Egg production of Creole hens fed with live larvae of the Black Soldier Fly (*Hermetia illucens* L.)

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ABSTRACT

Objective: To evaluate the consumption of live larvae of *Hermetia illucens* L. and a complement (corn, wheat bran, vitamins and minerals) in the productive response of Creole hens compared to a diet based on corn, soybean meal, vitamins and minerals.

Methodology: 44 Creole hens were used to evaluate 2 experimental diets: a diet based on corn-soybean and a diet with live larvae and a complement. The larvae used were produced in a rearing chamber with controlled temperature and relative humidity. To evaluate productive behavior, the following variables were measured during eigth weeks: feed intake (g bird^{-1} week^{-1}), egg production (kg bird^{-1} week^{-1}), feed conversion (kg kg^{-1}), laying percentage (%), average egg weight (g), egg mass (g) and mortality. The design was completely randomized, with repeated measurements over time using the MIXED procedure of SAS 9.0. The means were compared with Tukey's test (α=0.05).

Results: Significant differences (P≤0.05) were observed in feed intake and feed conversion, with the remaining means (P>0.05) there were no differences. The average values of each variable were not different (P>0.05).

Limitations of the study: The use of fly larvae implies a previous proximal analysis to know the nutritional contribution, this will depend on the type of substratum that is given to the larvae.

Conclusions: Live larvae of Black Soldier Fly with a supplement based on corn, wheat bran, vitamins and minerals can replace soybean meal in a diet for Creole hens.

Keywords: Soybean meal substitution, live fly larvaes, Creole birds.

INTRODUCTION

Commercial or intensive poultry farming heavily relies on the production of cereals and oilseeds, primarily corn and soybean meal, whose amino acid profile offers a

balance that closely matches the nutritional requirements of poultry. However, Mexico is not self-sufficient in the production of these inputs, and to meet national consumption, $8.18 billion are allocated to the importation of corn and soybean (USDA, 2023). The production of soybean and corn requires large land areas and significant amounts of water, which negatively affects ecosystems by causing deforestation of jungles and forests, changes in land use, and climate alterations. The increase in the demand for poultry products has generated the need to explore alternative sources of energy and protein with high nutritional value, in order to reduce the use of grains and oilseeds in animal feed. In this context, insects such as the larvae of the Black Soldier Fly (*Hermetia illucens* L.) represent a viable alternative to partially meet the nutritional needs of poultry farming. These larvae possess a high fat content (30%) and protein content (40%), which could meet the nutritional requirements of native hens. Additionally, they have a short life cycle, transform organic waste into high-value protein sources, and can feed on various by-products from the agri-food industry (Star *et al.*, 2020). Insect production requires significantly less land and water than grain production (Tahamtani *et al.*, 2021), which can contribute to the sustainable development of national poultry farming. The aim of this research was to evaluate the productive response of native hens fed a conventional diet based on corn and soybean meal, in comparison with an alternative diet based on live Black Soldier Fly larvae supplemented with a feed additive.

MATERIALS AND METHODS

Location

The study was conducted between spring and summer of 2024 at the experimental poultry farm of the Colegio de Postgraduados, Montecillo Campus, Texcoco, State of Mexico, located at coordinates 19° 27' 38" N and 98° 54' 10" W, at an altitude of 2,250 meters above sea level. The climate is temperate sub-humid, with summer rains, an average temperature of 14.6 °C, and an annual accumulated precipitation of 558.5 mm (García, 2004).

Animals and housing

The study was reviewed and approved by the Ethics Committee of the Colegio de Postgraduados (COBIAN/017/23; COLPOS, 2016). A total of 44 native hens (Creole hens) aged 44 weeks were used to evaluate two experimental diets: one diet formulated with corn, soybean meal, vitamins, and minerals (corn-soy diet), and another diet containing live larvae plus a supplement made from corn, wheat bran, vitamins, and minerals (larvae diet). The birds were randomly assigned, with 22 individuals per diet, for a period of eight weeks (each hen was considered an experimental unit). Prior to the trial, the birds underwent a two-week adaptation period to the experimental diets. The hens were housed individually in cages (45 cm × 30 cm × 23 cm) inside a shed with natural light and ventilation, regulated by side curtains. The photoperiod was gradually adjusted to reach 16L:8D. Temperature (20-22 °C) and relative humidity (47.1-64.3%) were recorded daily using a temperature and humidity sensor (Data Logger Humidity/Temperature, Model RHT10).

Black soldier fly larvae production

To establish the Black Soldier Fly population, live larvae were obtained from a supplier in Toluca, State of Mexico. The adult flies produced were exposed to sunlight daily (8-10 hours) to stimulate mating. The cage contained an attractant (moist poultry litter) and wooden boards (15 cm × 5 cm × 2 cm) secured with rubber bands to facilitate oviposition. Eggs were collected and placed in Petri dishes for 3-4 days; upon hatching, the larvae were transferred to plastic trays (33.5 cm × 27 cm × 7.5 cm) with an initial mixture of chicken feed (100 g), wheat bran (50 g), and water (200-400 mL). After five days, the mixture was increased to: chicken feed (300 g), wheat bran (150 g), water (300 mL), and vegetable (tomato, cucumber) and fruit (mango, apple, banana, grape) waste. The larvae were reared in a climate-controlled chamber (28-32 °C) with relative humidity (65-75%). In this study, fifth or sixth instar larvae were used, before the color change, to minimize chitin content (Bejaei & Cheng, 2020).

Diets

The diets were offered as follows: the corn-soy-based diet, with vitamins and minerals, was administered at a rate of 110 g of feed per bird per day; the larvae diet consisted of 72 g of live larvae per bird per day, plus 82 g of a supplement made with corn, wheat bran, vitamins, and minerals, provided *ad libitum* (Table 1).

Chemical analysis of the diets

The corn-soy diet, the larvae as offered, and the supplement were analyzed (AOAC, 2005) in the Animal Nutrition Laboratories of the Universidad Autónoma Chapingo and the Colegio de Postgraduados (Table 2).

Variables

To evaluate productive performance, the following variables were determined: feed intake (g bird^{-1} week^{-1}), egg production (kg bird^{-1} week^{-1}), feed conversion ratio (kg kg^{-1}), laying rate (%), average egg weight (g), egg mass (g) and mortality.

Statistical analysis

Productive variable data were analyzed under a completely randomized design with repeated measures over time, using the MIXED procedure of SAS software version 9.0 (SAS, 2002). Means were compared using Tukey's test (α=0.05).

RESULTS AND DISCUSSION

Productive variables

Significant differences (P≤0.05) were observed only in the variables feed intake and feed conversion ratio; no differences were found in the remaining variables (P>0.05) (Table 3). Birds fed with larvae consumed significantly less feed (80.91, 67.73, 110.3, 81.11, and 99.94 g) (P≤0.05) compared to the corn-soy-based diet during weeks 3, 4, 5, 6, and 8. Additionally, in week 2, the feed conversion ratio was lower (P≤0.05) with the larvae-based diet (0.50 kg of feed per kg of egg). Regarding the average values of each variable, no significant differences were observed (P>0.05).

Table 1. Composition (%) and calculated analysis of the corn-soy diet and the diet with larvae plus supplement, as-fed basis.

Ingredients	Corn-soybean diet	Diet with larvae*
Yellow corn (7.5% CP)	65.08	41.72
Soybean paste (46.5% CP)	23.93	0.00
Wheat bran (15% CP)	0.00	26.49
Fine calcium carbonate	4.39	4.13
Coarse calcium carbonate	4.39	4.13
Dicalcium phosphate (21% Ca/18% P)	1.28	0.53
Common salt	0.35	0.24
Soybean oil	0.23	0.00
*Premix of vitamins and minerals	0.20	0.19
Sodium bicarbonate	0.15	0.00
Live BSF larvae (32.56% DM)	0.00	22.51
Calculated analysis (%)		
ME (kcal/kg)	2650	2650
CP	16.00	16.00
Calcium	3.750	3.750
Total phosphorus	0.611	0.616
Available phosphorus	0.350	0.321
Lysine	0.842	0.723
Methionine	0.255	0.287
Methionine+cystine	0.530	0.504
Tryptophan	0.182	0.218
Threonine	0.608	0.567

*The sum of the composition of live larvae and the supplement is almost similar to that of the control diet. BSF: black soldier fly. DM: dry matter. *Premix of vitamins and minerals, Contribution per kg of feed: vitamin A, 12000 IU; vitamin D_3, 5000 IU; vitamin E, 85 IU; vitamin K_3, 3 mg; vitamin B_1, 3 mg; vitamin B_2, 8 mg; vitamin B_3, 62 mg; vitamin B_6, 4 mg; vitamin B_{12}, 0.017 mg; pantothenic acid, 14.5 mg; folic acid, 1.8 mg; biotin, 0.2 mg; Zn, 100 mg; Mn, 120 mg; I, 1.25 mg; Se, 0.3 mg; Cu, 15 mg; Fe, 80 mg.

Table 2. Nutritional composition determined from corn-soybean diet and diet with larvae plus a supplement, on a dry basis (%).

Variable (%)	Corn-soybean diet	*BSFL	Complement
Dry matter	93.56	32.56	93.58
Moisture	6.44	67.44	6.42
Crude protein	16.73	38.49	9.11
Ether extract	1.56	35.48	2.10
Ash	13.43	4.13	15.53

*BSFL: Black Soldier Fly Larvae. Dry matter and moisture are reported as fed basis. Crude protein, ether extract, and ash are reported as dry basis. Corn-soybean diet: 110 g $bird^{-1}$ day^{-1}, live larvae 72 g $bird^{-1}$ day^{-1} plus a complement 86 g $bird^{-1}$ day^{-1}. Amino acid content of BSFL expressed as percentage of crude protein: lysine, 5.243; methionine, 1.784; threonine, 3.624; tryptophan, 1.538; arginine, 4.725; cystine, 0.897; methionine + cystine, 2.466; isoleucine, 3.805; leucine, 6.986; valine, 5.272; histidine, 2.713; phenylalanine, 3.510; glycine, 5.058; serine, 3.617; proline, 4.928; and alanine, 5.747 (EVONIK Operations GmbH).

Table 3. Productive behavior of Creole hens fed with a corn-soy diet and a diet with live Black Soldier Fly larvae plus a supplement.

Diet	Week								Average
	1	2	3	4	5	6	7	8	
Feed consumption (g bird^{-1} week^{-1})									
Corn-soybean	517.15	507.32	535.25[a]	587.63[a]	626.48[a]	621.44[a]	538.01	511.23[a]	527.62
Larvae	482.13	491.66	454.34[b]	519.90[b]	516.18[b]	540.33[b]	504.97	411.29[b]	518.16
SE	36.24	35.72	33.81	33.93	35.22	35.11	37.09	38.17	17.47
Egg produced (kg)									
Corn-soybean	0.2696	0.2626	0.2250	0.2987	0.2205	0.2270	0.2218	0.2359	0.24
Larvae	0.2650	0.2526	0.1927	0.2175	0.2183	0.2078	0.1781	0.1978	0.22
SE	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.02
Feed conversion (kg kg-1)									
Corn-soybean	2.59	2.46[a]	2.94	2.87	3.32	3.32	3.67	3.36	3.00
Larvae	2.02	1.96[b]	2.78	2.87	3.08	2.98	2.93	3.36	2.89
SE	0.25	0.26	0.26	0.25	0.26	0.25	0.26	0.27	0.20
Posture (%)									
Corn-soybean	62.14	70.05	61.11	69.17	61.34	60.14	59.82	55.70	58.76
Larvae	70.76	69.64	59.27	58.63	59.98	56.39	50.33	50.84	59.78
SE	3.45	3.60	3.55	3.55	3.59	3.54	3.60	3.55	3.71
Average egg weight (g)									
Corn-soybean	53.20	53.37	50.37	52.61	52.47	54.00	54.30	54.49	51.97
Larvae	52.14	46.12	46.40	52.32	52.43	52.91	51.28	53.56	52.00
SE	1.08	1.12	1.12	1.13	1.13	1.12	1.14	1.16	0.94
Egg mass (g)									
Corn-soybean	37.85	37.52	32.15	36.54	31.80	32.42	31.68	30.33	31.00
Larvae	32.96	33.95	27.52	31.08	31.46	29.69	25.44	28.26	31.62
SE	1.86	1.92	1.90	1.90	1.92	1.90	1.92	1.92	2.02

[ab] Means with different superscript letters in each column within each variable indicate significant differences ($P \leq 0.05$). SE: Standard error.

Feed intake, during five of the eight weeks of the study, showed differences in favor of the larvae-based diet; however, the overall average was not significant. The data from this study differ from those reported by Star et al. (2020) in Dekalb White hens aged 67 to 78 weeks, where cumulative feed intake was lower with the diet containing 12 g of larvae and various protein sources (123 g bird^{-1} day^{-1}), compared to the control diet (133 g bird^{-1} day^{-1}) reported by those authors. These results align with those observed in weeks 46, 47, 48, 49, and 51 of age in the present study, with 72 g of live larvae bird^{-1} day^{-1} plus the supplement that did not include soybean meal. Feed conversion ratio in week 2 was higher by 500 g of feed per kg of egg produced for the birds fed the control diet, indicating a better performance of the birds fed the larvae-based diet (2.02 g g^{-1}). Star *et al.* (2020) reported similar values (2.391 g g^{-1}) in Dekalb White hens aged 67 to 78 weeks fed a live larvae diet. However, Bellezza *et al.* (2024) reported a similar feed conversion ratio between a wheat-soybean-sunflower diet (3.30 g g^{-1}) and the live larvae diet (3.40 g g^{-1}) in native hens aged

44 to 52 weeks. These results contradict the findings of this study, in which differences were observed (corn-soy diet: 2.46 g g^{-1}; live larvae diet: 1.96 g g^{-1}) at 45 weeks of age.

A possible explanation for this variability is that the nutritional requirements, in terms of protein and energy, of native hens may be lower than those of commercial layers, as they have not undergone selection for increased egg production. Therefore, egg production can be maintained using Black Soldier Fly larvae as a substitute for conventional ingredients such as soybean meal.

CONCLUSION

Live Black Soldier Fly larvae, supplemented with a mixture of corn, wheat bran, vitamins, and minerals, can replace soybean meal in diets for native laying hens. Further research is recommended, along with the development of a small-scale, low-cost larvae production model that benefits small-scale rural producers.

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