow milk, CMR = cricket milk replacer.

The cricket meal as part of the creep feed was continued to give for the post-weaning goat to evaluate the fermentability profile. The result is shown in Table 6 and Table 7.
Table 6. Feed intake of post-weaning etawah crossbred goats receiving a diet containing cricket

| Parameter      | CM-0       | CM-15     | CM-30     |
|----------------|------------|-----------|-----------|
| Dry matter     | 748.78     | 730.40    | 692.88    |
| Crude fat      | 20.34<sup>a</sup> | 41.17<sup>b</sup> | 57.35<sup>c</sup> |
| Crude Protein  | 132.08     | 136.55    | 129.33    |
| Crude fiber    | 80.23      | 78.20     | 88.82     |
| Calcium        | 13.86      | 13.22     | 14.28     |
| Phosphorus     | 4.36       | 4.13      | 4.15      |

Different superscript within the same row is significantly different at P<0.05. CM-0 = control diet, CM-15 = diet containing 15% cricket meal, CM-30 = diet containing 30% cricket meal.

Utilization of cricket meal to substitute soybean meal up to 30% in the concentrate had no negative effect on rumen fermentation profiles. All parameters were in normal values to support rumen fermentation activity. Data on rumen microbial population showed that there was no significantly different for the protozoa population, total bacteria, proteolytic bacteria and microbial protein synthesis among the dietary treatments.

Table 7. Rumen fermentation characteristics of post-weaning goat kids fed creep feed containing cricket meal

| Fermentation profile | CM-0         | CM-15        | CM-30        |
|----------------------|--------------|--------------|--------------|
| Total VFA (mmol/l)   | 91.79±62.82  | 119.42±36.42 | 97.13±30.98  |
| Acetic acid (%)      | 45.68±22.43  | 48.33±8.97   | 53.80±9.83   |
| Propionic acid (%)   | 36.78±11.10  | 41.49±8.67   | 35.58±12.77  |
| Butyric acid (%)     | 17.54±11.81  | 10.17±1.92   | 10.62±4.28   |
| Ammonia (mmol/l)     | 9.54±1.63    | 6.73±0.82    | 7.76±3.50    |

Microbial population:

| Protozoa (log cell/ml) | 6.25±0.2 | 5.93±0.14 | 5.74±0.47 |
| Total bacteria (cfu/ml)| 8.33±1.29 | 8.71±0.56 | 9.49±0.73 |
| Proteolytic bacteria (cfu/ml) | 9.49±1.30 | 9.45±0.81 | 9.69±0.21 |
| MPS (mg/ml)            | 192.46±54.66 | 168.4±65.04 | 164.33±39.3 |

CM-0 = control diet without cricket meal, CM-15 = diet containing 15% cricket meal, CM-30 = diet containing 30% cricket meal.

Daily weight gain was not significantly different among the treatments. Similarly, feed efficiency also was not significantly different between CM-0, CM-15 and CM-30 treatments.

Table 8. Performance and feed efficiency of post-weaning goat kids fed concentrate containing cricket meal

| Parameter          | CM-0         | CM-15        | CM-30        |
|--------------------|--------------|--------------|--------------|
| Initial weight (kg)| 11.01±1.79   | 11.19±2.29   | 11.62±1.82   |
| Final weight (kg)  | 21.79±4.45   | 21.42±4.41   | 23.19±5.58   |
| ADG (g/d)          | 135.30±30.35 | 123.41±37.98 | 136.54±39.60 |
| Feed efficiency (%)| 20.44±2.89   | 20.57±4.17   | 23.24±3.50   |

CM-0 = control diet without cricket meal, CM-15 = diet containing 15% cricket meal, CM-30 = diet containing 30% cricket meal.
4. **Silkworm pupae meal**

Application of silkworm pupae meal to substitute of fish meal for quail has been done to evaluate the egg production. The results of egg production showed that substitution of 25% or 75% fish meal protein with silkworm pupae (R1 or R3) significantly increased egg production (P<0.05) compared to control. Egg production in control lower than other treatments, in line with the low feed intake, which was influenced by nutrient consumption. However, any difference in protein consumption, that could be estimate affected egg production among the treatments. Control treatment has a lower real protein intake compared to other treatments. Egg physical quality was observed as egg weight, yolk color score, Haugh unit, egg white weight, yolk weight, shell weight, and shell thickness. The substitution of silkworm pupae meal was not significantly different in scores yolk color, Haugh unit, yolk weight, shell weight, and shell thickness. However, the substitution of silkworm pupae meals significant effect on increasing egg weight and egg white weight (P<0.05). Despite silkworm pupae have lower crude protein content, metabolizable energy content, unsaturated fatty acids, and amino acid composition of silkworm pupae higher than fish meal [29,15]

Table 9. The Average Quail Egg Production (Hen Day), Total of Egg Production, and Feed Conversion during 8 Weeks of Treatment silkworm pupae

| Parameter                      | R0                         | R1                          | R2                          | R3                          |
|--------------------------------|-----------------------------|------------------------------|------------------------------|------------------------------|
| Total Egg Production           | 223.25±21.75a               | 327.25±13.89c               | 262.50±14.48b               | 282.50±17.62b               |
| Egg weight (g)                 | 8.40±0.14a                  | 8.48±0.11a                  | 8.92±0.10b                  | 8.44±0.28a                  |
| White egg weight (g)           | 4.61±0.22ab                 | 4.54±0.19a                  | 4.89±0.21b                  | 4.37±0.22a                  |
| White egg percentage (%)       | 54.09±0.79                  | 54.38±0.47                  | 54.62±0.82                  | 53.20±3.97                  |
| Yolk weight (g)                | 2.76±0.18                   | 2.71±0.16                   | 2.85±0.19                   | 2.64±0.13                   |
| Yolk percentage (%)            | 33.37±0.35                  | 32.27±0.38                  | 32.74±0.86                  | 33.49±3.36                  |
| Eggshell weight (g)            | 1.07±0.07                   | 1.12±0.06                   | 1.12±0.01                   | 1.07±0.07                   |
| Eggshell percentage (%)        | 12.5±0.93                   | 13.35±0.39                  | 12.64±0.40                  | 13.31±0.78                  |
| Eggshell thickness (mm)        | 0.15±0.02                   | 0.15±0.00                   | 0.15±0.01                   | 0.15±0.01                   |
| Haugh unit                     | 92.72±0.61                  | 92.04±0.61                  | 92.23±0.76                  | 92.01±1.51                  |
| Yolk score                     | 5.93±0.19                   | 6.05±0.23                   | 6.50±0.19                   | 6.33±0.61                   |
| Feed Conversion                | 4.84±0.70b                  | 3.45±0.14a                  | 3.87±0.27a                  | 3.87±0.06a                  |

Different superscript in the same row indicates significantly different (P <0.05). R0: control; R1: diet contained silkworm pupae to substitute 25% of the fish meal; R2: diet contained silkworm pupae to substitute for 50% fish meal, and R3: diet contained silkworm pupae to substitute of 75% fish.

Chicken egg production by the administration of silkworm pupa meal as much as 6% was significantly higher (P<0.01) in comparison with diet without silkworm pupae meal and the egg production with diet silkworm pupae significant difference suggests that the quality of silkworm pupae protein was better than protein concentrate for laying hen [30]. [31] showed that substitution of silkworm pupae meal replace 25-75% of fish meal protein in the diet was not significantly different from controls. Egg production is influenced by a combination of saturated fatty acids and unsaturated fatty acids on diet. According to [32], unsaturated fatty acids such as eicosapentaenoic (EPA) and arachidonic fatty acid (AA) were an important precursor for prostaglandin, prostacyclin, thromboxane, and leukotriene. Prostaglandins such as FSH (follicle-stimulating hormone) and LH (luteinizing hormone) have been implicated in many reproductive functions [33]. Silkworm pupae meal contains linoleic acid 8.57% and linolenic acid 24.4%, with the total unsaturated fatty acids 67.48% [15] and contained polysaccharides (27.9%) [34]. The immunostimulatory effect of silkworm pupae was identified from the polysaccharide contents. High molecular weight polysaccharide can activate the innate immune.

5. **Conclusion**

It was concluded that insects have the potential to be used as a protein source in the poultry and pre-weaning small ruminant rations without any negative effect on the animal.
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References
[1] Makkar, H.P.S.; Tran, G.; Heuze, V.; Ankers, P. 2014. State-of-the-art on the use of insects as animal feed. Anim. Feed Sci. Technol. 2014, 197, 1-33.
[2] Khan, S.; Khan, R. U.; Sultan, A.; Khan, M.; Hayat, S. U.; Shahid, M. S.. 2016. Evaluating the suitability of maggots as a partial substitute of soybean on the productive traits, digestibility indices and organoleptic properties of broiler meat. J. Anim. Physiol. Anim. Nutr. 2016, 100, 649–656.
[3] Van Huis A. 2013. Potential of insects as food and feed in assuring food security. Annu Rev Entomol. 58: 563-583.
[4] Veldkamp T.G.; Van Duinkerken A.; Van Huis A.; Lakemond C.M.M.; Ottevanger E.; Bosch G.; Van Boekel. 2012. Insects as a sustainable feed ingredient in pig and poultry diets—a feasibility study. Wageningen (Netherlands): Wageningen UR Livestock Research.
[5] Sánchez-Muros, M.; Barroso, F.G.; Manzano-Agugliaro, F. 2014. Insect meal as a renewable source of food for animal feeding: A Review. J. Clean Prod. 2014, 65: 16-27
[6] Krook, S.; Harjes, A.G.E.; Roth, I.; Katz, H.; Wurtz S.; Susenbeth, A.; Schulz, C. 2012. When a turbot catches a fly: evaluation of a prepupae meal of Black soldier fly (Hermetia illucens) as fish meal substitute – growth performance and chitin degradation in juvenile turbot (Psetta maxima). Aquaculture. 2012, 364/365:345-352.
[7] Harlystiarini, R.; Mutia, I W. T.; Wibawan, D.; A. Astuti. 2019. In Vitro Antibacterial Activity of Black Soldier Fly (Hermetia illucens) Larva Extracts Against Gram-Negative Bacteria. Buletin Peternakan. 2019, 43, 125-129.
[8] Astuti D.A., R. H. Damanik, A. Anggraeny, Y. D. P. Aidismen. 2018. Utilization of insect as a protein alternative for goat rations. Proceeding of The 4th International Asian-Australasian Dairy Goat Conference. Vietnam 17-19 October 2018.
[9] Jayanegara, A.; Sholikin, M.M.; Sabila, D.A.N.; Suharti, S.; Astuti, D.A., 2017. Lowering chitin content of cricket (Gryllus assimilis) through exoskeleton removal and chemical extraction and its utilization as a ruminant feed (in vitro). Pak J Biol Sci. 2017, 20, 523-529.
[10] Chakravorty, J., Ghosh, S., Jung C. and Meyer-Rochow, V.B., 2014. Nutritional composition of Chondacris rosea and Brachytrupes orientalis: Two common insects used as food by tribes of Arunachal Pradesh, India. J Asia Pac Entomol 17: 407–415.
[11] Wang, D.; Shao, W.Z.; Chuan, X.Z.; Yao, Y.B.; Shi Heng, A.; Ying, N.X. 2005. Evaluation non-nutritional value of field crickets as a poultry feedstuff. Aust. J. Anim. Sci. 2005, 18, 667-670.
[12] Osimani, A., Garofalo, C.; Milanović, V.; Taccari, M.; Cardinali, F.; Aquilanti, L.; Pasquini, M.; Mozzon, M.; Raffaelli, N.; Ruschioni, S.; Riolo, P.; Isidoro N.; Clementi, F. 2017. Insight into the proximate composition and microbial diversity of edible insects marketed in the European Union. European Food Res. Technol. 2017, 243, 1157-1171.
[13] Ghosh, S.; Lee, S.M.; Jung, C.; Meyer-Rochow, V.B. 2017. Nutritional composition of five commercial edible insects in South Korea. J. Asia-Pacific Entomol. 2017, 20, 686-694.
[14] Jozefiak, D.; Jozefiak, A.; Kieronczyk, B.; Rawski, M.; Swiatkiewicz, S.; Długosz, J.; Engberg, R.M. 2016. Insects - a natural nutrient source for poultry - a review. Ann. Anim. Sci. 2016, 16, 297-313.
[15] Pereira, N.R., O. Ferrarese-Filho, and M. Matsushita. 2003. Proximate composition and fatty acid profile of Bombyx mori L.chrysalis toast. J. Food Composition and Analysis 16:451-457
[16] Anggraeni, N., Farajallahb A., Astuti D. A. 2016. Blood Profile of Quails (Coturnix coturnix japonica) Fed Ration Containing Silkworm Pupae (Bombyx mori) Powder Extract. Media Peternakan, April 2016, 39(1):1-8.
[17] Astuti , D A., Anggraenity A., Khotijah, L., Suharti, S. and Jayanegara A. 2019. Performance,
Physiological Status, and Rumen Fermentation Profiles of Pre- and Post-Weaning Goat Kids Fed Cricket Meal as a Protein Source. Tropical Animal Science Journal, August 2019, 42(2):145-151

[18] Ravi C., Jeyashree A., Renuka DK. 2011. Antimicrobial peptides from insects: an overview. Rscrb in Biotech 2(5): 01-07.

[19] Cutrignelli, M.I.; Messina, M.; Tulli, F.; Randazzo, B.; Olivotto, I.; Gasco, L.; Loponte, R.; Bovera, F. 2017. Evaluation of an insect meal of the Black Soldier Fly (Hermetia illucens) as soybean substitute: Intestinal morphometry, enzymatic and microbial activity in laying hens. Res. Vet. Sci. 2017, 117: 209-215.

[20] Mwaniki, Z.; Neijat, M.; Kiarie, E. 2018. Egg production and quality responses of adding up to 7.5% defatted black soldier fly larvae meal in a corn-soybean meal diet fed to Shaver White Leghorns from wk 19 to 27 of age. Poult. Sci. 2018, 97: 2829-2835.

[21] Ruhnke, I.; Normant, C.; Campbell, D.L.M.; Iqbal, Z.; Lee, C.; Hinch, G.N.; Roberts, J. 2018. Impact of on-range choice feeding with black soldier fly larvae (Hermetia illucens) on flock performance, egg quality, and range use of free-range laying hens. Anim. Nutr. 2018, 4, 452-460.

[22] Secci, G.; Bovera, F.; Nizza, S.; Baronti, N.; Gasco, L.; Conte, G.; Serra, A.; Bonelli, A.; Van Huis, A.; Itterbeeck, V. J.; Klunder, H.; Mertens, E.; Halloran, A.; Muir, G.; Veldkamp, T.; van Duinkerken, G.; van Huis, A.; Lakemond, C. M. M.; Ottevanger, E.; Bosch, G.; van Boekel, M. A. J. S. 2012. Insects as a sustainable feed ingredient in pig and poultry diets a feasibility study. Report 638, Wageningen UR Livestock Research, 2012.

[23] Andri Cahya Irawan. 2019. Impact of the feeding with the black soldier fly (Hermetia illucens) on egg physical quality, egg chemical quality and lipid metabolism of laying hens. Proceeding URICSE. Riau University, Riau, Indonesia. September 10, 2019.

[24] Dabbou, S.; Gai, F.; Biasato, I.; Capucchio, M.T.; Biasibetti, E.; Dezzutto, D.; Meneguz, M.; Plachà, I.; Gasco, L.; Schiavone A. Black solidar fly defatted meal as a dietary protein source for broiler chickens: Effects on growth performance, blood traits, gut morphology and histological features. J Anim Sci Biotechnol. 2018, 9: 49.

[25] Schiavone, A.; Dabbou, S.; Marco, M.D.; Cullere, M.; Biasato, I.; Biasibetti, E.; Capucchio, M.T.; Bergagna, S.; Dezzutto, D.; Meneguz, M.; Gai, F.; Zotte, A.D.; Gasco, L. 2018. Black soldier fly larva fat inclusion in finisher broiler chicken diet as an alternative fat source. Animal. 2018. 12:2032-2039.

[26] Boccazzi I.V.; Ottoboni, M.; Martin, E.; Comandatore, F.; Vallone, L.; Spranghers, T.; Eeckhout, M.; Mereghetti, V.; Pinotti, L.; Epis, S. 2017. A survey of the mycobiota associated with larvae of the black soldier fly (Hermetia illucens) reared for feed production. PLoS. 2017. 12 (8): e0182533.

[27] Ibitoye, E.B.; Lokman, I.H.; Hezme, M.N.M.; Goh, Y.M.; Zuki, A.B.Z.; Jimoh, A.A.; Danmaigoro, A.; Nicholas, P. 2018. Gut health and serum growth hormone levels of broiler chickens fed dietary chitin and chitosan from cricket and shrimp. Poult Sci. 2018, 98: 745-752.

[28] Lokman, I.H.; Ibitoye, E.B.; Hezme, M.N.M.; Goh, Y.M.; Zuki, A.B.Z.; Jimoh, A.A. 2019. Effects of chitin and chitosan from cricket and shrimp on growth and carcass performance of broiler chickens. Trop Anim Health Prod. 2019. Doi: 10.1007/s11250-019-01936-9.

[29] Leeson, S and J.D. Summers. 2005. Commercial Poultry Nutrition. Ed: 3rd. England, Nottingham University Press. p.198.205.

[30] Khatun, R., S.A. Azmal, M.S.K. Sarker, M.A. Rashid, M.A. Hussain, and M.Y. Miah. 2005. Effect of silkworm pupae on the growth and egg production performance of Rhode island red (RIR) pure line. J. Poult. Sci. 4(9):718-720.

[31] Mangisah, I., I. Estiningdiati and S. Sumarsih. 2004. Konsumsi pakan dan produksi telur akibat penggantian tepung ikan dengan tepung pupa dalam ransum. J. Indonesian Trop. Anim. Agric 29(1):39-43
[32] Wathes, D.C., D.R.E. Abayasekara and R.J. Aitken. 2007. Polyunsaturated fatty acids in male and female reproduction. Biol. Reprod. 77: 190-201

[33] Abayasekara, D.R.E. and Wathes D.C.. 1999. Effects of altering dietary fatty acid composition on prostaglandin synthesis and fertility. Prostaglandin, Leukotrienes and Essential Fatty Acid. 61(5):275-287

[34] Long, S., F. Ying, H. E. Zhao, M. A. Tao, & Z. Xin. 2007. Studies on Alkaline solution extraction of polysaccharide from silkworm pupa and its immunomodulating activities. Forest Res. 20:782-786.