

Palmistichus elaeisis (Hymenoptera: Eulophidae) rearing in *Tenebrio molitor* (Coleoptera: Tenebrionidae) submitted to different diets*

Palmistichus elaeisis (Hymenoptera: Eulophidae) criado em *Tenebrio molitor* (Coleoptera: Tenebrionidae) submetido a diferentes dietas


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ABSTRACT: The ecological, physiological and behavioral processes of insects are linked to their nutrition. The diet of host insects can modify the development of natural enemies and affect their reproductive performance. The objective of this work was to evaluate the development and reproduction of *Palmistichus elaeisis* Delvare & LaSalle, 1993 (Hymenoptera: Eulophidae) parasitizing pupae of *Tenebrio molitor* Linnaeus, 1785 (Coleoptera: Tenebrionidae) rearing in different diets. Pupae of *T. molitor* generated in six different diets (wheat bran, cornmeal, pelleted feed for rabbits, and bran, pelleted or crushed feed for laying hens) were individually placed in plastic pots and exposed to parasitism by six females of *P. elaeisis* during 72 h. The biological variables of *P. elaeisis* were observed and bromatological analyses were performed with pupae of *T. molitor* and the diets used. The percentage of parasitism and emergency was 100% in all treatments. There was no difference in the life cycle, the offspring number and longevity of the parasitoid. Pupae of *T. molitor* obtained from larvae fed with cornmeal were smaller and generated *P. elaeisis* offspring with low sex ratio and shorter length of the tibia. The *T. molitor* diet based on cornmeal was not suitable for the reproduction of *P. elaeisis* in the laboratory.

KEYWORDS: alternative host; biological control; parasitism.

RESUMO: Parte dos processos ecológicos, fisiológicos e comportamentais dos insetos está ligada à sua nutrição. O tipo de dieta pode influenciar o desenvolvimento do inimigo natural e afetar seu desempenho reprodutivo. Objetivou-se neste trabalho avaliar o desenvolvimento e reprodução de *Palmistichus elaeisis* Delvare & LaSalle, 1993 (Hymenoptera: Eulophidae) parasitando pupas de *Tenebrio molitor* Linnaeus, 1785 (Coleoptera: Tenebrionidae) criadas em diferentes dietas. Pupas de *T. molitor* geradas em seis diferentes dietas (farelo de trigo, fubá de milho, ração peletizada para coelhos, ração para aves poedeiras: farelada, peletizada e triturada) foram individualizadas em potes plásticos e expostas ao parasitismo por seis fêmeas de *P. elaeisis* durante 72 h. Foram observadas as variáveis biológicas de *P. elaeisis* e realizadas análises bromatológicas com pupas de *T. molitor* e as dietas utilizadas. A porcentagem de parasitismo e emergência de *P. elaeisis* foi de 100% em todos os tratamentos. Não houve diferença no ciclo de vida, número da prole e longevidade do parasitoide. Pupas de *T. molitor* formadas com fubá de milho foram menores e geraram prole de *P. elaeisis* com menor razão sexual e menor comprimento da tibia. A dieta para *T. molitor* à base de fubá de milho não foi adequada para a reprodução de *P. elaeisis* em laboratório.

PALAVRAS-CHAVE: hospedeiro alternativo; controle biológico; parasitismo.

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INTRODUCTION

Parasitoids can control populations of insect pests and stand out as one of the main groups of natural enemies. Several species of parasitoids are efficient and have been studied to be used in applied biological control programs (CRUZ et al., 2017; MARTINS et al., 2019).

Palmistichus elaeisis Delvare & LaSalle, 1993 (Hymenoptera: Eulophidae) is a promising natural enemy, parasitizing pupae of several defoliating caterpillars. It is a species of gregarious and generalist endoparasitoid with an important role in insect control in the forest sector (PEREIRA et al., 2008; 2010; CAMILO et al., 2016).

Palmistichus elaeisis can parasitize pupae from several alternative hosts (BITTENCOURT; BERTI FILHO, 1999; 2004; PEREIRA et al., 2009; ZANUNCIO et al., 2008; 2015; RODRÍGUEZ-DIMATÉ et al., 2016; MARTINS et al., 2019). The development of research to maximize its production in the laboratory and allow the development of applied biological control programs is important, but it is necessary to establish low-cost and easy-to-maintain methods that provide adequate nutrition to this species (PEREIRA et al., 2010).

Part of the ecological, physiological, and behavioral processes of insects is linked to their nutrition (VIEIRA et al., 2018). The diet of host insects can modify the development of natural enemies and affect their reproductive performance (LEMOS et al., 2003). Nutritional aspects can be qualitative and quantitative, when it comes to the nutrients that organisms need or when considering the proportion of food eaten, digested, and assimilated (PARRA, 2009).

Size, age, nutritional quality, mechanical resistance and immunological response to natural enemies' aspects must be considered when selecting the alternative host (BRODEUR; BOIVIN, 2004; MARTINS et al., 2019).

Tenebrio molitor Linnaeus, 1785 (Coleoptera: Tenebrionidae) infests stored grains, especially flours. Its immature stages provide a practical, economical and nutritious way to feed various species in rearings, such as fish, reptiles, birds and small mammals (MYERS et al., 1999). Also, their larvae and pupae are commonly used in the laboratory as alternative prey/hosts for rearing natural enemies (OTUKA et al., 2006), including *P. elaeisis* (ZANUNCIO et al., 2008). The host *T. molitor* can be easily multiplied on a large scale and at low cost (OTUKA et al., 2006; PEREIRA et al., 2009).

The diet offered to *T. molitor* can influence its development (MORALES-RAMOS et al., 2011) and, possibly, the performance of parasitoids that develop in this species. The wheat bran-based diet is the most widely used for rearing *T. molitor*, but some bird breeders have used alternative diets, such as poultry feed (MENEZES et al., 2014).

The objective of this work was to evaluate the development and reproduction of *P. elaeisis* in pupae of *T. molitor* rearing in different diets.

MATERIAL AND METHODS

The study has been conducted in the Biological Control Laboratory (Laboratório de Controle Biológico, LCB) of the Universidade Federal dos Vales do Jequitinhonha e Mucuri, in Diamantina, Minas Gerais, Brazil, in an air-conditioned room, with temperature ranging between 24 and 26 °C, a relative humidity of 60 and 80% and photoperiod of 12 h. The parasitoid *P. elaeisis* was obtained from the rearing of LCB, where it was kept in 500 mL plastic pots with newly formed *T. molitor* pupae as an alternative host and honey droplets for adult feeding.

Tenebrio molitor eggs were transferred to six plastic trays (42 × 26 × 7 cm) containing different diets, constituting the following treatments: T1: wheat bran, T2: cornmeal, T3 pelleted feed for rabbits; and T4: bran, T5: pelleted or T6: crushed feed for laying hens. A slice of sugarcane stalk was added to the trays (*Saccharum* spp. L.), changed weekly to provide moisture to the larvae.

The experimental design was completely randomized, with six treatments and ten replicates. Each replicate consisted of a pupa of *T. molitor* from different diets. These pupae were individualized in 250 ml plastic pots and exposed to parasitism for 72 h by six females of *P. elaeisis*, without previous experience of oviposition and fed with a drop of honey. Percentages of parasitism and emergence, number of emerged individuals, life cycle and sex ratio were observed. The sex ratio was calculated using the formula: $SR = (n^{\circ}\text{♀}/n^{\circ}\text{♂} + n^{\circ}\text{♀})$.

A couple from each replicate was used, placed in a 14 × 2.2 cm test tube, capped with a cotton ball, and fed with a drop of honey to assess longevity. After death, individuals were submitted to the analysis of morphometric variables. The size of the head capsule was measured at the median height of the eyes. The body size was measured from the midline of the insect's back, from the head to the abdominal end. Additionally, the length of the posterior tibia was obtained. A camera Optika OPTIKAM B5 attached to a stereoscope microscope with the software Optika Vision Lite 2.1 was used for these measurements.

Bromatological analyzes were carried out on the pupae of *T. molitor* from the different treatments, as well as on the diets used to feed the larvae. The moisture content was determined by the kiln drying method in air circulation (AOAC, 1997). The protein value was calculated from the total nitrogen content (JONES, 1941). Total lipids were determined by the Soxhlet extraction method, the fiber content by the enzymatic-gravimetric method, and the ash content by muffle incineration (AOAC, 1997). The carbohydrate content was calculated by the difference between 100 and the sum of the percentages of water, protein, total lipids, fiber and ash.

The data were subjected to the homoscedasticity and normality tests of the residues. If these assumptions were not met, data were transformed according to the distribution trend.

Longevity data underwent logarithmic transformation (Log x) and data referring to the morphology of the male body by $1/\sqrt{(x)}$. Analysis of Variance (ANOVA) was performed and in the case of normality, the means were compared by the Tukey's test ($p \leq 0.05$). When the data were transformed and still did not meet the assumptions, the Kruskal-Wallis test ($p \leq 0.05$) was used. In this case, comparisons were made between treatments, one-tailed and two-tailed. All tests were conducted with the R software, 0.99.903 version, package ExpDes.pt and Pgrimess (R CORE TEAM, 2016).

RESULTS AND DISCUSSION

The pupae biomass of the alternative host *T. molitor*, from the cornmeal-based diet, differed from the other treatments ($p < 0.01$; $F = 6.348$; $df = 5$) with the average of 89.31 ± 2.41 mg (Table 1). Once parasitized, the host becomes the only source of food and shelter for the endoparasitoid, and its size can influence the development, as well as the progeny of the natural enemy (VINSON; BARBOSA, 1987). In general, larger hosts contain more resources and can be considered to be of superior quality, as they can

Table 1. Body biomass of *T. molitor* pupae formed by different diets.

Treatments	Body biomass
Wheat bran	$110.92 \pm 4.99a$
Cornmeal	$89.31 \pm 2.41b$
Pelleted feed for rabbits	$114.59 \pm 5.24a$
Bran feed for laying hens	$118.40 \pm 3.47a$
Pelleted feed for laying hens	$112.62 \pm 6.96a$
Crushed feed for laying hens	$126.75 \pm 4.22a$

* The means followed by the same letter in the column do not differ from each other by the Tukey's test ($p < 0.05$).

influence survival and size in the adult stage of the parasitoid (WANG et al., 2014).

Chemical composition information of diets provided to insects is indispensable for studies of nutrition. It is important to know the essential components to choose a diet. Although carbohydrates, proteins and fats are nonessential, the insect must ingest at least one of these compounds, for energy production and use in metabolic processes (BECK; REESE, 1976).

The diet used for *T. molitor* based on cornmeal has a lower protein content ($p < 0.01$; $F = 24.766$; $df = 5$) ($6.77 \pm 0.47\%$) and lipids ($p < 0.01$; $F = 5.2782$; $df = 5$) ($13.63 \pm 0.67\%$) and higher carbohydrate content ($p < 0.01$; $F = 28.507$; $df = 5$) ($59.21 \pm 0.82\%$) compared to other diets (Table 2).

The nutrient content in the *T. molitor* diets, such as casein, glucose, cholesterol, yeast, carbohydrates and proteins, is important for the insect's development (URREJOLA et al., 2011). The lack of one or more of these nutrients can limit the growth and reproductive capacity of insects (BECK; REESE, 1976). The lower amount of protein present in cornmeal could have generated pupae with less biomass. However, even though carbohydrates are involved in energy-producing reaction cycles and are found in greater quantities in cornmeal, once it has not been assimilated (measured by the conversion efficiency of the ingested and digested food), it may not be nutritionally acceptable for the insect (LIPKE; FRAENKEL, 1956).

The nutritional analysis of *T. molitor* pupae showed no differences in moisture and carbohydrate levels (Table 3). Pupae formed with pelleted feed for laying hens showed a higher amount of fiber ($p = 0.011$; $F = 4.99627$; $df = 5$) ($8.10 \pm 0.15\%$), and those formed by pelleted feed for rabbits had a lower protein content ($p < 0.01$; $F = 6.007$; $df = 5$) ($15.07 \pm 0.58\%$) and greater amount of lipids ($p = 0.020$; $F = 4.1393$; $df = 5$) ($11.83 \pm 0.57\%$). The amount of energy supplied by *T. molitor* pupae varied from 149.47 ± 5.34 to $184.78 \pm 8.77\%$ ($p = 0.017$; $F = 4.3792$; $df = 5$).

Table 2. Percentage of centesimal composition of diets offered to *T. molitor* larvae.

Parameters	Treatments					
	Wheat bran	Cornmeal	Pelleted feed for rabbits	Feed for laying hens		
				Bran	Pelleted	Crushed
Humidity (%)	$7.36 \pm 0.37b$	$9.17 \pm 0.37a$	$7.76 \pm 0.03b$	$8.22 \pm 0.19ab$	$2.90 \pm 0.30c$	$7.70 \pm 0.05b$
Fiber (%)	$12.92 \pm 0.59de$	$10.43 \pm 0.43e$	$17.68 \pm 1.41bc$	$15.14 \pm 1.59cd$	$21.47 \pm 0.43b$	$27.93 \pm 0.25a$
Ashes (%)	$4.25 \pm 0.26cd$	$0.79 \pm 0.08d$	$9.67 \pm 0.51abc$	$8.66 \pm 0.09bc$	$15.20 \pm 2.78a$	$10.26 \pm 0.85ab$
Proteins (%)	$13.32 \pm 0.48a$	$6.77 \pm 0.47b$	$13.83 \pm 0.87a$	$13.39 \pm 0.62a$	$12.86 \pm 0.31a$	$13.81 \pm 0.36a$
Lipids (%)	$18.46 \pm 2.51ab$	$13.63 \pm 0.67b$	$22.37 \pm 1.32ab$	$25.00 \pm 3.13a$	$19.46 \pm 3.37ab$	$28.09 \pm 0.41a$
Carbohydrate (%)	$43.69 \pm 2.53b$	$59.21 \pm 0.82a$	$28.69 \pm 3.06c$	$29.58 \pm 2.89bc$	$28.11 \pm 5.27c$	$12.21 \pm 1.27d$
Energy (Kcal/100 g)	$394.14 \pm 12.39a$	$386.57 \pm 5.56ab$	$371.38 \pm 4.98ab$	$396.94 \pm 20.59a$	$338.99 \pm 11.13b$	$356.91 \pm 0.89ab$

* The means followed by the same letter in the line do not differ from each other by the Tukey's test ($p < 0.05$).

Inadequate nutrition of the host *T. molitor* causes limited use of resources by parasitoids. Parasitoids in inadequate hosts have a series of morphofunctional adaptations that regulate various physiological processes, such as longer development times and less body biomass. However, immature parasitoids can maximize the acquisition and use of nutrients inside the host and, thus, survive (PENNACCHIO; STRAND, 2006).

Parasitism and the emergence of *P. elaeisis* in pupae of *T. molitor* formed by different diets was 100% in all treatments (Table 4). The occurrence of host parasitism shows that the females of *P. elaeisis* evaluated the host as an adequate food source for feeding their offspring (VINSON; BARBOSA, 1987). Thus, the diet provided to the host did not interfere with these parameters. However, the host's nutritional status can influence the size, sex ratio and survival of the parasitoid (VINSON; BARBOSA, 1987). For parasitism and emergence of

pupae of *T. molitor* by *P. elaeisis*, rates of 100 and 90.76% have already been found (ZANUNCIO et al., 2008). For another parasitoid *Trichospilus diatraeae* Cherian & Margabandhu, 1942 (Hymenoptera: Eulophidae), 80% of parasitism was found in the same host exposed to parasitism by 20 females from 24 to 72 h (FAVERO et al., 2013). These data indicate that this host does not present nutritional or physiological barriers to the development of more than one species of endoparasitoid.

The duration of the life cycle of *P. elaeisis* in pupae of *T. molitor* in the six treatments did not present significant differences, ranging from 26 to 28 days ($p = 0.1105$; $F = 1.8962$; $df = 5$) (Table 4). The duration of the immature stages of this parasitoid in pupae of *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Noctuidae), *Diatraea saccharalis* (Fabricius, 1794), (Lepidoptera: Crambidae), *Heliothis virescens* (Fabricius, 1781), *Spodoptera frugiperda* (J.E. Smith, 1797) (both Lepidoptera:

Table 3. Percentage of the centesimal composition of pupae of *T. molitor* formed by the different diets.

Parameters	Treatments					
	Wheat bran	Cornmeal	Pelleted feed for rabbits	Feed for laying hens		
				Bran	Pelleted	Crushed
Humidity (%)	63.71 ± 0.32a	60.41 ± 1.46a	60.93 ± 0.44a	62.63 ± 0.84a	61.37 ± 0.74a	61.72 ± 0.53a
Fiber (%)	4.97 ± 0.92b	5.11 ± 0.50ab	7.47 ± 0.77ab	7.66 ± 0.79ab	8.10 ± 0.15a	7.72 ± 0.28ab
Ashes (%)	1.16 ± 0.02bc	1.21 ± 0.08abc	1.21 ± 0.07abc	1.14 ± 0.1c	1.47 ± 0.04ab	1.53 ± 0.07a
Proteins (%)	16.65 ± 0.55ab	18.41 ± 0.28a	15.07 ± 0.58b	17.34 ± 0.39a	16.74 ± 0.4ab	17.25 ± 0.42a
Lipids (%)	7.14 ± 0.61b	10.34 ± 0.56ab	11.83 ± 0.57a	7.04 ± 1.02b	7.69 ± 1.71ab	9.46 ± 0.73ab
Carbohydrate (%)	6.37 ± 0.58a	4.51 ± 1.17a	3.50 ± 0.39a	4.19 ± 1.35a	4.63 ± 1.53a	2.32 ± 0.48a
Energy (Kcal/100 g)	156.33 ± 4.92ab	184.78 ± 8.77a	180.75 ± 3.96ab	149.47 ± 5.34b	154.66 ± 10.27ab	163.43 ± 6.41ab

* The means followed by the same letter in the line do not differ from each other by the Tukey's test ($p < 0.05$).

Table 4. Parasitism (%), emergence (%), $\mu \pm$ standard error (EP) of the development cycle, offspring sex ratio ($\frac{\text{♀}}{\text{♀}+\text{♂}}$), female longevity and male longevity of progeny (in days) of *P. elaeisis*.

Parameters	Treatments					
	Wheat bran	Cornmeal	Pelleted feed for rabbits	Feed for laying hens		
				Bran	Pelleted	Crushed
Parasitism (%)	100	100	100	100	100	100
Emergence (%)	100	100	100	100	100	100
Cycle (days) ¹	25.90 ± 0.59a	26.20 ± 0.55a	28.00 ± 0.45a	27.30 ± 0.91a	28.00 ± 0.61a	27.7 ± 0.75a
Offspring	66.00 ± 7.83a	61.56 ± 10.02a	49.70 ± 6.78a	56.10 ± 7.31a	45.10 ± 4.21a	58.40 ± 10.51a
Sex Ratio ²	0.94 ± 0.01a	0.81 ± 0.01b	0.91 ± 0.02a	0.92 ± 0.01a	0.89 ± 0.01ab	0.89 ± 0.03ab
Longevity ♂ ¹	40.50 ± 2.65a	37.40 ± 3.76a	35.70 ± 3.24a	35.30 ± 3.79a	32.70 ± 3.87a	34.40 ± 3.72a
Longevity ♀ ¹	44.90 ± 3.45a	41.30 ± 4.48a	39.60 ± 3.71a	32.20 ± 3.45a	37.80 ± 2.53a	35.20 ± 3.08a

* The means followed by the same letter in the line do not differ from each other by the Tukey's test ($p < 0.05$). * The means followed by the same letter in the line do not differ from each other by the Kruskal-Wallis test ($p < 0.05$).

Noctuidae), *Thyrinteina arnobia* (Stoll, 1782) (Lepidoptera: Geometridae) was 18,9; 19,5; 22; 19,7 and 20,2 days, respectively (BITTENCOURT; BERTI FILHO, 2004). These results demonstrate that the host species can influence the period of development of *P. elaeisis*.

The density of parasitoids can also affect the development cycle of *P. elaeisis* (PASTORI et al., 2008; MARTINS et al., 2019). A shorter cycle was reported for this parasitoid in pupae of *T. molitor* ($23.42 \pm 0,18$ days) with the parasitoid/host density 4:1 (ZANUNCIO et al., 2008). There is a negative correlation between the increase in the number of parasitoid females per host and the length of the life cycle of *P. elaeisis*, since the immature competition for nutrients reduces the development time (PASTORI et al., 2012; MARTINS et al., 2019). This was also observed by exposing five densities of *Melittobia digitata* Dahms, 1984 (Hymenoptera: Eulophidae) per pupa of *Neobellieria bullata* (Parker, 1916) (Diptera: Sarcophagidae) (SILVA-TORRES; MATTHEWS, 2003). However, the reduction in the life cycle period was not observed in this study, with densities of 6:1 parasitoids/hosts showed a longer life cycle than in densities 4:1 (ZANUNCIO et al., 2008).

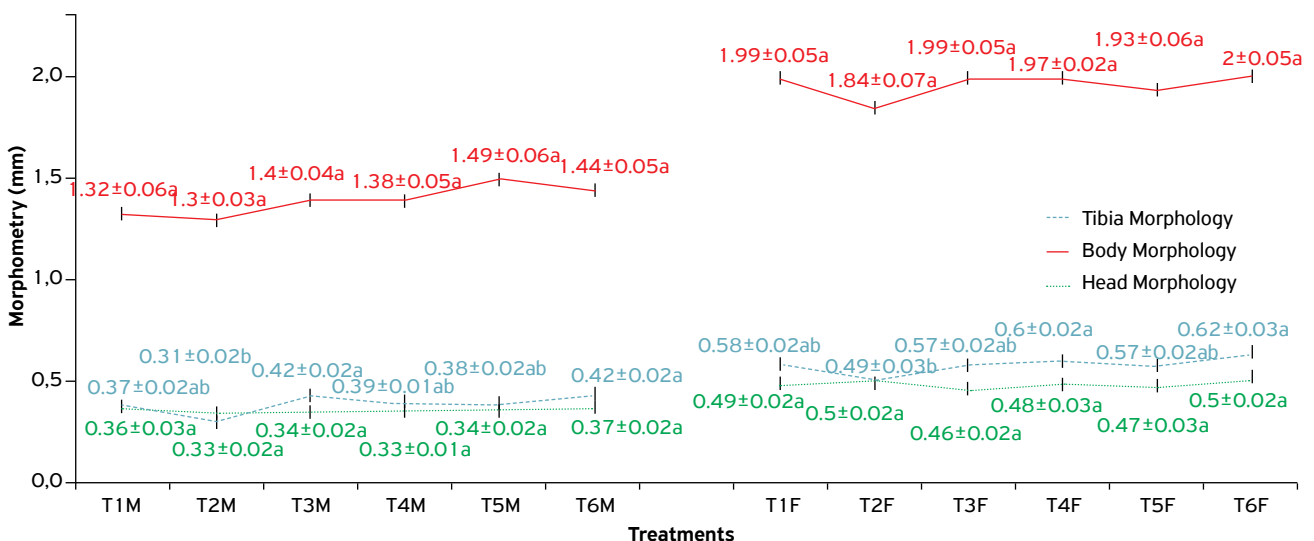
The number of parasitoids that emerged in the six treatments did not differ ($p = 0.4820$; $F = 0.9095$; $df = 5$) (Table 4). For *P. elaeisis*, 511 and 110 individuals emerged from pupae of *Bombyx mori* (Linnaeus, 1758) (Lepidoptera: Bombycidae) and *A. gemmatalis*, respectively (PEREIRA et al., 2009). These values were higher than those found in this study. The lower number of offspring of this parasitoid in pupae of *T. molitor* may be due to the higher biomass of pupae of *B. mori* and *A. gemmatalis* when compared to those of *T. molitor*. In the mass rearing of parasitoids, this can be offset by the low cost and effort required to produce pupae from the alternative host.

Tenebrio molitor fed with cornmeal produced a larger number of males of *P. elaeisis* in relation to those of the other diets ($p = 0.05$; $df = 5$). The sex ratio of *P. elaeisis* in cornmeal was $0,81 \pm 0,02$ (Table 4) which indicates that 1/5 of the progeny was composed of males. Reports show that the sex ratio values found for *P. elaeisis* are generally higher in this host (0,94) (ZANUNCIO et al., 2008). High sex ratio values for *P. elaeisis* are important for maintaining the population dynamics of the parasitoid since females are responsible for parasitism and the production of offspring.

The longevity of males ($p = 0.5890$; $F = 0.7510$; $df = 5$) and females ($p = 0.1504$; $F = 1.7015$ $df = 5$) of *P. elaeisis* did not change between treatments (Table 4). Male and female individuals had longevity greater than 30 days. Values lower than this (22.65 days for females and 28.3 days for males) were found for *P. elaeisis* in this same host with a lower density (4:1) of parasitoids per pupae (ZANUNCIO et al., 2008). The parasitoid in this study possibly obtained better nutrition. Adequate nutrition for immatures and adults could generate more long-lived individuals (VINSON; BARBOSA, 1987). This is important in the efficiency of biological control, considering that longer-lived adults have greater chances of mating, reproduction and the ability to parasitize a greater number of hosts in the field (PRATISSOLI et al., 2007).

No differences were found in the body and head size of males and females of *P. elaeisis* emerged in the six treatments ($p = 0.1110$; $F = 1.8938$; $df = 5$) ($p < 0.01$; $F = 1.0948$; $df = 5$); ($p = 0.7162$; $F = 0.5785$; $df = 5$) ($p = 0.7279$; $F = 0.5641$; $df = 5$) (Fig. 1).

The females of *P. elaeisis* presented body size ranging from 1.84 ± 0.21 to 2.0 ± 0.7 mm and cephalic capsule from 0.46 ± 0.07 to 0.5 ± 0.06 mm. Males, on the other hand, were smaller



T1: wheat bran, T2: cornmeal, T3: pelleted feed for rabbits; and T4: bran feed, T5: pelleted feed or T6: crushed feed for laying hens. M: male; F: female. *The means followed by the same letter arranged over the lines do not differ from each other by the Tukey's test ($p < 0.05$).

Figure 1. Morphometry of the cephalic capsule, body length and posterior tibia of males and females of *P. elaeisis*.

with body size ranging from 1.3 ± 0.09 to 1.49 ± 0.2 mm and cephalic capsule from 0.33 ± 0.04 to 0.37 ± 0.06 mm, respectively. This parameter was not influenced by the diets provided to the host. Sizes similar to those were found by ZANUNCIO et al. (2008). In Lepidoptera hosts such as *A. gemmatalis*, *D. saccharalis*, *S. frugiperda*, and *H. virescens* higher values were found for the body size of *P. elaeisis* females (2.23, 2.25, 2.21, 2.21 mm, respectively) (BITTENCOURT; BERTI FILHO, 1999). This shows that different hosts with different sizes can provide a greater or lesser nutritional source for the larvae of this parasitoid and influence the size of the offspring.

Competition for food and space between immature individuals of *P. elaeisis* may promote an increase in the number of smaller parasitoids (PEREIRA et al., 2009). Body size has a positive correlation with quality indicators such as longevity, copulation preference, fertility, reproductive longevity, progeny emergence and sex ratio, which can indicate the efficiency of parasitoids (PASTORI et al., 2012).

Males and females of *P. elaeisis* from pupae of *T. molitor* fed with cornmeal had tibia sizes of 0.31 ± 0.06 mm and

0.58 ± 0.06 mm, respectively. These values were lower than those found in the other treatments ($p < 0.01$; $F = 3.8278$; $df = 5$) ($p < 0.01$; $F = 3.7955$; $df = 5$). Larger females and males of *Anagyrus kamali* Moursi, 1948 (Hymenoptera: Encyrtidae) lived longer than smaller ones (SAGARRA et al., 2001). These authors found that females of this species showed no preference for copulation with large or small males. However, fertility was positively correlated with the size of females. In addition, the parasitism capacity, the daily rate of oviposition and the number of progenies of female parasitoids of *A. kamali* were higher among the larger parasitoids. Male parasitoids from *T. molitor* fed with cornmeal treatment, due to their smaller size of the tibia, could be less chosen by the females at copulation time (BITTENCOURT; BERTI FILHO, 1999).

The diets with wheat bran, pelleted feed for rabbits and bran, pelleted or crushed feed for laying hens provided to the host *T. molitor* allowed the proper development and reproduction of the parasitoid *P. elaeisis*. Cornmeal based diet provides lower body mass of *T. molitor* and sex ratio and length of the tibia of *P. elaeisis* not being suitable for the rearing of hosts for this parasitoid.

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