



Original Article

Laboratory assessment of the consumption rate of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on a mung bean (*Vigna radiata*)-based artificial diet

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ARTICLE INFORMATION



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ABSTRACT

Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) is an invasive pest in Indonesia. Therefore, limited insect stock is a limiting factor for researchers. The aim of this research rearing insects with mung bean-based as a protein source to modify the composition of the artificial diet. The parameters observed in this research were larva period, larval survival rate, pupal size, sex ratio, pupal-stage longevity, pupal survival rate, fecundity, and nutritional index. The results showed that an artificial diet with mung bean had a significant effect on sex ratio, pupal survival rate, efficiency of conversion of ingestion (ECI) food, efficiency of conversion digested (ECD) food, approximate digestibility (AD) 96,54% 4th instar; 95,45% 5th instar: 88,35% 6th instar, fecundity 307,14 eggs/female, pupal period and significant effect on larval period though instars are longer. Artificial diet-based mung bean had high potential for use in *S. frugiperda* rearing.

Keywords: Approximate digestibility; Efficiency of conversion of digested food; Metabolic cost; Relative consumption rate; Relative growth rate

1. Introduction

Corn is one of the most widely cultivated commodities in the world. In Indonesia, this crop is the second largest foreign exchange contributor after rice in the food sub-sector (Kementerian Perdagangan RI, 2018). In 2019, Indonesia faced a serious problem with the presence of an invasive pest, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), which damaged corn crops and caused losses amounting to 120 billion Rupiah in the following year (Agriesta, 2020).

S. frugiperda classified as a new pest in Indonesia, urges researchers to have a large stock of insects to study and control this pest. Therefore, with the availability of artificial diet to multiply the insects, researchers can have a large, sterile, and economical supply of insects (Susrama, 2017).

Mung bean (*Vigna radiata*) was selected as the primary ingredient for diet due to their high protein content, which is 24 g/100 g of dry beans. Essentially, insects use protein for molting, ovary maturation, and tissue formation (Susrama, 2017; Wang et al., 2021). In addition, mung beans are widely cultivated, so there is no limitation in the span of raw materials.

Based on the above description, it is important to conduct research on artificial diet mung bean-based for the rearing of *S. frugiperda* in the laboratory.

2. Materials and Methods

2.1. Research Site

The study was conducted in the Plant Pest Laboratory, Department of Plant Pest and Disease, Faculty of Agriculture, Hasanuddin University.

2.2. Artificial Diet Preparation

The mung bean-based diet modified Pinto et al. (2019) by substituting protein from the common bean (*Phaseolus vulgaris*) with mung bean flour (24 g/100 g dry). The artificial diet was prepared through a series of standardized steps (Figure 1). Initially, the dry ingredients were placed into a clean and dry container. Separately, dried yeast was dissolved in warm water, and the resulting solution was subsequently added to the dry ingredients. The mixture was stirred until a homogeneous dough was obtained. An agar solution was then prepared by combining agar with distilled water in an Erlenmeyer flask and heating the mixture in a water bath (double boiler) until complete

dissolution was achieved. The hot agar solution was incorporated into the dough mixture and stirred until fully integrated. Thereafter, a 3% hydrochloric acid (HCl) solution was introduced into the mixture, which was further stirred to ensure homogeneity. The final mixture was left undisturbed for a specific period to allow solidification. Once solidified, the artificial feed was considered ready for use as an alternative nutrient source.

2.3. Data Analysis

Observed data included survival rate, stage longevity, sex ratio, fecundity, pupal stage characteristics, and nutritional indices. Nutritional indices were calculated using [Waldbauer \(1968\)](#) formulas. The indices of food consumption and use were determined using the following equations:

$$\text{Relative consumption rate (RCR) (g/g/day)} = \frac{I}{B \times T} \quad (1)$$

$$\text{Relative growth rate (RGR) (g/g/day)} = \frac{B}{B \times T} \quad (2)$$

$$\text{Relative metabolic rate (RMR) (g/g/day)} = \frac{M}{B \times T} \quad (3)$$

$$\text{Approximate digestibility (AD) (\%)} = \frac{I - F}{I} \times 100\% \quad (4)$$

$$\text{Efficiency of conversion of ingestion (ECI) food (\%)} = \frac{B}{I} \times 100\% \quad (5)$$

$$\text{Efficiency of conversion of digested (ECD) food (\%)} = \frac{B}{I - F} \times 100\% \quad (6)$$

$$\text{Metabolic cost (CM) (\%)} = 100 - \text{ECD} \quad (7)$$

Where as,

- T : duration of feeding period (days);
- Af : weight of food supplied to the insect (g);
- Ar : weight of leftover food (g) after T;
- F : weight of excretory produced (g) during T;
- B : (I - F) - M: weight gain by larvae (g) during T;
- B⁻ : mean weight of larvae (g) during T;
- I : weight of food consumed (g) during T;
- I - F : food assimilated (g) during T; and
- M : (I - F) - B: food metabolized during T (g).

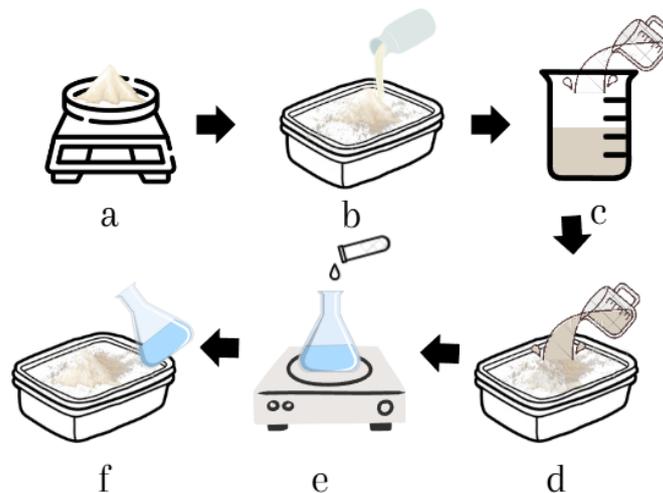


Figure 1. Illustration the preparation of mung bean-based artificial diet, (a) dry ingredients were placed into clean and dry containers, (b) dried yeast was dissolved in warm water, (c) agar was mixed and distilled water, (d) the agar solution was poured into the dough mixture, (e) the mixture was stirred after the addition of 3% hydrochloric acid solution, (f) the mixture was allowed to solidify.

3. Results

3.1. Biological Features

The effect of artificial diets based on mung bean on the development of *S. frugiperda* showed that the insect's biological characteristics were influenced by the type of diet consumed, particularly during the larval stage ([Table 1](#)).

These findings underscore the substantial impact of dietary composition on key developmental parameters of *S. frugiperda*, emphasizing the artificial diet's adequacy in supporting both larval and pupal development. The high

pupal survival rate further indicates efficient nutrient assimilation during earlier developmental stages.

The reproductive capacity of *S. frugiperda* reared on the mung bean-based artificial diet revealed considerable fecundity. On average, females produced 307.14 eggs or 10.97 eggs per female.

3.2. Nutritional Indices

Nutritional indices serve as critical metrics to evaluate the physiological responses of insects to dietary regimes, offering insights into their growth efficiency, digestion, and nutrient assimilation. [Table 2](#) presents the calculated

indices for larvae at the 4th, 5th, and 6th instars. The relative consumption rate (RCR) increased progressively across instars, recorded at 12.69, 40.73, and 77.24, respectively. A similar trend was observed in the relative growth rate (RGR), with values of 1.24, 7.34, and 28.39. The efficiency

of conversion of ingested food (ECI) improved markedly from 9.79% at the 4th instar to 36.75% at the 6th instar, while the efficiency of conversion of digested food (ECD) exhibited a comparable pattern, rising from 10.14% to 41.59%.

Table 1. Biological characteristic of the larval and pupal stages of *Spodoptera frugiperda*

Characteristics	Mung bean	Common bean in artificial diet *	Baby corn**	Soybean***
Larval period (days)	33.50	15.60	19.90	32.95
Larva survival rate (%)	64.00	92.00	89.91	60.00
Pupal length (mm)	15.62	-	16.00	14.79
Pupal period (days)	11.53	11.60	10.00	12.70
Pupa survival rate (%)	98.00	73.40	63.21	96.00
Sex ratio (%)	80.00	56.00	68.00	70.00
Fecundity (eggs/female)	307.14 (n=28)	1850.00 (n=10)	133.25 (n=1)	409.57 (n=23)

*Pinto et al. (2019)

**Nurfauziah (2020)

***Thamrin et al. (2022)

Table 2. Nutritional indices in 4th–6th instar of *Spodoptera frugiperda*

Indices	Mung Bean			Common bean in artificial diet *
	4 th instar	5 th instar	6 th instar	4 th instar
Relative consumption rate (RCR) (g/g/day)	0.17	0.55	1.04	2.30
Relative growth rate (RGR) (g/g/day)	0.02	0.10	0.38	0.67
Approximate digestibility (AD) (%)	96.54	94.50	88.35	57.30
Efficiency of conversion of ingested food (ECI) (%)	9.97	18.03	36.75	30.80
Efficiency of conversion of digested food (ECD) (%)	10.14	19.08	36.75	55.30
Metabolic cost (MC) (%)	89.86	80.92	54.81	44.70

*Pinto et al. (2019)

4. Discussion

The disruption of the nervous system causes insects to not produce ecdysone hormones maximally instead, the insects produce a lot of juvenile hormones, leading to an increased mortality rate (Cholifah et al., 2012). This explains that protein is not the only key in the molting process, but the balance of phytochemicals and nutrients in the diet is also important to consider. This also occurs in artificial diet soybean-based with the same protein content as conducted by Thamrin et al. (2022).

A sex ratio of 80% indicates that the percentage of female insects is higher than that of males, which shows a high potential for egg (fecundity) that reflects the population status in an area (Hidayat et al., 2018). If the availability of, then most of the insect's gender will develop into males. Furthermore, the duration of female in the larval period was longer, which is associated with morphism and allometric growth (Söber et al., 2019; Teder, 2014). This could also be a reason why the larval duration was long.

The characteristics of the pupal phase in the mung bean diet was not much different from the other diets. Even in this diet the pupa survival rate is the highest at 98%. This phase illustrates the ability of insects to successfully meet nutritional needs and continue the stages of metamorphosis (Ramadhan & Nurhidayah, 2022). In line with that, the provision of high protein can affect the mass and weight of *S. frugiperda* pupae (Ajmal et al., 2024).

Artificial diet made from mung beans was able to make the insects survive and complete the perfect metamorphosis process. This indicates that the nutrients in the diet are able to meet the needs of insects. One of them is the 10 essential amino acids that diet must have, namely threonine, methionine, phenylalanine, histidine, lysine, valine, isoleucine, leucine, tryptophan, and arginine (Ramos et al., 2014). Furthermore, these amino acids are already possessed by mung beans is 52,161 mg/100 g protein (Polyiam & Thukhammee, 2024; Yi-Shen et al., 2018).

The dieting indices calculation revealed that the approximate digestibility, consumption and growth rates, energy used for metabolism, and efficiency of conversion of

ingested and digested food into the biomass of a larva. The calculation of the nutritional index was referred to [Waldbauer \(1968\)](#) gravimetric method.

The RGR and RCR values are directly proportional to each instar. However, the grade of RGR is still lower compared to RCR, as is ECD. The mention explains that only a portion can be metabolized by the insects. RGR is associated with the bioavailability of food, nutrients, minerals, and allelochemicals that affect growth and development ([Ajmal et al., 2024](#)). Similar to [Waldbauer \(1968\)](#) the decrease in RGR in the treatment with *Calophyllum soulattri* diet, driven by low ECD and not RGR, indicates the presence of toxic compounds in the larvae's body after the diet is digested.

The low ECI and ECD values indicate that only a portion of the diets can be assimilated by the insects. It is evident from the metabolic cost value that larvae use excess energy to maintain physiological balance through detoxification, as evidenced by the amount of feces produced ([Lucchese-Cheung et al., 2021](#)).

The high approximate digestibility (AD) of the mung bean-based diets at each instar indicates that insects require nutrient intake for growth and development. However, the low ECD value of the 4th instar insects on the mung bean-based diets, when compared to [Pinto et al. \(2019\)](#), is relatively low. This explains that the insects are attempting to detoxify by maximizing their fecal output ([Gajger & Dar, 2021](#); [Slansky & Scriber, 1985](#)).

The fecundity of *S. frugiperda* is one of the indicators of the success of artificial diet. The fecundity of *S. frugiperda* fed with the artificial diet could be seen in Table 1. The fecundity of eggs produced by *S. frugiperda* insects on a mung bean-based artificial diet was 307.14 eggs/28 female insects, which is still higher compared to the use of baby corn by [Nurfauziah \(2020\)](#). However, when compared to common beans in an artificial diet and an artificial diet soybeans-based, the use of this diet is considered contrasting. This may be due to the nutritional imbalance in the diet when consumed during the larval phase, resulting in a decreased ability of the insects to lay eggs. A similar occurrence was noted by [Abdullah et al. \(2000\)](#) where the eggs produced by *S. exigua* fed with mung bean artificial diets also experienced a decrease in the number of ovarian eggs in the dissected insects.

Vitamins are necessary raw materials in diet production for growth and reproduction, with the addition of ascorbic acid according to [Pinto et al. \(2019\)](#). However, [Pinto et al. \(2019\)](#) added several types of additional vitamins in the diets, including niacin-amide, calcium potentiator, riboflavin, folic acid, biotin, and vitamin B12, while the mung bean-based diet only relies on the naturally available compounds in the diet's primary ingredients. Therefore, mung bean-based diets, only depend on the naturally available compounds in the diet's primary ingredients. Thus, the addition of inorganic compounds is why the fecundity and resilience of insects are lower in the mung bean-based diets compared too.

5. Conclusion

Mung bean-based artificial diet can be an alternative in the rearing of *S. frugiperda*. The inclusion of artificial diet recipient increased real sex ratio, survival rate of pupae, and

fecundity. Likewise, the high nutritional index value of approximate digestibility.

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