The Bioscan 6(3) : 475-481, 2011
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

SOME ASPECTS OF THE IDENTIFICATION OF NUTRITIONALLY EFFICIENT SILKWORMS (INSECTA: LEPIDOPTERA: BOMBYCOIDEA), THEIR METABOLIC RATE AND SUSTAINABLE DEVELOPMENT AS ENERGY RESOURCES

NITU KUMARI AND S. P. ROY*
University Department of Zoology,
T. M. Bhagalpur University, Bhagalpur - 812 007
E-mail: drsp_roy@yahoo.com

KEY WORDS
Nutritionally efficient
Metabolic rate
Sustainable development
Energy resources

Received on :
22.02.2011

Accepted on :
29.07.2011

***Corresponding author**

ABSTRACT

In the present investigation the nutritional efficiency of mulberry and tasar silkworms have been analysed. The tasar silkworms have highest activities in term of their relative rate of consumption (5.333g), assimilation (3.183g), growth (0.220g) and metabolism (2.963g) recorded in 4th larval stage. But their highest consumption rate (0.4907g/g/day), assimilation rate (0.3493g/g/day), growth rate (0.01730g/g/day) and metabolic rate (0.3319g/g/day) was observed in 2nd larval stage. Interestingly in mulberry silkworm the maximum consumption, assimilation, growth and metabolism were measured in 3rd larval stage. The maximum values of consumption, assimilation, growth and metabolism were as 0.740g, 0.693g, 0.065g and 0.628g respectively. But their rates of consumption (0.162g/g/day), assimilation (0.1520g/g/day), growth (0.010g/g/day) and metabolism (1.405g/g/day) was found maximum in 1st larval stage. In mulberry silkworms the cocoon weight (1.480-1.731g), reelability (70%) and filament length (389m) was lesser than the tasar silkworm cocoon weight (7.61g-10.50g), reelability (80%) and filament length (683m). Thus, on the comparative basis the tasar silkworms have more metabolic rate and has more silk production capacity than the mulberry silkworms.

INTRODUCTION

The silkworms are very important economic insect which contributes substantially to the national economy and Gross Domestic Production (GDP) of many countries like China, India, Thailand etc. (Chen, 2003; Chen and Gu, 2006). Sericulture is an agro-based cottage industry practiced in more than 6000 villages in India. Tasar silkworm is the sericgenous wild variety insects of tropical India and *Bombyx mori* (Mulberry silkworms) is completely domesticated in nature. The present study provides the nutritional characteristics and comparative analysis of food consumption (C), assimilation (A), growth (P) and metabolism (R) of the mulberry and tasar silkworms. The value of nutritional indices on dry weight basis of silk worms are significant for all the parameters for each larval instar with the aim of enhancing commercial sericulture in India and other countries of the region, where this activity is increasingly perceived as a promising alternative source of income generation for rural small scale farmers.

Silkworm larvae obtain nutrients from mulberry leaves to build up body, sustain life, spin cocoons and egg production. Such nutritional requirements in food consumption have direct impact on the overall physical and genetical traits such as larval and cocoon weight, quantity of silk production, pupation and reproductive traits. Silkworm nutrition refers the substances required by silkworm for its growth and metabolic functions and obtained from ingested food remaining other nutritional components are being synthesized itself through various biochemical pathways including proteineous silk fiber of commercial interest.

The nutritional adequacy of the food materials can be judged only by its ability to support growth in successive instars. In silkworm rearing food is a factor of paramount importance which regulates its growth, development and silk yield in sericulture. Silkworm breeds also differ in their nutritional requirements depending on the variety, rearing environment, season and quantum of nutrition. The efficiency of conversion of ingested food will vary with both the digestibility of a food and the proportional amount of the digestible portion of that food converted into body substance and metabolized for energy to maintain larval life. It was stated that the assimilation efficiency did not vary significantly as a function of reduced food consumption. The insect growth rate is related to the capacity of food intake (Kaufman and Bayers, 1972) and nutrients absorbed by the body from different host plants (Deshmukh *et al.,* 1977; Joshi 1985). Hiratsuka (1920) gathered detailed information on the ingestion, digestion and utilization of mulberry leaves as well as consumption of nutrients for both the growth and maintenance of life of *Bombyx mori*. The nutritional studies in mulberry silkworm with respect to food utilization have been studied in relation to growth, body weight, food digested and ingested by Ueda and Suzuki (1967), Horie and Watanabe (1983). The food consumption, assimilation and growth of silkworms have been elaborately studied in *Bombyx mori* (Hamamura, 1959; Hori, 1962; Ito, 1967; Bandan and Tara, 1984; Periasami and

Radhakrishnan, 1985; Sharma *et al.,* 1986; Naik and Delvi, 1987. However, practically no information is available on the nutritional biology of tasar silkworms due to its wild nature. Therefore, the objective of the present study will to add some information on the comparative nutritional efficiency of the tasar and mulberry silkworms under laboratory conditions.

MATERIALS AND METHODS

The study was undertaken with larval growth and their efficiency with which ingested food is converted to biomass is calculated by dividing the dry weight of food ingested into the dry weight gained by the larvae. For experiment 10 healthy silkworms *B. mori* (Nistari race) and *A. mylitta* (Daba ecorace) larvae were taken in a plastic tray. The weighed fresh mulberry and arjun leaves were provided and moisture content of leaves was maintained with utmost care by covering wax paper. A parallel batch of larvae was also maintained to replenish the missing larvae and also the dry weight and subsequently increment in larval weight separately was determined. The weight was taken and healthy silkworm larvae were counted daily and the missed larvae were replaced from reserved batch left over. The missing larvae were collected on subsequent day on daily basis and kept in a paper cover after separating manually. The left over leaves, excreta and reserve batch larvae were dried in hot air oven daily at about 60ºC to attain constant weight. For further observation the dry weight of left over leaves, excreta and larvae were recorded.

Then, the scheme for determination of nutritional efficiency was done after following by the modified IBP formula (Petrusewicz and Macfadyen, 1970). The most applicable scheme has been adopted in the present study as mentioned below:

$$C = P + R + F$$

Where, *C* = Food consumed; *P* = Growth; *R* = Metabolism (during wt loss); *F* = Fecal matter (undigested food).

I The food consumed (*C*) was calculated by total in take of dry weight of leaves by silkworm larvae during each instar.

Consumption (ingesta) = Dry weight of leaf – Dry wt of leaf left over

II Assimilation (*A*) was estimated by subtracting feed (excreta) from consumption (ingesta).

Assimilation = Consumption – Fecal matter

(Digesta) = Ingesta – Excreta

$$A = C – F$$

III Larval growth (P) was estimated by subtracting the initial dry weight of larvae in each instar from the final dry weight of respective instar.

P = Initial dry wt – Final dry wt.

IV Metabolism is measured as total biochemical reactions involving both catabolic as well as anabolic reactions of an organism. Metabolism (R) was estimated as difference between larval growth (P) and assimilation (A).

Metablism = Larval growth – Assimilation

$$R = P – A$$

The rates of consumption (Cr), assimilation (Ar), growth (Pr) and metabolic rate (Mr) were calculated by dividing the respective amount of weight by the product of mid body wt or mean wt (g) of the larvae and durations (days) required for the completion of respective instars (Waldbauer, 1968).

For estimation of various rates the following formulas have been considered

$$\text{Consumption rate (Cr)} = \frac{C}{\text{Mid body wt. x day}} \text{ g/g/day}$$

$$\text{Assimilation rate (Ar)} = \frac{A}{\text{Mid body wt. x day}} \text{ g/g/day}$$

$$\text{Growth rate (Pr)} = \frac{P}{\text{Mid body wt. x day}} \text{ g/g/day}$$

$$\text{Metabolic rate (Mr)} = \frac{R}{\text{Mid body wt. x day}} \text{ g/g/day}$$

All consumption and growth parameters were measured on dry weight basis. The indices used were relative consumption rate (Cr), growth rate (Gr), approximate digestibility (AD), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) to biomass according to Waldbauer (1968).

The following indices are as follows:

1. Consumption index (CI) = C\T*M
2. Relative growth rate (Gr) = P\T*M
3. Apporoximate Digestibility (AD) = {(C-F\C)}*100
4. Efficiency of conversion of ingested (ECI) = (Gr\CI)\100 food to body substance.
5. Efficiency of conversion of digested (ECD) = {P\(C-F)}*100 food to body substance.

Where,

M = mean weight of larvae during feeding
F = weight of faeces produced
C = weight of food consumed
P = weight gain by larvae
T = duration of feeding (days)

Statistical analysis: The data were subjected to analysis of variance (ANOVA) to determine the values of Treatment and the Control was significant. The CD ($p < 0.05\%$) and ANOVA of two factors (instar and food metabolism) such as their interaction with consumption, assimilation, growth and metabolism was calculated.

RESULTS

Table 1A, shows the highest level for consumption (5.333g), assimilation (3.183g), growth (0.220g) and metabolism (2.963g) in 4th instar of tasar silkworm larvae. The weight gain (growth) in tasar larva was recorded to be (0.070g) on the first instar of feeding. It kept on increasing on the first instar of feeding. It kept on increasing on successively till 4th instar reached upto (0.220g) and decreasing weight gain was recorded on late 5th instars due to stop feeding behaviour it results decrease in consumption, assimilation, growth and metabolism of larvae. The tasar larva consumed 1.133g of leaf on the first instars of feeding and food consumption increased progressively on successive days consumption was lowest till (0.250g) of leaf.Assimilation was calculated to be 0.783g on first instar of feeding and it increased successively

Table 1A: Measurement of food consumption, assimilation, growth and metabolism of Tasar (*Antherea mylita*) silkworm

Stage	Consumption (C–g)	Assimilation (A–g)	Growth (P–g)	Metabolism (R–g)
1st Instar	1.133	0.783	0.070	0.713
2nd Instar	2.550	1.816	0.090	1.726
3rd Instar	3.616	2.334	0.140	2.194
4th Instar	5.333	3.183	0.220	2.963
5th Instar	0.250	0.233	0.120	0.113

Table 1B: ANOVA of food consumption, assimilation, growth and metabolism of Tasar (*Antherea mylita*) silkworm

Source of variation	Sum of square	d.f.	Mean sum of square	F
Treatment (C,G,A,M)	15.3717	3	5.1239	7.91O915
Block Stage (I to V)	18.9351	4	4.7338	7.308553
Error (S.E)	7.77187	12	0.6477	
Total (T)	42.07857	19		
C.D (p<0.05%) = 1.10962				

Table 2A: Measurement of food consumption, assimilation, growth and metabolism of Mulberry (*Bombyx mori*) silkworm

Stage	Consumption (C–g)	Assimilation (A–g)	Growth (P–g)	Metabolism (R–g)
1st Instar	0.500	0.466	0.030	0.406
2nd Instar	0.625	0.582	0.040	0.543
3rd Instar	0.740	0.693	0.065	0.628
4th Instar	0.625	0.576	0.060	0.516
5th Instar	0.100	0.008	0.050	0.042

Table 2B: ANOVA of food consumption, assimilation, growth and metabolism of Mulberry (*Bombyx mori*) silkworm

Source of variation	Sum of square	d.f	Mean sum of square	F
Treatment (C,G,A,M)	0.685495	3	0.228498	21.0332
Block Stage(I to V)	0.560927	4	0.140232	12.9083
Error (S.E)	0.130364	12	0.0108634	
Total (T)	1.376786	19		
CD (p<0.05%) =0.143706				

Table 3A: Measurement of food consumption rate, assimilation rate, growth rate and metabolism rate of Tasar (*Antherea mylita*) silkworm

Stage	Consumption rate (C–g)	Assimilation rate (A–g)	Growth rate (P–g)	Metabolism rate (R–g)
1st Instar	0.4053	0.2797	0.0143	0.2546
2nd Instar	0.4907	0.3493	0.0173	0.3319
3rd Instar	0.3690	0.2381	0.0143	0.2239
4th Instar	0.2693	0.1608	0.0111	0.1496
5th Instar	0.0080	0.0074	0.0038	0.0036

Table 3B: ANOVA of food consumption rate, assimilation rate, growth rate and metabolism rate of Tasar (*Antherea mylita*) silkworm

Source of variation	Sum of square	d.f	Mean sum of square	F
Treatment (C,G,A,M)	0.2278312	3	0.075944	14.195355
Block Stage(I to V)	0.1983344	4	0.049584	9.268736
Error (S.E)	0.0641987	12	0.005349	
Total (T)	0.4903643			
CD (p<0.05%) =0.10085 at 0.05%				

till 4th instar (3.183g). Simultaneously assimilation decreased in 5th instar of larvae. The assimilation of 1st, 2nd, 3rd, 4th and 5th instar was 0.783g, 1.816g, 2.334g, 3.183g and 0.233g respectively. The metabolism was 0.713g on 1st instar and increased till 4th instar (2.963g) but it decreased in 5th instar (0.113g) respectively.

Table 2A shows the highest value of consumption (0.740g), assimilation (0.693g), growth (0.065g) and metabolism observed in 3rd instar of silkworm. Weight gain (growth) in *B.mori* was calculated as (0.030g) on 1st instar of feeding. It was found to 0.030g, 0.040g, 0.065g on successively alternate till 3rd instars respectively. But in 5th instar growth was recorded to decreasing till (0.050g). The food consumption was 0.050g of leaf on first instars. It increased progressively on 3rd instar like 0.500g, 0.625g, 0.740g respectively. Lowest consumption was recorded in 5th instar till (0.100g) of leaf and highest 0.625g in 3rd instar.The assimilation of the larva was in 1st instar (0.466g), 2nd instar (0.582g), 3rd instar (0.693g), 4th instar (0.576g) and (0.008g) respectively.The assimilation increased 1st to 3rd instar and decreased on subsequently till 5th instar to larvae. In mulberry silkworm the value of metabolism was recorded (0.406g) in 1st instar of feeding and progressively increased in metabolism to larva was observed till 3rd instar (0.628g) larvae. After a slight decline the larvae attained (0.516g) on 4th instar and (0.092g) on 5th instar respectively.

Table 4A: Measurement of food consumption rate, assimilation rate, growth rate and metabolism rate of Mulberry (*Bombyx mori*) silkworm

Stage	Consumption rate (C–g)	Assimilation rate (A–g)	Growth rate (P–g)	Metabolism rate (R–g)
1st Instar	0.1612	0.1520	0.0100	0.1405
2nd Instar	0.1011	0.0943	0.0065	0.0879
3rd Instar	0.0839	0.0785	0.0075	0.0712
4th Instar	0.0534	0.0493	0.0050	0.0441
5th Instar	0.0057	0.0005	0.0025	0.0024

Table 4B: ANOVA of food consumption rate, assimilation rate, growth rate and metabolism rate of Mulberry (*Bombyx mori*) silkworm

Source of variation	Sum of square	d.f	Mean sum of square	F
Treatment (C,G,A,M)	0.0180838	3	0.006028	0.17703
Block Stage(I to V)	0.028084	4	0.007021	0.20619
Error (S.E)	0.40861	12	0.0340508	
Total (T)	0.454718			
CD (p<0.05%) =0.2544194				

Table 5A: Evaluation of difference of food consumption, assimilation, growth and metabolism of *A. mylita* and *B.mori*

Stage	Consumption (C–g)	Assimilation (A–g)	Growth (P–g)	Metabolism (R–g)
1st Instar	0.633	0.317	0.040	0.307
2nd Instar	1.925	1.234	0.050	1.183
3rd Instar	2.876	1.641	0.075	1.566
4th Instar	4.708	2.607	0.160	2.447
5th Instar	0.150	0.225	0.070	0.071

Table 5B: ANOVA of food consumption, assimilation, growth and metabolism of *A. mylita* and *B.mori*

Source of variation	Sum of square	d.f	Mean sum of square	F
Treatment (C,G,A,M)	9.856808	3	3.285603	6.12858
Block Stage (I to V)	14.586614	4	3.646654	6.80204
Error (S.E)	6.433341	12	0.536112	
Total (T)	30.870697			
CD (p<0.05%) =1.00952 at 0.05%				

Table 6A: Evaluation of difference of food consumption, assimilation rate growth rate and metabolism rate of *A. mylita* and *B.mori* silkworms

Stage	Consumption rate (C–g)	Assimilation rate (A–g)	Growth rate (P–g)	Metabolism rate (R–g)
1st Instar	0.2441	0.1277	0.0043	0.1141
2nd Instar	0.3896	0.2550	0.0108	0.2440
3rd Instar	0.2851	0.1596	0.0068	0.1527
4th Instar	0.2159	0.1115	0.0061	0.1055
5th Instar	0.0023	0.0069	0.0013	0.0012

Table 6B: ANOVA of food consumption, assimilation rate growth rate and metabolism rate of *A. mylita* and *B.mori* silkworms

Source of variation	Sum of square	d.f	Mean sum of square	F
Treatment (C,G,A,M)	0.123513	3	0.041171	12.20243
Block Stage(I to V)	0.103004	4	0.025751	7.63219
Error (S.E)	0.040485	12	0.003374	
Total (T)	0.267002			

Table 7: Comparative values of silk production

Species	Temperature (ºC)		Relative humidity (%)		Cocoon wt (g)		Shell wt (q)		Reelability (%)	Filament Length (m)
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
Mulberry	20	20	60	70	1.480	1.731	0.255	0.327	70	389
Tasar	28	30	75	85	7.61	10.25	0.85	1.46	80	683

Table 3A in tasar silkworm an average metabolic rate was measured among all stage of larvae. The value of consumption rate (0.4907g/g/day), assimilation rate (0.3493g/g/day), growth rate (0.0173g/g/day) and metabolic rate was observed maximum level of larvae respectively. Larval growth rate increased in 1st to 2nd instar as 0.0143 g/g/day to 0.0173g/g/day respectively. After the growth rate was decreasing on subsequently till 3rd to 5th instar like 0.0143g/g/day, 0.011g/g/day and 0.0035g/g/day respectively. The highest growth rate observed in 2nd instar and lowest in 5th instar (0.0038g/g/day) and (0.0173g/g/day) respectively. The consumption rate in 1st to 5th instar was (0.4053g/g/day), (0.4907g/g/day), (0.3690g/g/day), (0.2693g/g/day) and (0.0080g/g/day) respectively. The consumption rate increased progressively in first (0.4053g) to 2nd instar (0.4907g) respectively subsequently decreased from 3rd to 5th instar like 0.3690g, 0.2693g and 0.0080g respectively. The metabolic rate was (0.2546g/g/day), (0.3319g/g/day), (0.2239g/g/day), (0.1496g/g/day) and (0.0036g/g/day) for 1st, 2nd, 3rd, 4th and 5th instars of tasar silk worm respectively. The maximum metabolic rate observed in 2nd instar and minimum in 5th instar of larvae due to maximum food utilization in 2nd instar and minimum in 5th instars respectively.

Table 4A the value of consumption rate (0.1612g/g/day), assimilation (0.150g/g/day), growth rate (0.0100g/g/day) and metabolic rate (0.1405g/g/day) were observed highest level in 1st stage of larvae in mulberry silkworm. The larval growth rate decreased subsequently from 1st to 5th instar as (0.0100 to 0.0025g/g/day) respectively. The highest growth rate was calculated in 1st stage and lowest in 5th stage of larvae.The consumption rate was highest in 1st instar (0.1612g/g/day) and lowest in 5th instar (0.0057g/g/day) in mulberry silkworm larvae. The consumption rate was found successively decreasing in 1st to 5th instar like (0.1612g/g/day), (0.1011g/g/day), 0.0839g/g/day), (0.0534g/g/day), (0.1011g/g/day), (0.0057g/g/day) respectively. As usual assimilation was also progressively decreased in 1st to 5th instar like (0.1520g/g/day), (0.0534g/g/day) and (0.0057g/g/day) respectively. As usual assimilation was also progressively decreased in 1st to 5th instar like (0.1520, 0.0943, 0.0785, 0.0993 and 0.005g/g/day) respectively.

Table 5A, the maximum difference in food consumption (4.708g), assimilation (2.607g), growth (0.160g) and metabolism (2.447g), of mulberry and tasar was found in 4th instar larvae. The difference in consumption, assimilation growth and metabolism increased progressively till 4th instar subsequently decreased in 5th instar (0.07g) respectively.

Table 6A, the consumption (0.3896g/g/day), assimilation rate (0.2550g/g/day), growth rate (0.0100g/g/day) and metabolic rate (0.2440g/g/day) was differentiated at maximum level in 2nd instar and lowest in 5th.

In Table 1B the analysis of variance value varied from 5.1239 to 4.7338 and value of CD ($p<0.05\%$) was 1.10962.In table 2B, the rate of their metabolic rate was also varied significantly between 0.228498 to 0.140232, CD was 0.143706 at $p<0.05\%$.

In Table 3B the analysis of the efficiency of ingested food was converted to larval. Growth which get increased 0.075944 to 0.049584 and CD value was 0.10085 (significant at $p<0.05\%$). Table 4B indicates the ANOVA value that differ 0.006028 to 0.007021.

In Table 5B the analysis of variance of their rate get decreased due to low rate of their ingested food (3.285603 to 3.646654) and significant at CD ($p<0.05\%$) was 1.009518. Table 6B showed the evaluation of difference of their ingested food that differ significantly from 0.041171 to 0.025751 at $p<0.05\%$.

From the Table 7 in the *Bombyx mori* (Bombycoidae) the cocoon weight (1.480-1.731g), reeliability (70%) and filament length (389m) was found lesser than the *Antherea mylita* cocoon weight (7.61g-10.50)g, reeliability (80%) and filament length (983m).

The present observation revealed that the tasar silkworms have greater role in the conversion of plant materials to silk filament per unit time than the mulberry silkworm.

The relative data provides information about comparative study of food, consumption, assimilation, growth and metabolism evaluated on dry weight and biomass basis of the larvae of silkworms. The relative growth rate increased when the consumption of food and gain in body weight increased with increase in number of instars. Hence, on comparative basis it can be concluded that the consumption assimilation, growth and metabolism was highest in 4th stage of larvae in tasar silkworms and 3rd stage in mulberry silkworms respectively.

DISCUSSION

Food consumption and utilization were lowest in young instars and measured gradually as the growth progressed in both mulberry and tasar silkworms. In tasar silkworms the highest results of consumption (5.333g), assimilation (3.183g), growth (2.220g) and metabolism (2.963g) was observed on 4th instars of larvae. In 5th instars the value of these parameters is lowest due to stop feeding behaviour. The lowest value of consumption (0.250g), assimilation (0.233g), growth (0.120g) and metabolism (0.113g) was observed in 5th instar of tasar silkworm lavae.

Food utilization parameters have been studied in many insects (Rath *et al.,* 2003). The nutritive value of mulberry leaves depends on various agro–climatic factors and any deficiency in food and nutrients affect silk synthesis in the silkworms. Nutritional management directly influences the quality and quantity of silk production (Hiware, 2006). This finding clearly indicates that the varieties with highest conversion efficiencies may reduce the larval span and consequently less quantity of the food is needed to support optimal growth (Sarkar and Fujita, 1994). Nutrition of leaves play an important role in the silkworm growth and overall silk production (Adolkar *et al.*, 2007). Any effort to improve the yield requires considerations of cumulative effect of the major traits which influence the silk yield. Vyjayanthi and Subramanyam (2002) stated in the silkworm, *B. mori* feeding behaviour depends on the niche, amount of food offered, quality of food, age and health of larvae. As most phytophagous Lepidopterans are voracious feeders any imbalance in the inputs from various factors affect food intake and result in poor larval development (Waldbauer, 1968; Vyjayanthi and Subramanyam, 2002). Gangwar *et al.* (1993) reported that *B. mori* has been found to ingest more mulberry leaves during night hours as compared to day hour. Basu *et al.* (1995) evaluated the food quality relevant to all the aspects of insect performances including growth, development and reproductive potential of mulberry silkworms. In the study conducted by Raman *et al.* (1994) approximate digestibility (AD) and efficiency of conversion of ingested food to body substance (ECI) were inversely correlated with the larval age.

Koilpillai (1995) observed that the increase in feeding duration in silk worm *B. mori* from 3 to 24 hr a day resulted in a decrease in consumption rate, assimilation rate and metabolic rate but an increase in conversion rate and gross and net conversion efficiencies. Restriction of feeding duration affected with the egg production in terms of number and biomass and first instars weight considerably. Production efficiency increased with increase in feeding duration and correlation studies were carried out on the economic parameters viz. larval, cocoon weight shell wt and nutritional parameters viz ingesta, digesta and approximate digestibility (AD) of dry matters by Raman *et al*. (1995). The patterns of correlation were different in bivoltine and multivoltine hybrids, which clearly indicated that the contributory factors for the productivity were very different. The study conducted by Singh and Ninangi (1995) indicated that ingestion, digestion and utilization of food were mostly dependent on the feeding level and genotype of the hybrid. Other factors affect on nutritional indices and arranged metabolism resulting in decreased growth may be due to nutritional stress caused by the parasitization leading to increased utilization of nutrients by the parasite under rapid multiplication (Rath *et al*., 2003). The quiescence in the absence of food also suggests that long term diet deprivation might induce a reduced metabolic state in the larva that would minimize energy loss or nutrient depletion (Nagata and Nagasawa, 2006). Srivastava *et al*. (1982) studied the effects of food deprivation on larval duration weight of cocoon and fecundity of silkworms. He found that larvae took longer time to pupate when they were deprived of food than those feeding 24 hr/day. He observed a decrease in weight of cocoon (shell) and a marked loss of fecundity due to food deprivation during feeding period.

In *B. mori* it was reported that the growth is heterogenic (Mathur *et al*. (1989) and varied according to silkworm race, quality and quantity of food intake (Krishnaswami *et al*., 1973) and climatic conditions Sharma *et al*. (1986) has undertaken to investigate various parameters such as comparative weight gain, total larval period, pupation %, weight of the cocoon formed, amount of food utilized, consumption index, growth rate, approximate digestibility, efficiency of conversion of ingested and digested food etc in the case of silkworms fed on different varieties of mulberry. Nutritional physiology is an important aspect in insect life cycle and the food consumption at different larval stages determines their relative growths which have direct relevance in rearing performances. In both silkworms the food ingested, fecal matters produced, weight gained by larvae were determined daily on a dry weight basis.

As an index of digestibility the ratio of the amount of food ingested referred to as the 'Assimilation efficiency' or the coefficient of digestibility Waldbauer, (1968) was used. The reduced larval growth and development would become evident in either the reduced digestibility of the food or in a reduction of the efficiency of conversion of ingested to larval biomass. Waldbauer (1968) as the efficiency of conversion of digested matter and by as the growth efficiency decreases as the proportion of digested food metabolized for energy and maintenance of physiological functions increases.

Measurement of the food intake and the utilization of the food elucidate to a great degree the physiological processes occurring in silkworms insect of utilization may be different although food source are similar in their ability to support growth. For instance, low food intake may be offset by a high utilization of ingested or digested food and a very high food intake may well lead to a very low efficiency in the utilization of ingested on digested food. Remadevi *et al*. (1993) studied the correlation of nutritional and economic characters of multivoltine silkworms in three different seasons. The correlation coefficient of ingesta and digesta was significantly positive. The correlation of ingesta to body weight gain vs cocoon weight, shell weight and fecundity were highly significant and positive. The larval duration increased with increase in ingesta. The rate of food consumption is influenced by the physical and chemical nature of food and the physiological state of insects Waldbauer (1968). The decreasing trend of consumption index with the increasing age of insect larvae is attributed to their differential response to the bulk water content, physical and chemical constitution of food etc. (Delvi and Pandian, 1971; Mehrotra *et al.,* 1972; Ramdev and Rao, 1979) has also reported slight decrease in consumption indices of fifth instar. The tendency of such increase consumption index (CI) of fifth instar larvae seems to be due to the preparatory phase to enhance the reproductive potential of emerging female moth. Simultaneously for the production of heavy trend of decreasing CI with the increasing age of larvae. Thus, the important physiological changes going on inside the maturing silkworm larvae influence the rate of consumption of food.

Tzenov (1995) studied the daily ingestion, digestion and utilization of food in pure breeds on silkworms. Fotedar and Dandin (1997) studied the efficiency of the leaves of different mulberry varieties growing under different standing conditions as diet for silkworms in the fifth instars. Hamaro *et al*. (1994) studied the relationship between food consumption and molting of silkworm *Bombyx mori* L. According to Mishra and Upadhyay (1995) all the indices of consumption and utilization viz., CI, Gr, AD, ECI and ECD were influenced significantly by both temperature [18, 22, 26, 30 and 34ºC] variation and change in larval instars in mulberry silkworms.

Thus, on the comparative basis the Saturniidae species (tasar silkworms) have more active metabolism and gave more silk production than the mulberry silkworms. Hence, tasar silkworms will be more beneficial and may be exploited for their commercialization as cottage industry for their sustainable development as energy resources.

The highest values of growth, consumption and their relative rates during IV instar larvae instead of Vth instar due to stop age feeding activity at late Vth instar stage. The absolute values for food consumption, assimilation, tissue growth and metabolism were increased upto IV instar, where decreases in V instar due to less intake of food nutrients.

The less food consumption affects the metabolism and their various conversion rates. Any physiological effect that would significantly reduce larval growth and development became evident in either the reduced digestibility of food or in a reduction of the efficiency of conversion of ingested food to larval biomass.

The absolute values for food consumption, assimilation, tissue growth and metabolism were increased upto IV instar, where as decreases in Vth instar due to less intake of food nutrient.

REFERENCES

Adolkar, V. V., Raina S. K. and Kimbu D. M. 2007. Evaluation of various mulberry *Morus Spp*. (Moraceae) Cultivars for the rearing of the bivoltine hybrid race Shaanshi BV-333 of the silkworm *B.mori*. *Int. J. Trop. Insect Sci*. **27**: 6-14.

Badan, P. and Tara, J. S. 1984. Comparative weight gain in silkworm, *Bombyx mori* L. fed on different varieties of mulberry. *Zoological, Orientalix*. **2:** pp. 53 – 54.

Basu, R., Roychoudhury, N., Shamsuddin, M., Sen, S. K. and Sinha, S. S. 1995. Effct of leaf quality on rearing and reproductive potential of *Bombyx mori* L. *Indian Silk*. **95:** pp. 21-22.

Chen, C. H. and GU, S. H. 2006. Stage dependent effects of starvation on the growth, metamorphosis and ecdysteriodogenesis by the prothoracic glands during last larval instar of silkworm *B.mori J. Insect. Phys*. **52**: 968-974.

Chen, Y. 2003. Variable tolerance of the silkworm *Bombyx mori* to atmospheric fluoride pollution. *Fluoride*. **36:** 157 – 162.

Delvi, M. R. and Pandian, T. J. 1971. Ecophysiological studies on the utilization of food in the paddy field grasshopper Oxya Velox. *Oecologia*. **8:** 267-275.

Deshmukh, P. O., Rathore, Y. S. and Bhattacharya, A. K. 1977. Studies on growth and development of *Diacrisia obliqua* (Lep., Arctri.) on sixteen plant spp. Z., *Ang. Ent*. **84:** 431-435.

Fotedar, R. K. and Dandin, S. B. 1997. Chemical composition and feeding studies of different elite mulberry varieties under temperature conditions. *Indian J. Ser*. **36**: 22-26.

Gangwar, S. K., Samasundaram, P. and Thangavelu, K. 1993. Feding behaviour of silkworm *Bombyx mori* L. *J. Adv. Zool*. **14(2):** 115-118.

Hamamura, Y. 1959. Food selection by silkworm larvae. *Nature*. **183:** 1746-1747.

Hamaro, K., Ikeda, A. and Shen, W. 1994. Relationship between food consumption and molting of the silkworm *Bombyx mori Proc. Jpn. Acad. Ser.B. Phys. Biolo. Sci*. **70(9):** 146 – 150

Hiratsuka, E. 1920. Researches on the nutrition of the silkworm. *Bull. Seric. Xp. Stn. Japan*. **1:** 257-315.

Hiware, C. J. 2006. Effect of fortification of mulberry leaves with homeopathic drug Nux Vomica on *Bombyx mori*. L. *Homeopathy*. **95:** 148 -150

Hori, Y. 1962. Effect of various fractions of mulberry leaves on the feeding of silkworm, *Bombyx mori* L. *J. Seri. Sc. Japan*. **31:** 258-264.

Horie, Y. and Watanabe, K. 1983. Daily utilization and consumption of dry matter in food by the silkworm *B.mori* L (Lepidoptera : Bombycoidae). *App. Entomol. Zool*. **18**: 70-80.

Ito, T. 1967. Nutritional requirement of the silkworm *Bombyx mori* L. *Proc. Japan Acad*. **43:** 57 - 61

Joshi, K. L. 1985. Studies on growth indices of Eri silkworm, Philosamia ricini Hutt. (Lepi.: Sat.). *Sericologia*. **25(3):** 313-319.

Kaufman, G. A. and Bayers, R. J. 1972. Relationship of weight, length and body composiotn in the *Medala orizes latipas*. *Amer. Medd. Natl*. **88:** 239-245.

Koilpillai, 1995. Impact of nutritional modulation on survival, growth bioenergetics and reproductive potential in silkworm, *Bombyx mori* L.J. *Entomol Res*. **19:** 223-227.

Krishnaswami, S., Narasimhanna, M. N., Suryanarayan, S. K. and Kumararaj, S. 1973. Manual of Sericulture, Vol. II (Silkworm Rearing) Published by F.A.O., U.S.A., Rome, Agri. *Service Bulletin* AGS, ASB/ 15, pp. 64.

Mathur, S. K., Roy, A. K., Sen, S. K. and Subba Rao, G. 1989. Studies on the growth of Silkworm *Bombyx mori* L. (Lepi. : Bom.) under tropical conditions. *Indian J. Seric*. **28(1):** 71-79.

Mehrotra, K. N., Rao, P. J. and Faraoqui, T. N. A. 1972. The consumption, digestion and utilization of food by locust. *Ent. Exp. Appl*. 90 – 96.

Nagata, S. and Nagasawa, H. 2006. Effect of diet-deprivation and physical stimulation on the feeding behaviour of the larvae of the silkworm. *Bombyx mori J. Insect Phys*. **52**: 807-815.

Naik, P. R. and Delvi, M. R. 1987. Food utilization of different races of silkworm, *Bombyx mori* L. (Lepi. : Bom.). *Sericologia*. **27(3):** 391-397.

Periasami, K., Radhakrishnan, R. 1985. Quantitative study of food utilization and silk production in *B.mori* L. or evaluation of superior varieties. *Sericologia*. **25**(**4**)**:** 491-500.

Petrusewicz, K. and Macfadyen, A. 1970. Productivity of terrestrial animals *Principles and method* . IBP Handbook, No 13 Blackwell Scientific Pbs., Oxford and Edinburgh. p. 190.

Raman, A. K. V., Magdum, S. B., Shivakumar, G. R., Giridhar, K. and Datta, R. K. 1995. Correlation studies on different economic and nutritional parameters in *Bombyx mori* L.hybrids. *Indian J. Seric*. **34:** 118-121.

Raman, K. V. A., Mgdum, S. B. and Datta, R. K. 1994. Feed efficincy of the silkworm *Bombyx mori* L. hybrid (NB4DC x KA) *Insect Science and Appl*. **15(2):** 111-116.

Ramdev, Y. P. and Rao, P. J. 1979. Consumption and utilization of castor, *Ricinus communis* Linn. by castor semilooper, *Achaea janata* Linn. Indian J. Ent. 41: 260 - 266.

Rath, S. S., Prasad, B. C. and Sinha, B. R. R. P. 2003. Food utilization efficiency in fifth instar larvae of *Antherea mylita* (Lepidoptera : Saturniidae) infected with *Nosema sp*. and its effect on reproductive potential and silk production. *J. Invert. Pathol*. **83**:1-9.

Remadevi, O. K., Magadum, S. B., Benchamin, K. V. and Datta, R. K. 1993. Mutual correlation among the nutritional and economic characters of the multivoltine silkworm, *Bombyx mori* L. (Lpidoptera : Bombycidae). *Indian J.Sric*. **32(2):** 189-195.

Sarkar, A. and Fujita, H. 1994. Better technique for nutritive evaluation of mulberry leaves for silkworm, *Bombyx mori* L. *Indian J. Ser*. **33:**19-22.

Sharma, B., Badan, P. and Tara, J. S. 1986. Comparative consumption, population and silk production in silkworm, *Bombyx mori* fed on various varieties of mulberry existing in Jammu division of Kashmir State. *Sericologia*. **26(26):** 419-429.

Singh, G. B. and Ninangi, O. 1995. Comparative studies on food utilization efficiency in some silkworm strains under different feeding level, *Sericologia*. **35(4):** 667-675.

Srivastava, A. D., Mishra, S. D. and Poonia, F. S. 1982. Effect of food depreivation on larval duration, cocoon (shell) weight and fecundity of eri silkmoth, *Philosamia ricini Hutt* (Lepidoptera:Saturnidae). *Indian J. Seric*. **21-22:** 11-15.

Tzenov, P. 1995. Studies on the daily ingetion, digestion and utilization of dry matter in food in pure breeds of silkworm, *bombyx mori*, L. Bulgarian *J. Agric. Sci*. **1:** 189-196.

Ueda, S. 1982. Theory of the growth of silkworm larvae and its application. *JARQ*. **15(3):** 180-184.

Ueda, S. and Suzuki, K. 1967. Studies on the growth of silkworm, *Bombyx mori* L. I.chromological changes of the amount of food ingeted and digested, body weight and water content of the body and their mutual relationships. *Bull. Seric. Exp. Stn*. Japan. **22(1):** 65-67.

Vyjayanthi, N. and Subramanyam, M. V. V. 2002. Effect of fenvalerate-20EC on sericigenous insects: I. food utilization in the late-age larva of the silkworm, *Bombyx mori* L. *Ecotoxic. Environ. Saf*. **53**: 206-211.

Waldbauer, G. P. 1968. Consumption and utilization of food by insects. *Adv. Insect Phyciol*. **5:** 229-288.