Black soldier fly larvae (*Hermetia illucens*) meal in low inclusion rates is a suitable protein source for broiler chickens

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**Abstract**

The use of black soldier fly larvae meal (BSFL) as an alternative protein source to soybean meal (SBM) is becoming increasingly important in broiler diet. This study evaluated the effect of partially replacing SBM with defatted-BSFL in the broiler’s diets. A total of 90 one-day-old male chicks (Ross 308) were allocated equally (6 pens/treatment, 5 birds/pen) to one of three treatments: 0, 7.5, and 15% BSFL meal in total diet. Birds were fed in two phases (starter d1-21; finisher d21-35; ad libitum) and raised in standard commercial management conditions. Body weight (BW) and feed intake (FI) were recorded weekly to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed conversion ratio (FCR). There was no difference (P>0.05) in BW, ADG, and ADFI of birds among treatments BSFL0 and BSFL7.5 over the whole trial period (e.g., BW35: 2.80 and 2.81 kg), whereas BSFL15 had lower (P<0.05) BW (e.g., BW35: 2.03 kg; -28%), ADG (-28%) and ADFI (-18.5%) than control. The lowest FCR was observed for BSFL0 during the grower and total trial period (BSFL0 < BSFL7.5 < BSFL15; P<0.05). There was no difference (P>0.05) in AID of CP and ileal histomorphology, but BSFL resulted in higher relative organ weights (P<0.05). In conclusion, SBM can be replaced by 7.5% BSFL, without significant reductions in performance in the diets of broiler chickens. However, a replacement of SBM with 15% of BSFL in the diet negatively affected growth performance compared to the control diet.

**Introduction**

The poultry industry is growing significantly due to an increase in the demand for highly desirable poultry meat, with an ever-growing human population in many parts of the world. This also leads to an increase in demand for protein-rich feedstuffs used in poultry diets. However, there is a growing concern about whether the planet’s limited resources, such as agricultural land and freshwater, can meet the growing food demand (FAO and WHO, 2019). The continued increasing demand for protein requires sustainable poultry production, and research into alternative and sustainable feeds for poultry is progressing. Soybean meal has been traditionally used as the primary protein source in poultry diets, but its price and sustainable supply are in question now. Previous studies have shown that black soldier fly larvae (BSFL) are a suitable protein source for broiler chickens due to their nutritional composition. BSFL meal is rich in crude protein (CP, e.g., 57.3%) and crude fat (CL, e.g., 8.5%) and the amino acid composition is similar to soybean (Makkar et al., 2014). Since the regulation VO (EU) 2021/1372, the processed protein meal of BSFL has been approved for use in pigs and poultry diets.

The presented study evaluated the effects of defatted BSFL meal as a partial substitute for soybean meal (SBM) in the diets of broiler chickens. An animal feeding trial was done to evaluate the effects of BSFL meal on growth performance and feed efficiency, apparent ileal digestibility of crude protein (AID CP), organ weight, and ileal histomorphology of broiler chickens.
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Materials and methods

The feeding trial took place for 35 days on the teaching and demonstration farm of the University of Applied Sciences in Bingen, Germany. A total of 90 one-day-old male broiler chickens (Ross 308) were allocated equally (6 pens/treatment) to one of three treatments: zero, approx. one quarter, and half of SBM replaced by BSFL diets (0%, 7.5%, and 15% in total diet; BSFL0, BSFL7.5, BSFL15). The diets were balanced to be isocaloric and isonitrogenous. Birds were fed diets in two phases (starter d1-21, 5 birds/pen; finisher d21-35, 3 birds/pen; ad libitum) and raised in standard commercial management conditions. Body weight (BW) and feed intake (FI) were recorded weekly to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed conversion ratio (FCR).

For AID CP determination, digesta was collected at the end of the experiment (day 35, postmortem) from the ileum section between Meckel’s diverticulum and approximately 3 cm before the ileo-ceco-colic junction. The proventriculus, gizzard, and liver were collected to determine relative organ weight (ROW) to live body weight at day 35. Tissue samples (approx. 1 cm) of the ileum (2 cm before ileo-ceco-colic junction) were analyzed to determine histomorphologic indices.

Results

The results of the growth performance parameters are shown in Table 1. At the end of the starter period, BSFL7.5 had the highest BW (P>0.05). BSFL15 showed significantly lower BW than BSFL0 and BSFL7.5 (P<0.001). This trend continued until the end of the experiment (day 1-35). Over the whole trial period, birds in BSFL7.5 had the highest ADFI (P<0.05). Birds in BSFL15 had an average 18.5% lower ADFI and were significantly different from BSFL0 and BSFL7.5 (P<0.001). This BW and ADFI performance reflected in FCR as well. During the whole trial period, increasing BSFL content in the diet increased FCR (P<0.05).

Table 1: Growth performance: Black soldier fly larvae (BSFL) meal in broiler diets. 2 phases: starter (day 1-21), finisher (day 21-35); 35 days of trial; weight at day 1, 7, 14, 21, 28, 35.

<table>
<thead>
<tr>
<th>(g/broiler)</th>
<th>BSFL0</th>
<th>BSFL7.5</th>
<th>BSFL15</th>
<th>SEM</th>
<th>p-value1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW (d 1)</td>
<td>52 ±2</td>
<td>52 ±2</td>
<td>52 ±2</td>
<td>0.24</td>
<td>1.000</td>
</tr>
<tr>
<td>BW (d 21)</td>
<td>1093 ±123</td>
<td>1128 ±108</td>
<td>762 ±103</td>
<td>21.14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BW (d 35)</td>
<td>2796 ±207</td>
<td>2812 ±131</td>
<td>2026 ±246</td>
<td>58.72</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ADG (d 1-35)</td>
<td>78 ±4</td>
<td>79 ±4</td>
<td>56 ±7</td>
<td>1.68</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ADFI (d 1-35)</td>
<td>108 ±6</td>
<td>112 ±3</td>
<td>88 ±2</td>
<td>1.23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FCR (d 1-35)</td>
<td>1.35 ±0.02</td>
<td>1.35 ±0.02</td>
<td>1.52 ±0.02</td>
<td>0.01</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

The results of AID CP are shown in Table 2. A numerical but no significant difference (P>0.05) in AID CP was observed. In the starter period, AID CP was lowest in BSFL7.5 (-17.5% vs. BSFL0) and highest in BSFL15 (+9% vs. BSFL0). In the finisher period, the AID CP decreased with increasing content of BSFL meal in diets (BSFL7.5 -11%, BSFL15 -14% vs. BSFL0; P>0.05).

The results of ROW in relation to live BW at day 35 are shown in Table 3. The ROW proventriculus and liver increased with increasing content of BSFL in the diets. The differences were only in BSFL15, ROW liver significantly higher compared with the other treatments (+32.6%, P<0.001). ROW gizzard was lowest in BSFL7.5 and highest in BSFL15, with BSFL0 being in between (BSFL7.5 < BSFL0 < BSFL15; P<0.001).

The results of the histomorphological analysis of the ileal section are shown in Table 4. The BSFL content in diets had a numerical but not significant effect on the histomorphological parameters of broilers.
Villus height (VH) and Crypt depth (CD) were lower in the BSFL supplemented groups (BSFL7.5 and BSFL15), but the VH/CD ratio was the same in BSFL0 and BSFL7.5 ($P>0.05$).

Table 2: Apparent ileal Digestibility (AID): Black soldier fly larvae (BSFL) meal in broiler diets.

<table>
<thead>
<tr>
<th>AID (%)</th>
<th>BSFL0</th>
<th>BSFL7,5</th>
<th>BSFL15</th>
<th>SEM</th>
<th>p-value1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein (d 21)</td>
<td>72.9 ±12.8</td>
<td>60.4 ±9.4</td>
<td>79.5 ±2.5</td>
<td>7.68</td>
<td>0.093</td>
</tr>
<tr>
<td>Crude Protein (d 35)</td>
<td>81.6 ±7.9</td>
<td>72.4 ±8.2</td>
<td>70.3 ±6.1</td>
<td>5.80</td>
<td>0.163</td>
</tr>
</tbody>
</table>

n = 3 (day 21); n = 4 (BSFL0, BSFL7.5, day 35); n = 3 (BSFL15, day 35)


Table 3: Relative organ weight (ROW): Black soldier fly larvae (BSFL) meal in broiler diets.

<table>
<thead>
<tr>
<th>ROW (g/kg BW)</th>
<th>BSFL0</th>
<th>BSFL7,5</th>
<th>BSFL15</th>
<th>SEM</th>
<th>p-value1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proventriculus</td>
<td>2.77 ±0.39</td>
<td>2.84 ±0.78</td>
<td>3.07 ±0.29</td>
<td>0.22</td>
<td>0.352</td>
</tr>
<tr>
<td>Gizzard</td>
<td>11.28 ±2.81</td>
<td>8.82 ±1.98</td>
<td>13.77 ±1.66</td>
<td>0.90</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Liver</td>
<td>22.00 ±1.77</td>
<td>23.93 ±2.71</td>
<td>29.18 ±3.96</td>
<td>1.21</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

n=12/treatment; day 35

Table 4: Ileal histomorphology: Black soldier fly larvae (BSFL) meal in broiler diets.

<table>
<thead>
<tr>
<th>Index</th>
<th>BSFL0</th>
<th>BSFL7,5</th>
<th>BSFL15</th>
<th>SEM</th>
<th>p-value1</th>
</tr>
</thead>
<tbody>
<tr>
<td>VH (μm)</td>
<td>570 ±79</td>
<td>532 ±96</td>
<td>557 ±66</td>
<td>33.10</td>
<td>0.515</td>
</tr>
<tr>
<td>CD (μm)</td>
<td>184 ±32</td>
<td>171 ±21</td>
<td>181 ±27</td>
<td>10.97</td>
<td>0.486</td>
</tr>
<tr>
<td>VH/CD ratio (μm/μm)</td>
<td>3.14 ±0.44</td>
<td>3.14 ±0.62</td>
<td>3.10 ±0.38</td>
<td>0.20</td>
<td>0.976</td>
</tr>
</tbody>
</table>

VH = Villus height, CD = Crypt depth; n=12/treatment; day 35

Discussion

The results of the present study showed similar growth performance and feed efficiency of animals fed with 7.5% BSFL meal compared with the control group. Lower BW, ADG, ADFI, and FCR were observed in BSFL15. Murawska et al. (2021) also observed a negative linear relationship between BW, ADG, ADFI, and FCR in broilers with increasing levels of BSFL. They suggested that the lower performance was mainly due to reduced ADFI, which was probably caused by impaired protein digestion associated with increased dietary chitin content in BSFL. Studies show that chitin has a negative effect on ADFI and CP digestibility (Sánchez-Muros et al., 2014) in broilers. In this study, ADFI increased in BSFL7.5 over the whole trial period, but it was significantly lower in BSFL15 than in BSFL0. AID CP decreased ($P>0.05$) with increasing BSFL content in the diets. The BSFL diets in this study were not analyzed for their chitin content. Therefore, it cannot be conclusively determined if the reduced ADFI and FCR were due to the chitin content in the BSFL meal.

ROW results showed a numerical increase in ROW proventriculus and an increase in ROW liver with increasing BSFL content in diets. According to Zaefarian et al. (2019), lower ADFI, as observed in BSFL15, may lead to higher metabolic activity of the liver and an increase in liver size. No linear trend was observed in the ROW gizzard (BSFL7.5 < BSFL0 < BSFL15; $P<0.05$). Facey et al. (2023) also observed an increase in the ROW of several organs with increasing BSFL content in diets. They suggested that the chitin content in broiler diets with high levels of BSFL meal influenced the increase in gizzard weight. Again, it cannot be confirmed if there was a correlation between organ development and chitin content in this study.

Maintenance of gut health is essential for good feed efficiency, growth performance, and health of monogastric animals (Jha et al., 2019). In this study, the inclusion of BSFL meal in broiler’s diet resulted in a moderate variation in intestinal morphology. Lower VH and CD but unchanged VH/CD ratio were observed in BSFL7.5 compared to BSFL0. In contrast, Dabbou et al. (2018) observed significantly lower VH and higher CD and a lower VH/CD ratio at high levels of BSFL in broiler diets.
Conclusion

The results of this study indicate that BSFL meal may be suitable as an alternative protein source in broiler chicken diets at low levels (7.5% in this case). BSFL meal is rich in essential amino acids and could be a valuable resource in the feed industry for broiler chickens. At 7.5% BSFL meal in the broiler diet, the growth performance showed comparable performance with those in the control group. Moreover, there were no negative effects of BSFL inclusion on organ weight and ileal histomorphology.

The use of 15% BSFL was unfavorable during the whole growing period. Decreased growth performance and feed efficiency compared to the control group and negative effects on organ development were observed in BSFL15 diets-fed birds. Moderate changes in nutrient digestibility and intestinal morphology were observed in BSFL15. Thus, it is probably that the low growth performance of animals fed 15% BSFL meal was due to the low ADFI. Consequently, lower inclusion rates of BSFL might be more appropriate for broiler chickens.

References


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