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Winter energy budget of larvae of Indian tropical tasar silk insect *Antheraea mylitta* Drury living in the host plant *Ziziphus jujuba*

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Abstract

The energy budget of the larvae of *Antheraea mylitta* Drury living in host plant *Ziziphus jujuba* Gaertn was prepared in winter. In the fifth instar the rate of food energy consumption, absorption, body growth, silk gland growth and respiration increased when compared to other instars. The amount of consumption, absorption, body tissue growth and silk gland growth during fifth instar was 81%, 82%, 82%, 97% respectively of the total amount used in the entire larval period. The fifth instar female larvae showed significantly higher overall efficiencies than male larvae. There was a gradual increase in amount of energy stored per mg dry body weight from first to fifth instar. The absorption and growth efficiency was lowest in second instar. Hence, it is the most vulnerable instar needing more care during rearing. Highest all-round efficiency was observed in fifth instar larva. Therefore, optimum care should be given to fifth instar larva during feeding and rearing in order to maximize silk productivity.

Key words: *Antheraea mylitta*; energy budget; host plant; instar; *Ziziphus jujuba*.

Introduction

Antheraea mylitta is polyphagous insect and its larvae feed on a number of host plants. Ber (*Ziziphus jujuba*) is one of such host plants which is recently considered to have primary importance on the basis of the cocoon crop performances on it.[1] The lepidopteran larvae act as energy transformer and show certain level of efficiency in particular ecological conditions. Thus, studying the energetic parameters of *A. mylitta* is important to trace out clues for optimizing silk production efficiency since it is the only food energy consuming stage of its life cycle.

Ecological energetic of some species of silk worm are known such as *Bombyx mori*,[2,3] *Philosamia ricini*,[4,5] and *Antheraea proylei* Jolly.[6] Post larval energy budget of *A. mylitta* on some food

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plants was reported earlier.[7-9] But no information is available on energy budget of *A. mylitta* feeding on *Z. jujuba* during winter season. Since the winter is the prediapause period (6 months from January to June), the metabolic strategy and the trend of energy budget adopted by the insect was investigated.

MATERIALS AND METHOD

The study was conducted at the State Tasar Research Farm, Durgapur in the district of Mayurbhanj of Odisha during winter (November-December) of 2009. For energy budget preparation, IBP formula[7] is followed, which is represented as C=P+R+F+U where 'C' is food consumption (here expressed as total ingestion of energy as food), 'P' is production (here energy utilized for body growth), 'R' is energy loss as heat due to metabolism, 'F' is energy loss as faecal matter and 'U' is energy loss as nitrogenous excretory products. *A. mylitta* excretes mainly uric acid combined with faeces as solid pellets and it is presumed to be of negligible amount.[10] However F+U will give the data for faeces + nitrogenous matter.

In this study a number of healthy ber plants (*Z. jujuba*) were selected at random and freshly hatched *A. mylitta* were maintained as reserve batch for experimental use. The fresh and dry weight of consumed leaf, egested faecal pellets, gained body tissue, cast off exuviate and dissected out silk gland were measured for each instar stage along with measurement of amount of oxygen consumed.

At the beginning of each instar (except the fifth), an experimental population of two hundred healthy larvae were selected randomly from the large reserve batch and were reared on *Z. jujuba* during winter. During each instar the initial (just after hatching for the first instar and after moulting for the remainder) and the final (just before moulting when the gut was empty) fresh and dry (oven drying)[11] body weight of 20 larvae was measured by bomb calorimetry. For the fifth instar larvae the above method was followed separately with each sex. Another 20 larvae at hatchling stage were chosen at random from the experimental batch and were allowed to feed on 20 different branches of *Z. jujuba* having sufficient leaves for the worms to spend their whole larval life. The area of all leaves on each branch was determined by tracing and each leaf was marked serially. The worms were prevented from escaping by encircling the base of experimental branch with a plastic cone. The 20 larvae were kept under continuous observation. The leaf consumption on fifth instar larvae was measured separately for the male and female larvae. The leaf collected at each instar were oven-dried,[11] powdered, mixed thoroughly and subjected to bomb calorimetry.

The faecal pellets egested by the above experimental larvae were collected every day for each instar by tying a plastic sheet below the branch. The fresh and dry weights of the pellet collected for each instar were determined. Then they were powdered, thoroughly mixed and 20 samples were subjected to bomb calorimetry. The absorbed energy was calculated by subtracting 'F+U' from 'C'. For measuring the oxygen consumption, 20 larvae at each instar were collected from the experimental batch every day, and each larva was subjected to respirometry for half an hour during the early morning, noon, evening, night and mid-night. The daily rate of oxygen consumption per hour was calculated from the average value so obtained. Thus the total amount of oxygen consumption throughout each instar was estimated. For the fifth instar, the amount of oxygen consumption was measured separately for each sex. The oxyjoulerific conversion (19.64 J/ml) of consumed oxygen was made to know the energy lost in respiration during each instar.

The exuviate casted off after moulting by the twenty feeding larvae were collected at each instar. The fresh and dry weights of the collected exuviate were measured. Then they were powdered, thoroughly mixed and 20 samples were subjected to bomb calorimetry. For knowing silk budget, 20 larvae at beginning and end of each instar were collected and their silk glands were dissected out. The initial as well as final fresh

Table 1. Mean energy (joules ± SD) budget of different instars of *A. mylitta* larva living in host plant *Z. jujuba* during winter season.

Instar	N	Energy consumed (C)	Energy lost in faeces(F+U)	Energy absorbed (A)	Oxygen respired (ml± SD) & energy (J) lost in respiration (R)	Energy utilized for body growth (P)	Energy lost in exuviate (E)	Energy utilized for silk gland growth (S)
First	100	1415.46±0.93	1236.97±1.16	178.49±0.20	3.43±0.14 (67.36)	103.63±0.22	5.74±0.10	2.64±0.06
Second	100	7768.29±3.50	6834.83±3.11	933.46±1.66	20.18±1.69 (396.33)	508.04±0.92	21.52±0.53	19.08±0.34
Third	100	34095.79±7.13	29367.91±7.25	4727.88±2.33	99.62±1.82 (1956.54)	2675.05±1.75	83.81±0.71	116.44±1.75
Fourth	100	125209.06±25.43	107099.72±25.97	18109.34±11.51	336.15±7.06 (6601.98)	10550.50±8.94	875.00±5.75	542.40±6.96
Fifth ♂	100	744081.92±52.51	642440.33±53.62	101641.59±22.97	2191.66±10.17 (43044.20)	58454.08±14.62	-	22474.14±19.27
Fifth ♀	100	786361.91±73.47	663925.36±71.06	122436.55±42.41	2520.37±12.36 (49500.06)	72776.29±33.31	-	23468.41±18.51

and dry weight (oven drying)[11] of removed silk glands were recorded. The energy content of silk gland of each instar larva was measured by bomb calorimetry. The efficiency of absorption, body growth, silk gland growth of each instar larva was calculated as indicated in Table 1. The energy budgeting per mg dry body weight (J/mg) at each instar was made as shown in Table 2. The experiment was repeated for five years in winter season. Statistical analyses of data using ANOVA and *t* test were made following Sokal and Rohlf.[12]

Results and Discussion

The amount of energy consumed, absorbed and allocated for body and silk gland growth increased gradually from first to fourth instar and rapidly during fifth instar (Table 3). Analysis of ANOVA test indicated significant difference of consumption, absorption, body growth and silk gland growth during fifth instar and it was about 81%, 82%, 82%, and 97% of the total amount utilized for the entire larval period, respectively. The increase was nearly five times of the fourth instar for all above energy budget parameters except silk gland budget which was exceptionally forty times more. The t-test indicated significantly ($P<0.01$) higher consumption, absorption, body growth and silk gland growth in female larva than male larva. The loss of energy in faeces and respiration increased gradually from first to fourth instar and suddenly during fifth instar (Table 1). ANOVA test indicated significant difference in amount of energy loss in faeces and respiration among different instars. The t-test also showed significantly ($P<0.01$) higher allocation of energy for metabolism in case of female larva than the male larva. The loss of energy in egests and metabolism during the final instar was about 82% and 84% respectively of the entire larval period. Loss of energy in faeces and respiration suddenly increased towards fifth instar and it was nearly five to six times more than fourth instar. The absorption efficiency (100 A/C), gross growth efficiency (100 P/C), net growth efficiency (100 P/A), gross silk gland growth efficiency (100 S/C) and net silk gland growth efficiency (100 S/A) were usually found lowest in second instar larva

Table 2. Allocation of energy budget per milligram dry body weight (J/mg) of *A. mylitta* larva living in host plant *Z. jujuba* during winter season.

Instar	N	Energy consumed (C)	Energy lost in faeces(F+U)	Energy absorbed (A)	Oxygen respired (ml/ mg) &energy (J) lost in respiration (R)	Energy utilized for body growth (P)
First	100	278.63	243.50	35.13	0.67 (13.16)	20.40
Second	100	327.22	287.90	39.32	0.85 (16.69)	21.40
Third	100	282.32	243.17	39.15	0.82 (16.10)	22.15
Fourth	100	268.33	229.52	38.81	0.72 (14.14)	22.61
Fifth ♂	100	287.81	248.49	39.31	0.84 (16.49)	22.61
Fifth ♀	100	247.98	209.37	38.61	0.79 (15.51)	22.95

among all the instars (Table 3). The absorption and growth efficiency of body as well as silk gland increased significantly ($P<0.01$) from third to fourth instar. The t-test indicated significantly ($P<0.01$) higher all round efficiency of female than the male except silk gland gross and net growth efficiency which was higher in male than female larva. During fifth instar about 58 to 59% of the total absorbed energy was allocated for body growth and about 22% and 19% for silk gland growth by male and female larva respectively.

The mean allocation of energy per milligram dry body weight (J/mg) is given in Table 2. In general the second instar showed highest values for all the budget parameters except in case of energy utilized for body growth which is highest in fifth instar. Absorption value was highest in second instar and lowest in first instar. The 'P' value was lowest in first instar followed by second, third, fourth and fifth instar. The energy allocated for growth in fifth instar was significantly higher than other instars. The t-test indicated significantly higher energy level per mg dry body weight of the male larvae than the female larvae for all budget parameters except growth. The 'P' value of female was significantly higher than male. The energy allocated for growth per mg dry body tissue increased from the first to fifth instar. The energy flow budget of male and female larva is presented in Figure 1 and 2 respectively.

The energy budget allocated for pupal life was 49.38 KJ and 62.72 KJ in male and female larvae respectively. The budgetary saving for pupal life (diapause period) was more than 67% and 71% of the total body tissue energy budget of male and female larvae respectively. The energy flow budget of both male and female larvae is given below (Figs.1&2). In the present study it was observed that only fifth instar larva consumed more than 82% of the total food energy consumption throughout the entire larval life of *A. mylitta*. Waldbauer (1968) reported that lepidopterans consume more than 70% of total larval consumption during last instar only.[11]

In *A. mylitta* an increasing trend of ingestion, absorption, body tissue production and food oxidation through respiration was found with advance of instars. Similar trends were recorded in *P. ricini*.[5] Both sexes of fifth instar larva of *A. mylitta* allocated more than 58% of total absorbed energy for body tissue. But 40.28% of total absorbed energy was allocated for body tissue by *A. proylei*. Higher metabolic rate was noticed in larva of *A. mylitta* in later stage. Earlier it was recorded in *A. proylei*.[13]

The consumption of food energy during fourth instar was about 13% of the total food energy consumed throughout its larval life, but in *B. mori* it was approximately 9%.[3] The efficiency of utilization of energy for the body growth during fifth instar of male and female *A. mylitta* larvae was 58% and 59% respectively. But in *B. mori* the efficiency of utilization of energy to whole body by the fifth instar male and female larvae ranged between 46.4-65.5% and 51.7-61.8% respectively. The net growth efficiency (100 P/A) of *A. mylitta* larva ranged between 54-59%. In *Hyalophora cecropia* larva it was found to be 53.1%. The gross growth efficiency (100P/C) of *A. mylitta* ranged between 6-9% during different instars whereas in *H. cecropia* it was 19.4%.[14]

At fifth instar stage the male and female larva of *A. mylitta* on average, consumed 287.81 and 247.98 joules of food energy per mg dry body weight respectively (Table 2). The male *A. mylitta* larva was found to show higher consumption of energy per mg dry body weight than female larva. During fifth instar of *A. mylitta* the average absorption and metabolic loss of energy per mg dry body weight of male and female larvae was 39.31 and 38.61 and 16.49 and 15.51 J/mg respectively. It was observed that the average absorption and metabolic consumption per mg dry body weight of male and female larva of *B. mori* in fifth instar were 12.54 J/mg and 4.37 J/mg respectively.[4] It appears that the amount of absorption and metabolic cost per mg dry body weight of *A. mylitta* larva is much higher than *B. mori* larva.

An increasing trend of stored energy per mg dry body weight was observed in successive in-

Table 2. Allocation of energy budget per milligram dry body weight (J/mg) of *A. mylitta* larva living in host plant *Z. jujuba* during winter season.

Instar	N	Gross growth efficiency (100 P/C)	Net growth efficiency (100 P/A)	Absorption efficiency (100 A/C)	Gross silk gland growth efficiency (100 S/C)	Net silk gland growth efficiency (100 S/A)
First	100	7.32	58.06	12.61	0.18	1.48
Second	100	6.54	54.42	12.02	0.24	2.04
Third	100	7.84	56.58	13.87	0.34	2.46
Fourth	100	8.43	58.26	14.46	0.43	2.99
Fifth ♂	100	7.85	57.51	13.66	3.02	22.11
Fifth ♀	100	9.25	59.44	15.57	2.98	19.17

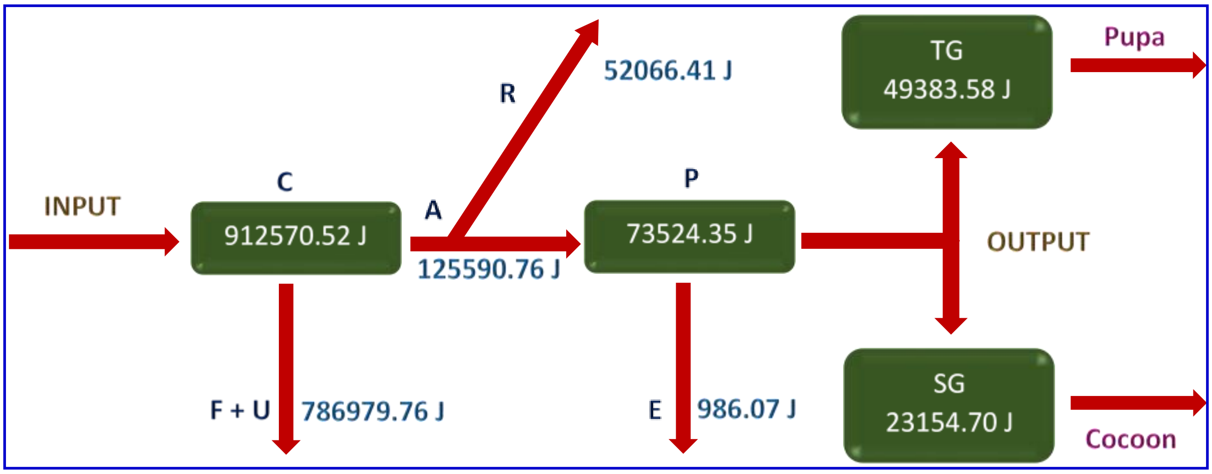

Figure 1. Winter energy flow budget of male larva of Indian tasar silkmoth *A. mylitta* living in Ber (*Z. jujuba*) host plant.

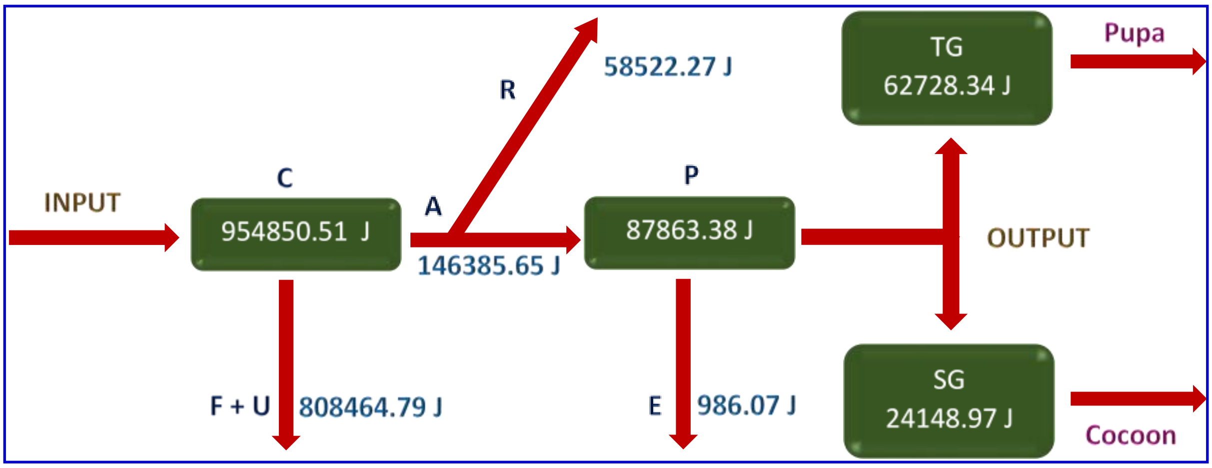

Figure 2. Winter energy flow budget of female larva of Indian tasar silkmoth *A. mylitta* living in ber (*Z. jujuba*) host plant.

stars of *A. mylitta* larva. Hiratsuka (1920) reported a similar trend in *B. mori*.[2] He stated that it might be due to an increase in relative amount of fat deposition in successive instars. It was observed that the fifth instar of *A. mylitta* larva is very important of all instars and especially for silk production. Because the energy utilized for silk production during fifth instar was about 97% of the total amount gathered over the entire larval period. Similar trend was observed in *B. mori,*[3] and *P. ricini*.[14] The female larva of *A. mylitta* utilized more energy for total silk synthesis than male larva. The gross and net silk gland growth efficiencies of *A. mylitta* larva at fifth instar ranged between 2-3% and 19-22% respectively, and it was also higher in male than female larvae. Higher net and gross silk gland growth efficiency in male larva than female larva was observed in *B. mori* and its range was within 23-27%.[4] The male and female *A. mylitta* larva allocated about 32% and 27% of the accumulated body energy for silk gland respectively. The allocation of absorbed energy for silk preparation was 18% and 16% by male and female larvae respectively. Yokoyama (1962) reported that about 25% of absorbed energy of *B. mori* larva is contributed for silk production. In *B. mori* 34% of total amount of body energy is diverted for silk matter.[4]

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