

Food Utilization Efficiency in *Antheraea mylitta* Fed on *Terminalia arjuna* Leaves

Sudhansu Sekhar Rath

Central Tasar Research and Training Institute, Piska Nagri,
Ranchi-835 303, Jharkhand (India)

Abstract: *Antheraea mylitta* is an economically important silk producing insect. The nutritional ecology of the insect was studied using *Terminalia arjuna* leaves as the source of food. In order to have a detailed picture of the food utilization, daily measurement of dry matter ingested, faeces produced and biomass gain by the larva were recorded. Absolute value for dry matter ingested, digested, efficiency of conversion of digested food and biomass gain were increased with the advancement of larval development; while, the relative consumption rate was declined. The relative growth rate reached at its peak during II instar (0.488) and declined significantly thereafter. Results revealed that the larva ingest about 95-96% of their total intake during the last two instars and about 99% during the last three instars and accounts for a similar biomass production. Male larva expends about 92.38% and female about 89.61% of the digested food towards respiration, moulting, larval-pupal and pupal-adult transformation. A total of 5.94% and 5.47% of the digested dry matter were allotted for silk production by male and female respectively, while only 2.78% was expended for egg production by a female. At the time of death about 1.68% and 2.14% of the digestible food remained in male of in female respectively.

Key words: *Antheraea mylitta* • *Terminalia arjuna* • Food utilization • Larva

INTRODUCTION

Nutrition is a factor of paramount importance that regulates growth, development and reproduction. Intake and growth targets are important to reach the functional optima in an insect [1]. The physiological potential of life performance of the insect is always challenged by abundance of food and its quality, various abiotic factors, presence of predators, parasites and disease [2-5]. Food consumption and their utilization influence metabolism, enzyme synthesis, nutrient storage and other activities. *Antheraea mylitta* an economically important silk (tasar silk) producing insect is polyphagous and wild, but two host plants namely, *Terminalia tomentosa* and *T. arjuna* are more suitable for commercial rearing owing to higher survival and growth with superior commercial characters [6,7]. The quality and quantity of food intake, its digestibility and their utilization influences the growth, developmental time, final weight, survival and above all silk synthesis and reproduction. Quantitative nutrition in *A. mylitta* was a subject of interest of many [7-9] but only one detail report on food allocation budget is available where the food plant *Terminalia tomentosa* was used as the source of food [10]. *T. arjuna* being another suitable

host plant of the insect it is felt necessary to have a complete and comparative picture of nutritional budget which is the aim of the present investigation. Simultaneously emphasis was also given to find out the dry matter utilization, dry matter economy and dry matter requirement for unit growth, cocoon shell and egg production in *A. mylitta*.

MATERIALS AND METHODS

Antheraea mylitta (Lepidoptera: Saturniidae; ecorace: Daba bivoltine) was selected because of their higher exploitation potency. Leaves of host plant *Terminalia arjuna* were preferred as the source of food for the insect which is next to *T. tomentosa* with respect to nutritional status of the host plant that support the growth of the larvae better [6,7,11]. Evaluation of food consumption and utilization in this insect in *in situ* condition (*i.e.*, the out door condition on the host plant) is restricted by the wild nature of the larva and also by a number of other factors like natural calamity and presence of pest, predator and parasites. Secondary contaminations with protozoan disease called 'pebrine' caused by *Nosema* sp. and parasitic infestation by uzi fly influence the food

consumption and utilization to a great extent [12-14]. To overcome such situations *ex situ* conditions (indoor rearing) was given preference to study the quantitative aspect of food consumption, utilization and nutrient economy.

Freshly hatched out healthy *A. mylitta* larvae were reared in indoor condition (temperature $28^{\circ} \pm 3^{\circ}\text{C}$ and R.H. $77\% \pm 7\%$, photoperiod 11h L: 13h D). The silkworms were fed with sufficient quantities of fresh *T. arjuna* leaves twice a day to attain full growth and maturity [5, 7].

There were 7 replications each with 20 larvae. Buffer stocks were maintained *at par* simultaneously to compensate mortality. Larvae of same age and weight from the buffer stock were used to replace the loss due to mortality and larvae used for dry weight determination. Leaves and faeces were kept at 80°C in an oven to determine the dry weight. Larvae of known weight were killed by placing them in a freezer for a short time and then dried in an oven at 80°C to a constant weight. Thus, for each day of feeding period dry matter ingested, digested, faces produced and increase in larval weight were recorded. Sex could not be separated up to IV instar in the present study but separate records were kept for different sexes during V instar. The data recorded during first four instars were common for both the sexes. After gut purging the worms were mounted on the bushes of *T. arjuna* outdoor for spinning of cocoons. The harvested cocoons were kept separately till the reproductive activity were completed and the commercial (cocoon weight and shell weight) and adult characters (moth weight, fecundity and egg weight) were recorded.

For dry weight determination 5 each of larvae, pupae, moths and 100 eggs were used and dry matter requirement for unit growth, cocoon shell and egg production were calculated; and dry matter economy was constructed for male and female separately.

The various nutritional parameters were recorded and expressed on dry weight basis [15] relative growth rate (RGR) = P/TA , relative consumption rate (RCR) = E/TA , approximate digestibility (AD%) = $100(E - F)/E$, efficiency of conversion of ingested food (ECI%) = $100P/E$, efficiency of conversion of digested food (ECD%) = $100P(E - F)$ [where A is mean dry weight of the larvae during the feeding period; E, the dry weight of food eaten; F, dry weight of faeces produced; P, dry weight gain of the larva; and T, duration feeding (days)].

Students t-test was used to study the sex difference in various parameters while the significant different of different parameters among instars were studied using ANOVA and correlation.

RESULTS

The newly hatched *A. mylitta* larva (dry weight 0.002 g) continue feeding on the leaves of host plant till maturation and recorded a dry weight gain of about 7.91 g in male and 9.04 g in female. The male larvae increased by 4700 times while a female increased by 5490 times during the entire larval span. The absolute value of ingestion and digestion increases significantly with the advancement of developmental stages ($P < 0.001$) but the relative consumption rate (RCR) declined significantly ($P < 0.001$) from early (3.051 during I instar) to late instars (0.595 in male and 0.527 in female during V instar). The RCR differ significantly among the instars. The ingestion and digestion though did not change significantly among the first two instars, in the late instars it differs significantly. The approximate digestibility (AD%) declined significantly up to III instar followed by a significant and temporary increase during IV instar and then declined to its lowest level during V instar (34.5% in male and 40.57% in female). The efficiency of conversion of ingested food (ECI %) tends to increase significantly up to IV instar followed by a significant decline during V instar, while the efficiency of conversion of digested food (ECD%) increased with advancement of development up to V instar ($P < 0.001$). Absolute biomass gain increase significantly as development proceeds but the relative growth rate (RGR) reaches its peak during II instar (0.488) and then declined to the lowest during V instar (0.087 in male and 0.077 in female) (Table 1).

Significant sexual differences were observed in all the parameters (except ECI %) during V instar and when the entire larval stage was taken in to account. While the values for the parameters like feeding period, food ingested, digested, AD%, biomass gain were significantly higher in female, in other parameters male excels the female (Table 1).

The percentage of total ingestion, digestion and biomass production increases gradually as the development proceeds. The larva ingest about 95-96% of their total intake during the last two instars and about 99% during the last three instars and accounts for a similar biomass production. Male recorded higher percentage of total ingestion, digestion and biomass production during different instars than their female counter parts till the larvae was IV instar but these parameters recorded for female excel the males during V instar (Table 2).

Table 1: Dry Matter Ingested, Digested, Biomass Produced and its Utilization Efficiency in Different Instars Tropical Tasar Silkworm *A. mylitta* Fed with *T. arjuna*

Parameters	Larval stage					Correlation (r)	Entire larval stage
	I	II	III	IV	V		
Feeding period (days)	4.2	3	3.7	7.6	M 12.6 F 15.4		M 31.1 F 33.9*
Food ingested (g)	0.120 a	0.536 a	1.768 b	8.236 c	M 38.23 d F 46.04 e	M 0.8156*** F 0.7994***	M 48.89 F 56.70*
RCR	3.051 a	2.871 b	1.760 c	0.795 d	M 0.595 e F 0.527 f	M -0.9617*** F -0.9652***	M 0.398 F 0.370*
Food digested (g)	0.083 a	0.330 a	0.955 b	5.159 c	M 13.17 d F 18.68 e	M 0.8799*** F 0.8403***	M 19.70 F 25.21 *
AD%	69.09 a	61.51 b	54.08 c	62.66 b	M 34.50 d F 40.57 e	M -0.7962*** F -0.7979***	M 40.29 F 44.46*
Biomass gain (g)	0.015 a	0.091 a	0.329 b	1.682 c	M 5.61 d F 6.74 e	M 0.8605*** F 0.8412***	M 7.91 F 9.04 *
ECI%	12.22 a	17.09 b	18.66 c	22.60 d	M 14.73 e F 14.65 e	M 0.4062 (P, NS) F 0.4025 (P, NS)	M 16.18 F 15.94 (P, NS)
ECD%	17.70 a	27.80 b	34.49 c	36.07 c	M 42.66 d F 36.13 c	M 0.9564*** F 0.8862***	M 40.16 F 35.86*
RGR	0.372 a	0.488 b	0.327 c	0.179 d	M 0.087 e F 0.077 f	M -0.8725*** F -0.8746***	M 0.064 F 0.059*

M: male, F: female. Different alphabets show significant difference among different instars at 5% level (one way ANOVA). * Significant at 5% (t-test), *** significant at 0.1%

Table 2: Percentage of Ingestion, Digestion and Biomass Production During Different Instars of *A. mylitta*

Instar	% of total during entire larval life					
	Ingestion		Digestion		Biomass production	
	Male	Female	Male	Female	Male	Female
I	0.25	0.21	0.42	0.33	0.19	0.17
II	1.10	0.95	1.68	1.31	1.15	1.01
III	3.62	3.12	4.85	3.79	4.16	3.64
IV	16.85	14.53	26.19	20.47	23.54	20.60
V	78.20	81.20	66.85	74.11	70.96	74.56

Table 3: Dry Matter Economy in Tropical Tasar (*A. mylitta*) Fed with *T. arjuna* Leaves

Sl. No.	Parameters	Sex	Dry matter (g) per larva	Performance of female over male (%)
1.	Ingestion of dry matter during the entire larval period	Male	48.89	
		Female	56.70	+ 15.97*
2.	Assimilation of dry matter during the entire larval period	Male	19.70 (100%)	
		Female	25.21 (100%)	+ 27.97*
3.	Consumption of dry matter during the entire larval period in moulting, respiration etc.	Male	11.79 (59.85%)	
		Female	16.17 (64.14%)	+ 37.15*
4.	Gain in dry weight by the larva during its entire larval period	Male	7.91 (40.15%)	
		Female	9.04 (35.86%)	+ 14.28*
5.	Consumption of dry matter from initiation of cocoon shell formation to larval-pupal ecdysis	Male	5.23 (26.55%)	
		Female	4.76 (18.88%)	- 8.99*
6.	Conversion dry matter into cocoon shell	Male	1.17 (5.94%)	
		Female	1.38 (5.47%)	+ 17.95*
7.	Conversion dry matter into pupa	Male	1.51 (7.66%)	
		Female	2.90 (11.50%)	+ 92.05*
8.	Consumption of dry matter during pupa stage	Male	0.74 (3.76%)	
		Female	1.35 (5.36%)	+ 82.43*
9.	Conversion of dry matter into egg by the female larva	Female	0.70 (2.78%)	
10.	Conversion of dry matter into moth (excluding egg in female)	Male	0.77 (3.91%)	
		Female	0.85 (3.37%)	+ 10.38*
11.	Consumption of dry matter by the moth	Male	0.44 (2.23%)	
		Female	0.31 (1.23%)	- 29.54*
12.	Residual dry matter at the time of death	Male	0.33 (1.68%)	
		Female	0.54 (2.14%)	+ 63.64*

*Significant at 5% level

Table 4: Dry Matter Requirement for Growth, Cocoon Shell and Egg Production in *A. mylitta* Fed with *T. arjuna*

Parameters	Dry matter requirement (g/g)	
	Male	Female
Ingesta (g)/growth (g)	6.18	6.27
Digesta (g)/ growth (g)	2.49	2.79
Ingesta (g)/cocoon shell (g)	41.79	41.09
Digesta (g)/ cocoon shell (g)	16.84	18.27
Ingesta (g)/egg production (g)	-	81.00
Digesta (g)/ egg production (g)	-	36.01

The dry matter economy in *A. mylitta* fed with *T. arjuna* leaves revealed that the female larvae ingests and digests more to a tune of about 16% and 28% respectively than male. Female always excel male in conversion of assimilated food into larva (14.3%), pupa (92.05%) and moth (10.45%). But the total expenditure on various life activities in male is higher than female. From the time of first feeding to completion of reproductive activities about 92.38% and 89.61% of digested food were expended for respiration, moulting, larva-pupa and pupa-adult transformation in male and female respectively. The mature larva retains about 36% and 40% of the assimilated food in female and male respectively. Male larvae shares about 5.94% of digestible food for cocoon shell production while the female contribute only 5.47% leaving 7.66% and 11.5% for pupa in male and female respectively. The female diverts about 2.78% of digestible matter towards egg production. At the time of death male retains only 1.68% of digestible food, while it constitutes 2.14% in female (Table 3).

The dry matter requirement of ingested and digested food for unit growth, cocoon shell production and egg production revealed that for tissue growth of 1 g the larva require ingesting about 6.2 to 6.3 g of dry matter which equals to 2.5 to 2.8 g of digested food. While both male and female requires about 41-42 g of dry matter ingesta for production of 1 g cocoon shell, the digesta requirement in female (18.27 g) was higher than that of male (16.84 g). The female larva requires ingesting 81 g dry matter for production of 1 g of egg that equals to 36 g of digesta (Table 4).

DISCUSSION

Antheraea mylitta, like other lepidopteron insect is highly specialized for rapid growth primarily achieved by a higher rate of food acquisition. The feeding behaviour is adapted to maximise the rate at which the nutrition is absorbed from the gut and thus maximum rate the growth is achieved [16] although this leads to lower the efficiency of food utilization. In the present study, we

have observed a remarkable increase in larval weight by 4700 to 5490 times during the entire larval span following an increase in food acquisition by 319 to 383 times which leads to an increase in the digestion by 159 to 225 times. *Antheraea mylitta* silkworm larvae show an accelerating rate of absolute growth being highest (71 to 75% of the total biomass gain) during the V instar. This absolute growth remain concealed if only RGR is described which fell continuously from I to V instar after reaching a peak during II instar. During the period of V instar development (which is longer comparatively) the value of this index also witnessed a declining trend which implies that the larger animals put relatively less effort into growth than the smaller ones, despite the maintenance of a high absolute growth rate as also evidenced from earlier studies [10,16]. The larger proportions of digested food (67 to 74% of total) are available during the V instar for the higher tissue growth and to meet highest metabolic cost during silk protein synthesis and egg production.

In the present study, the rate of dry matter intake (RCR) declined with advancement of larval development, while corresponding ECI (except in V instar) and ECD increased which is corroborated with the earlier findings [15] which maintained the larval growth. The decline in RCR might be due to shorter residence time of food in the gut in younger larvae [2].

The proportional food intake during different larval instars revealed that about 95-96% of the total intake of dry matter was ingested during the last two instars and account for a 99% during last three instars of *A. mylitta*. *Bombyx* and *Protoparce*, both lepidopteran leaf feeders eat about 97% of their total intake during last two instars and about 99% during last three instars confirms our findings [15] and in *A. mylitta* fed with *Terminalia tomentosa* [10].

Approximate digestibility declines with age in *A. mylitta* so also in many other insects [15]. In contrast, Kasting and McGinnis [19] have reported a more or less constant AD in *Agrotis* during last three instars of development. The reason behind decline in AD though not clear but are attributed to the enormous growth of the

larva. Further the decline in AD with age in this insect might be due to the consumption of a higher proportion of indigestible fibre during the final instar (V instar).

Female larva ingest 16% more than male and digests 28% more in *A. mylitta* and also have significantly AD% value than male, but at the same time female registered a lower ECD value leading to lower growth rate. The results confirmed the earlier finding in the same insect with *T. tomentosa* as the source of food [10]. In contrast, no sex differences in the values for AD, ECI and ECD was reported during the V instar development of *B. mori* [18, 19].

A. mylitta retained 40% and 36% of assimilated food as matured larva in male and female respectively. About 5.94% of assimilated food in male and 5.47% in female were diverted for silk production and 2.8% for egg production, in contrast *B. mori* spends 20% for silk production and 12% for egg production. At death the *A. mylitta* female retained 2.14% and male 1.68% of assimilated food while in *B. mori* the female retained 14% and male 25% of assimilated food at the time of death. *A. mylitta* exhausted 89-92% assimilated food for respiration, moulting, larva-pupa and pupa-adult transformations which is comparable to the total expenditure of 90-91% in the same insect fed with *T. tomentosa* [10], in contrast only 52% was spent in *B. mori* [18] which may be attributed to the wild nature of *A. mylitta* which is comparatively less efficient in converting the assimilated food into growth and production of silk and eggs.

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