

MEALWORM (*TENEBRIO MOLITOR*) DIETS RELATIVE TO THE ENERGY REQUIREMENTS OF SMALL MYGALOMORPH SPIDERS (*PARAPHYSA* SP.)



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Abstract

This article describes the basic prey requirements of *Paraphysa* sp., a small mygalomorph spider from the central Andes. *Paraphysa* sp. can be maintained in captivity using mealworms (*Tenebrio molitor*) as its primary food source. During a period of 66 days the prey requirements (larvae/day) were calculated for weight maintenance and compared with findings of previously reported resting and active metabolic rates. The spiders in this study ate at frequencies between 0.18 and 0.59 larvae/day, with an average of 0.43 ± 0.14 larvae/day. From the regression line between frequency of feeding (larvae/day) and weight gain, we determined that 0.31 larvae/day were needed for a weight gain of 0. Thus, for the spiders to increase their weight, they would need to eat more than 1 larva every 3 days. This frequency yields a caloric intake of 0.193 kcal/d, or equivalently, a carbon dioxide production of 0.189 mL CO₂/g · h. The findings in this report are greater than the resting metabolic rate at 35°C, and they agree with the active metabolic requirements of this spider in the field. Copyright 2012 Elsevier Inc. All rights reserved.

Key words: basal energetic requirements; diet; mealworm; *Tenebrio molitor*; mygalomorph spider; *Paraphysa* sp.

A small mygalomorph spider (*Paraphysa* sp. Simon, 1892) lives in an area called the Farel-lones (33°21'S, 70°20'W) in the Chilean Andes. This locale has an environment with a wide variation of daily and seasonal temperatures.^{1,2} This species of spider is copper brown in color and has copper-colored hairs in its femora, typical fine white stripes on the tarsi, and a patch of urticating hairs on the center of the abdomen. *Paraphysa* spp. weigh between 6 and 10 g as adults and are primarily a crepuscular and nocturnal predator that feeds on small insects (e.g., crickets, cockroaches). Their general appearance and behavior are very similar to those of *P. parvula* Pocock, 1903, the species to which they were previously thought to belong.³⁻⁵ The *Paraphysa* sp. described in this article is found at altitudes above 2000 m, commonly under flat rocks^{4,5} in environs dominated by low shrubs. This species of *Paraphysa* successfully inhabits these high-altitude environments and is capable of withstanding temperatures close to the upper limit, over which there is danger of dehydration.^{5,6} It can easily be kept in terrariums as a pet, where its preferred temperature range is 29°C to 30°C in spring and summer.⁴

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It has been reported that mygalomorph spiders maintain low metabolism compared with other arthropods,^{5,7-9} that starvation can cause metabolic depression at high temperatures,² and that the low metabolism of spiders can be supported by a small number of prey.⁹ However, except for the anecdotal information supplied by arachnoculturists, little is known about the prey requirements of mygalomorph spiders. The aim of this study was to assess the basic energetic requirements of the small mygalomorph spider, *Paraphysa* sp.

METHODS

Ten adult female *Paraphysa* sp. were caught in the Andean locality of Farellones at approximately 2200 m. Their initial body mass was $m_b = 5.44 \pm 1.42$ g. The captured spiders were adapted to laboratory conditions for 3 weeks and were kept in individual terrariums ($28 \times 14 \times 10$ cm) with an environmental temperature of $20 \pm 4^\circ\text{C}$, $60 \pm 5\%$ humidity, and a 12-hour photoperiod. A mealworm (*Tenebrio molitor*) ($m_b = 0.096 \pm 0.031$ g) was offered daily for 66 days to the spiders in a Petri dish. The mealworms were cultured in a mixture consisting of sawdust and decaying vegetation in which the larvae grew and reproduced.

The feeding of each spider was recorded as to whether the larvae were eaten. A larva was offered each day, regardless of whether the spider consumed the prey item the previous day. Spiders were weighed daily to the nearest 0.001 g on an electronic scale before being offered the larva. They were provided with water daily by means of a soaked, 5×5 cm blotter in a Petri dish. The date, spider identification, weight, and whether the spider had eaten (coding 1 if the larva had been eaten and 0 otherwise) were recorded daily in a database. The weight and feeding curves were plotted. The mass gain (G_w) of each spider was determined and described statistically. For each spider, data were gathered for the number of meals (larvae), feeding frequency (f_a), and body mass gain. The relationship between feeding frequency and body mass gain was analyzed by linear regression analysis, and from this information we determined the frequency of consumption required to maintain body mass (f_a^* ; $G_w = 0$). Normality of the data was assessed with the Kolmogorov-Smirnov test (K-S), and the

TABLE 1. Alimentation frequency (f_a) and weight gain (G_w) of *Paraphysa* sp. spiders fed *Tenebrio molitor* larvae

Spider	Larvae Eaten (n)	f_a (Larvae/Day)	G_w (g)
1A	19	0.29	0.07
1B	32	0.48	0.33
6C	38	0.58	1.11
6B	24	0.36	0.13
5A	28	0.42	0.23
5B	39	0.59	0.62
7A	36	0.55	0.84
4C	36	0.55	0.71
3C	25	0.38	0.42
1D	12	0.18	-0.48
Mean $\pm$ standard deviation	28.9 ± 8.9	0.44 ± 0.14	0.40 ± 0.45

residuals of the regression model were inspected with normal plots. The level of statistical significance was $\alpha = 0.05$.

RESULTS

Each spider ate between 12 and 39 larvae during the 66 days of observation; the data were normally distributed (K-S = 0.134, $P > 0.05$). The average was 28.9 ± 8.9 larvae (mean $\pm$ standard deviation). The spiders ate at frequencies between 0.18 and 0.59 larvae/day. The data were normally distributed (K-S = 0.190, $P > 0.05$), with an average of 0.43 ± 0.14 larvae/day (Table 1). The weight gains were normally distributed (K-S = 0.18, $P > 0.05$). Based on the food eaten, the spiders had an average weight gain of 0.40 ± 0.45 g. Nine of the 10 spiders gained weight during the study, whereas the remaining animal lost weight. The spider that lost weight ate at the lowest frequency (0.18 larvae/day), which may explain the inconsistent result.

The spiders that had the highest alimentation frequency gained the most weight. The regression line of alimentation frequency (larvae/day) on weight gain (G_w) (Fig. 1) was $G_w = -0.942 + 3.06 f_a$ ($R^2 = 0.84$, $F_{1,8} = 43.0$, $P < 0.00018$). The residuals of the model were a good distribution in the normal plot. From this relationship, a weight gain of 0 requires $f_a^* = 0.31$ larvae per day. Therefore, for the spiders to maintain their weight, they should be fed 1 larva every 3 days. However, if one wants to increase a spider's body mass, the animal should be fed more often than once every 3 days.

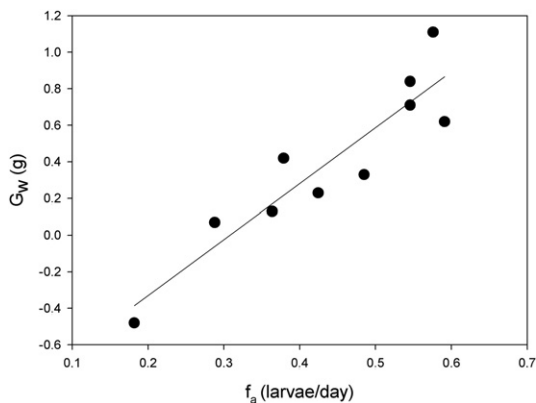


FIGURE 1. Relationship and regression line between the alimentation frequency (f_a) and the weight gain (G_w) in *Paraphysa* sp. spiders fed mealworms (*Tenebrio molitor*).

DISCUSSION

The small tarantula, *Paraphysa* sp., can be easily fed with *Tenebrio molitor* larvae, achieving an increase of weight with a frequency of feeding above 0.31 larvae/day. Changes in weight do not appear associated with amount of water intake. The spiders' use of the soaked blotters as a water source probably did not constitute an adequate intake of water; thus, they were slightly water restricted during the study. It is possible that if the spiders were allowed to drink directly from bodies of standing water, as is typical for theraphosid spiders, the weight gain for the subject animals would have been higher.

Ninety percent of the spiders were able to increase their body mass, with one having a slight decrease in its body weight. Our regression analysis suggests a frequency of 0.31 larvae/day for a *Paraphysa* sp. to maintain its body weight. Because, on average, each larva weighs 0.0961 g and has a caloric value of 6.49 kcal/g,¹⁰ the caloric intake (E) is 0.193 kcal/d (Table 2). Using the average body mass of 5.69 g, this corresponds to a mass-specific energetic intake (E_m) of 0.00141 kcal/g h. Moreover, based on a respiratory quotient of $RQ = 0.92$ ¹¹ and a caloric equivalent of O_2 (ce) of 5 kcal/L,¹² a predictive value of carbon dioxide (CO_2) production of 0.259 mL

$CO_2/g \cdot h$ can be made. This estimation assumes 100% digestibility of the prey; however, to our knowledge there is no information available regarding mealworm digestibility in spiders. In vertebrate species, mealworm digestibility values have been reported to be 73% to 75%.^{13,14} Using the lower value, an energy supplied estimation of 0.189 mL $CO_2/g \cdot h$ is obtained ($0.73 \times V_{CO_2}$).

The resting metabolic rate in *Paraphysa* sp. is dependent on body temperature, ranging from about 0.020 to 0.13 mL $CO_2/g \cdot h$ between 25°C and 40°C⁵; these values are lower than the energy supplied by 0.31 larvae/day. Thus, the minimum support requirements are easily satisfied, though the resting metabolic rates generally do not exceed the resting metabolism at 35°C, which is approximately 0.060 mL $CO_2/g \cdot h$.⁵ However, the spiders in this study were not post-absorptive, therefore one should expect values above the resting metabolic rate. There have been reports of increases, 10 to 12 times from the resting metabolic rate to the maximum metabolic rate for *Aphonopelma anax*,¹⁵ and an activity aerobic scope of 8 in *Brachypelma smithi*.¹⁶ In sub-maximum aerobic activity the scope is smaller, typically about 4.¹⁷ Considering a scope of activity equal to 4, one may expect the spiders in this study to have energetic requirements between $4 \cdot 0.020 = 0.08$ (25°C) and $4 \cdot 0.060 = 0.24$ mL $CO_2/g \cdot h$ (35°C); values that are in the range of estimated energy intake with the consumption of 0.31 larvae/day (≈ 0.0298 g/d). It is likely that the spiders in this research investigation have an activity very similar to that usually deployed in the field, because they are sit-and-wait predators similar to other theraphosids that have a strategy of

Therefore, for the spiders to maintain their weight, they should be fed 1 larva every 3 days. However, if one wants to increase a spider's body mass, the animal should be fed more often than once every 3 days.

TABLE 2. Formulas used in the energetic estimations

Variable (Symbol)	Formulas	Comments
Energy intake (E)	$E = f_a \cdot m \cdot \varepsilon$	f_a is the feeding frequency, m the mealworm body mass (g), and ε the energy content (kcal/g)
Specific energetic intake (E_m)	$E_m = E/24m_b$	m_b is the spider body mass (g)
Carbon dioxide production (V_{CO_2})	$V_{CO_2} = RQ \cdot (E_m/ce)$	RQ is the respiratory quotient and ce is the caloric equivalent of O_2

Consequently, the results obtained for *Paraphysa* sp. could be applicable to other theraphosid spiders and other prey species of similar energetic content.

minimum energy expenditure.⁹ Thus, it is expected that in its habitat the requirements of *Paraphysa* sp. are satisfied with insect prey of similar nutritional value (e.g., crickets).

The resting metabolic rate of mygalomorph spiders is very similar. For example, *Grammostola rosea*, *Aphonopelma eutylenum*, and *A. californicum* had metabolic rates between 0.013 and 0.027 mL O₂/g · h (equivalent to 0.012 and 0.025 mL CO₂/g · h for an RQ = 0.92).^{1,9,18} This means that prey required to satisfy these energetic requirements would be similar. Consequently, the results obtained for *Paraphysa* sp. could be applicable to other theraphosid spiders and other prey species of similar energetic content, such as cockroaches (*Periplaneta americana*; 6.07 kcal/g), domestic crickets (*Acheta domestica*; 5.34 kcal/g) and night crawlers (*Lumbricus terrestris*; 4.93 kcal/g).¹⁰

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