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Immature Development Time of *Hermetia illucens* L. in Different Varieties of Feed

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Abstract

Larvae of *Hermetia illucens* (Diptera: Stratiomyidae) (Black Soldier Fly) are voracious feeders which consume a wide range of organic materials. Thus, they can be used in simple mechanical systems to reduce organic waste and also as a nutritional factor for animal livestock, in the context of recycling the organic matter. In the present study we investigated the effect of two combinations of nutrient substrates on the immature development time of *H. illucens*. Poultry feed and urban bio-waste (catering organic waste) were used as nutritional substrates in two rates, 150 and 250 mg/larva. Results showed that both the food source and the quantity affected the BSF immature development time significantly. In total, significantly shorter immature development was recorded in poultry feed treatment compared with the catering waste. Moreover, immature development time in the 250 mg/larva/day treatment was significantly shorter compared with the 150 mg/larva/day treatment. Results of the present study could be useful and offer optimal solutions for BSF larvae cultivations, especially in large commercial scale units.

Keywords

Black Soldier Fly, Immature Development, Feed, Recycling, Productive Insects

1. Introduction

It is now clear that the human population has been growing at an accelerated rate, estimating for 2050 nine billion people and the need for livestock to grow near 60% - 70% [1]. In addition, the livestock sector accounts for about 14.5% of all anthropogenic GHG emissions of 7.1 gigatons, equivalent to CO_2 per year [2], which combined with high food consumption, produces huge amounts of or-

ganic or non-organic waste [3].

New strategies for food production have emerged, such as reducing meat consumption, increasing the efficiency of the food chain from "field to fork", or changing diets towards victuals requiring less land. Developing insect breeding methods for feed and food is considered a sustainable strategy that can potentially contribute to global food safety. Rearing of the Black Soldier Fly (BSF) (*Hermetia illucens* L.) could suggest an innovating implementation of these strategies. The BSF is a non-pest fly (Diptera) of the Stratiomyidae family, which originates from the southern USA and it has spread throughout the tropics and subtropics. The adult fly is black, wasp-like and 15 - 20 mm long [4]. The adult females mate two days after emerging and oviposit into dry cracks and crevices adjacent to a food source [5]. Larvae have hemi-developed cephalic capsule (hemicephalous) with compound eyes, well-developed labrum, mandibular-maxillary complex, which move rapidly on the vertical axis, as is customary in most Brachycera. Their mandibular system is ideal for rapid degradation of organic materials under rotting (wastes) and classifies this species in scavengers [6] [7]. The insect has 6 larval instars [8].

Each larva can consume 25 - 500 mg of fresh mass per day, on a wide range of decaying organic materials, such as rotting fruits and vegetables, coffee bean pulp, fish offal and, particularly, animal manure and human excreta [4] [9]. As black soldier adults do not eat, they need to accumulate a large fat body in their larval stage to maintain adult survival [10]. Therefore, it is important to store large amounts of fat in the larval stage.

Not all the organic materials are suitable for larval nutrition. Newby [11] reports that while larvae consume all kinds of vegetables (raw and processed), they have limited ability to transform animal products (meat and fat) even when they are reflected in less than 10% of the available food in the laboratory. Nguyen *et al.* [12] studied the development of larvae in 6 different food sources. Growing in animal manure the larvae were of the smallest size and mass and the growth time lasted longer. On the other hand, kitchen wastes yielded longer and the heavier larvae with the highest average reduction of materials, whilst hose that were fed to fish offal and liver had almost 100% mortality. As far as plant material is concerned, it is a natural source of food for BSF, but not all of them are ideal, with grass plants being the main examples, where larvae are incapable of breaking down lignin [13]. Diener *et al.* [14] found that the daily dose of food given to the larvae was a major contributor to the efficiency of consumption, and concluded that an ideal diet is 100 mg/larva/day.

The scope of the present study was to investigate the effect of the food source and the food quantity on the immature development time of the BSF, as well as their interaction, if any.

2. Materials and Methods

2.1. Parent Colony

The study was conducted in the Laboratory of Agricultural Zoology and Ento-

mology of the Agricultural University of Athens. Larvae of the parent colony were kept in metal box, in order to be protected from enemies (birds, mice, insects), in room conditions (T = 25˚C ± 5˚C, RH = 60% ± 5%). The box contained a ramp to facilitate pre-pupae harvesting, when it moves to leave the habitat. The feeding substrate of 1st - 3rd instar larvae consisted of 70% hen feed and 30% wheat bran, whilst for larvae 3rd - 5th instar consisted of 25% hen feed, 25% wheat bran and 50% organic catering waste (pasta, vegetables, meat). The feeding substrate was frequently stirred to avoid anaerobic conditions. The pre-pupae were collected and placed in containers with paper sheets in order to dry. The pupae and the adults were bred in mesh cages (BioQuip Products Inc.) in a growth chamber (T = 27˚C ± 2˚C, RH = 65% ± 5%).

2.2. Experimental Design

The source and the quantity of food were tested to determine the effect on the immature development duration of the BSF. Newly emerged 1st instar larvae from the aforementioned colony were reared in two different food sources (substrates), poultry feed (synthetic complete nourishment laying chicks), which served as control, and organic catering waste (pasta, vegetables, meat), and on two different daily diets of 150 mg/larva/day and 250 mg/larva/day. Ten newly hatched larvae were put in 40 ml small glass containers. A hole was created in the lid of each container, which was sealed with fine muslin for better ventilation. In each container, 1.5 g or 2.5 g of food was added, in order to achieve the specific diets of 150 and 250 mg/larva, respectively. For each of the four treatment combinations, 5 replicates were used. Every 24 h, the larvae were removed from the containers with a soft entomological tweezer and checked for ecdysis. Then, they were placed in the same container after renewal of the substrate.

2.3. Statistical Analysis

The immature development time was compared in two different food sources and two different quantities with a 2-way ANOVA, using the food type and the food quantity as factors. Data were log-transformed prior to the analysis. If any difference existed, the means were compared using the Student's *t*-test. All the statistical analyses were performed using JMP 13 [15].

3. Results

Both the food source and the quantity affected the BSF immature development time significantly ($t_{food\ source} = 2.44$, $P_{food\ source} = 0.0268$, $t_{food\ quantity} = 4.05$, $P_{food\ quantity} = 0.0009$). Their interaction was not significant ($F = 1.83$, $P = 0.0867$). In total, significantly shorter immature development was recorded in poultry feed treatment (26.5 ± 0.86 days) compared with the catering waste (28.2 ± 0.53 days) (**Figure 1**). Moreover, immature development time in the 250 mg/larva/day treatment was significantly shorter (25.9 ± 0.71 days) compared with the 150 mg/larva/day treatment (28.8 ± 0.47 days) (**Figure 2**).

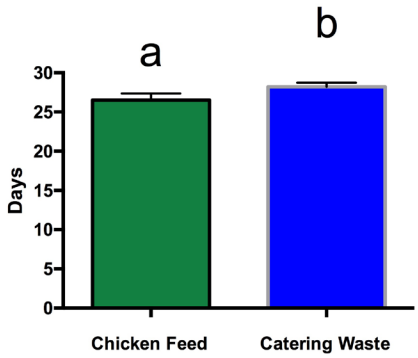

Figure 1. Immature development time (mean ± s.e.) of Black Soldier Fly, *Hermetia illucens* L., when reared in different food sources. (Columns without common letters have significant difference, $P < 0.05$).

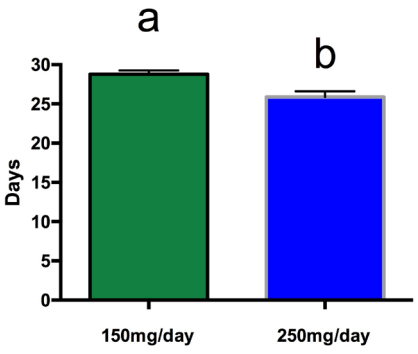

Figure 2. Immature development time (mean ± s.e.) of Black Soldier Fly, *Hermetia illucens* L., when reared in different food quantities. (Columns without common letters have significant difference, $P < 0.05$).

4. Discussion

In this study, we examined two types of food: 1) poultry feed and 2) catering waste, regarding their potential effect on the immature development of the Black Soldier Fly. Results showed that larvae feed in catering waste need longer time to reach the pupal stage, regardless of the amount of food. Our results agree with similar studies. Gobby *et al.* [16] found longer development time for the larval stage, when they reared in meat meal, compared with hen feed. On the contrary, Nguyen *et al.* [12] found that the larvae reared in kitchen waste, which had the second highest fat content after fish-feed, and developed just as fast as poultry feed. This difference may be due to the different nutritional value of the wastes. Concerning the different quantities, we observed shorter development time for the larvae fed on 250 mg/larva/day, regardless of the food source. Our results agree with Diener *et al.* [14], who revealed that the larvae fed on 200 mg/larva/day of poultry feed (wet weight, 60% moisture) required less time to reach the pre-pupal stage than those fed on 100 mg/larva/day.

As the Black Soldier Fly is not required to be fed during the adult stage, they need to accumulate large quantities of nutrients and fat in the larval stage, in order to maintain adult survival and fecundity [10]. Consequently, it is reasonable to conclude that it takes longer for the larvae to acquire the threshold body fat,

in order to gain the critical weight (defined as the minimal weight which is required) for a normal metamorphosis and pupation. Furthermore, it takes longer to complete their development if they only have as resources substrates low in fat [12] [14]. In conclusion, the quantity and the quality of the food are of high importance for the development time of the larvae. Results of the present study could be useful and offer optimal solutions for BSF larvae cultivations, especially in large commercial scale units.

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