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Relation among Food Consumption, Conversion and Cocoon Production in Silkworm, *Bombyx Mori* L. Reared at Different Temperatures

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Rearing temperature influences food consumption, conversion and cocoon production in silkworm *Bombyx mori* L. Young age (1st to 3rd instar) worms of Pure Mysore, a multivoltine were reared at 26, 28, 30 and 32°C followed by combinations of these temperature levels during late age (4th and 5th instar). Food consumption, conversion, larval duration and growth for each instar were recorded. The influence of combinations of these temperature levels during rearing on survival and cocoon production was assessed. Food consumption increased with the temperature up to 4th instar and decreased during 5th instar. Temperature beyond 28°C during young age followed by higher temperature (30°C and above) has shown deleterious effect on cocoon production. The paper discusses the rearing performance in relation to food intake and conversion under the tested temperature levels.

Key words: *Bombyx mori* L., Cocoon production, Food intake, Conversion

Introduction

Rearing temperature plays a prominent role in food intake, conversion and economic characters of silkworm *Bombyx mori* L. (Muniraju *et al.,* 1999). Information on consumption and utilisation of food is of great importance to identify the factors responsible for the crucial stage that contributes more to adjudicate the superiority of promising races (Afthab Ahamed and Chandrakala, 1999). There are reports on temperature directly affecting the performance of silkworm (Shivakumar *et al.,* 2000). The food intake in the larval instars significantly influences the resulting pupae, adult, egg and silk production in *B.mori* (Maribashetty *et al.,* 1999). Slansky and Scriber (1985) reported that the ambient temperature alters food consumption, conversion and related parameters. However, there is no information on the effect of constant and combinations of rearing temperature during young age (1st to 3rd age) and late age (4th and 5th age) on food consumption, conversion and influence of these parameters on cocoon production. These temperature-oriented factors are inseparable components (Ullal and Narasimhanna, 1994) for silkworm rearing. Hence, studying its influence in combination effect was felt relevant and useful. Keeping this in view an effort has been made to study the relevance of temperature in each instar on food intake, conversion and its impact on cocoon production in silkworm.

Materials and Methods

Larvae of multivoltine Pure Mysore (PM) race were reared at constant temperature of 26, 28, 30 and 32°C during young age and combinations of these levels during late age using separate isolation chambers, having facility to maintain the set temperature, humidity, light and air flow throughout the rearing period for each identified temperature (Sekharappa *et al.*, 1995). Treatments selected were as shown in Table 1.

Four replicates of 400, 200, 100, 50 and 25 larvae each were maintained during 1st, 2nd, 3rd, 4th and 5th instars respectively in relation to their leaf consumption capacity. Fresh mulberry leaves from irrigated M_5 garden were used *ad libitum* for the experiments. Leaf samples of known weight were kept in the hot air oven for drying to estimate the dry weights. The amount of food intake was measured following standard gravimetric method described by Waldbauer (1968). While calculating, appropriate corrections were incorporated for water loss during feeding period.

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Table 1. Treatment schedule for silkworm rearing

Treatment	Young age rearing temperature (°C)	Late age rearing temperature (°C)
T1a	26	26 (Control)
T1b	26	28
T1c	26	30
T1d	26	32
T2a	28(Control)	26(Control)
T2b	28	28
T2c	28	30
T2d	28	32
T3a	30	26(Control)
T3b	30	28
T3c	30	30
T3d	30	32
T4a	32	26 (Control)
T4b	32	28
T4c	32	30
T4d	32	32

Left over leaf and litter were collected separately and daily at 10 am before giving fresh leaf and dried in hot air oven at 100°C till the constant weight is attained (Waldbauer, 1968).

Simultaneously experiments were conducted to study the effect of temperature on rearing performance. Larvae from 25 disease free layings (dfls) for each treatment (approximately 10,000 larvae) were brushed *en mass* and reared at identified constant temperature of 26, 28, 30 and 32°C during young age, in separate isolation chambers. Larvae after 3rd moult from each of the treatments with 4 replicates larvae were transferred to identified late age temperatures for further rearing. Batches of both the experiments were maintained in the identified isolation chambers and the experiments were repeated thrice. Recommended humidity was maintained as per the age of the larvae (Ullal and Narasimhanna, 1994). Instar wise data on food intake, conversion, cocoon weight and yield were recorded. The data of the three trials were pooled and analised statistically using ANOVA (Sundararaj *et al.*, 1972).

Results

Consumption

The dry food consumption increased with rearing temperature in all the batches up to 4th instar and decreased during 5th instar (Table 2, 3, 4, 5). For instance, the food consumption during 1st instar at T1a is 1.63 mg/larva and increased to 1.73, 2.27 and 2.85 mg/larva for T2a, T3a and T4a. The same trend was observed for other treatments upto 3rd instar. Even after shifting to different combinations of temperature, the larvae maintained the same trend of increased food consumption during 4th instar and the food

Table 2. Food consumption and rearing performance of Pure Mysore under 26°C during young age and different rearing temperature levels during late age

Parameters	Age of the larvae	Late age rearing temperature (°C)				F test	CD@	
		26(T1a)	28(T1b)	30(T1c)	32(T1d)		5%	1%
	1st instar	1.63	---	---	---	---	---	---
Food	2nd instar	10.54	---	---	---	---	---	---
intake	3rd instar	49.22	---	---	---	---	---	---
(mg/larva)	4th instar	267.87	268.29	292.83	319.91	HS	8.70	12.19
(dry wt.)	5th instar	3059.60	2974.58	2817.80	2663.47	HS	61.11	85.67
	Total	3389.28	3303.81	3172.01	3044.76	HS	68.54	96.09
	1st instar	0.39	---	---	---	---	---	---
Conversion	2nd instar	1.48	---	---	---	---	---	---
(mg/larva)	3rd instar	6.16	---	---	---	---	---	---
(dry wt.)	4th instar	33.55	32.37	32.42	31.53	HS	0.75	1.05
	5th instar	387.35	377.87	360.61	344.07	HS	16.25	28.21
	Total	428.93	410.24	393.03	375.59	HS	13.89	23.41
Cocoon yield (No)	(10000 larvae)	9444	9287	9221	8016	HS	366.00	628.00
Cocoon yield (wt.)	(kg/10000 larvae)	10.42	10.36	10.41	8.58	HS	0.92	1.76
Cocoon wt. (g)		1.14	1.15	1.17	1.10	HS	0.24	0.41

Note: HS-Significant at 1%.

Table 3. Food consumption and rearing performance of Pure Mysore under 28°C during young age and different rearing temperature levels during late age

Parameters	Age of the larvae	Late age rearing temperature (°C)				F test	CD	
		26(T2a)	28(T2b)	30(T2c)	32(T2d)		5%	1%
	1st instar	---	1.73	---	---	---	---	---
Food	2nd instar	---	10.64	---	---	---	---	---
intake	3rd instar	---	57.72	---	---	---	---	---
(mg/larva)	4th instar	324.63	330.98	332.42	348.12	HS	8.70	12.19
(dry wt.)	5th instar	3005.06	2986.40	2958.40	2831.40	HS	61.11	85.67
	Total	3407.58	3376.61	3381.12	3232.47	HS	68.54	96.09
	1st instar	---	0.39	---	---	---	---	---
Conversion	2nd instar	---	1.45	---	---	---	---	---
(mg/larva)	3rd instar	---	6.92	---	---	---	---	---
(dry wt.)	4th instar	36.76	34.22	33.19	32.98	HS	1.03	1.96
	5th instar	369.66	355.16	362.29	332.88	HS	12.28	20.26
	Total	406.42	398.14	395.49	365.85	HS	15.82	25.69
Cocoon yield (No)	(10000 larvae)	9154.00	9433.00	9367.00	8979.00	HS	126.00	216.00
Cocoon yield (wt.)	(kg/10000 larvae)	10.28	10.55	10.42	10.00	HS	0.16	0.28
Cocoon wt. (g)		1.17	1.15	1.16	1.11	HS	0.04	0.07

Note: HS-Significant at 1%.

Table 4. Food consumption and rearing performance of Pure Mysore under 30°C during young age and different rearing temperature levels during late age

Parameters	Age of the larvae	Late age rearing temperature (°C)				F test	CD @	
		26(T3a)	28(T3b)	30(T3c)	32(T3d)		5%	1%
	1st instar	---	---	2.27	---	---	---	---
Food	2nd instar	---	---	12.54	---	---	---	---
intake	3rd instar	---	---	62.54	---	---	---	---
(mg/larva)	4th instar	319.73	325.73	356.20	343.52	HS	8.33	11.68
(dry wt.)	5th instar	3069.90	3048.87	3010.60	2903.60	HS	25.00	49.23
	Total	3474.31	3459.28	3451.48	3331.80	HS	78.00	135.21
	1st instar	---	---	0.40	---	---	---	---
Conversion	2nd instar	---	---	1.62	---	---	---	---
(mg/larva)	3rd instar	---	---	7.09	---	---	---	---
(dry wt.)	4th instar	36.71	31.53	35.36	34.08	HS	1.25	2.04
	5th instar	371.86	359.25	359.30	317.91	HS	15.23	28.26
	Total	408.57	390.78	403.77	351.99	HS	16.25	30.89
Cocoon yield (No)	(10000 larvae)	9271	9296	8971	5561	HS	561.00	1052.00
Cocoon yield (wt.)	(kg/10000 larvae)	10.92	10.41	10.34	5.78	HS	3.47	5.76
Cocoon wt. (g)		1.19	1.18	1.15	1.11	HS	0.06	0.10

Note: HS-Significant at 1%.

Table 5. Food consumption and rearing performance of Pure Mysore under 32°C during young age and different rearing temperature levels during late age

Parameters	Age of the larvae	Late age rearing temperature (°C)				F test	CD @	
		26(T4a)	28(T4b)	30(T4c)	32(T4d)		5%	1%
	1st instar	---	---	---	2.85	---	---	---
Food	2nd instar	---	---	---	13.77	---	---	---
intake	3rd instar	---	---	---	69.87	---	---	---
(mg/larva)	4th instar	334.38	344.82	400.44	369.06	HS		
(dry wt.)	5th instar	3177.87	3162.86	3055.77	2603.47	HS	89.60	125.62
	Total	3576.40	3601.86	3535.37	3051.48	HS	83.80	117.49
	1st instar	---	---	---	0.43	---	---	---
Conversion	2nd instar	---	---	---	1.58	---	---	---
(mg/larva)	3rd instar	---	---	---	7.42	---	---	---
(dry wt.)	4th instar	37.11	39.31	37.80	34.40	HS	1.895	3.213
	5th instar	366.45	352.68	336.16	289.45	HS	23.7	52.37
	Total	403.56	392.00	373.96	333.29	HS	8.79	15.19
Cocoon yield (No)	(10000 larvae)	9213	8817	7450	5100	HS	668.00	1108.00
Cocoon yield (wt.)	(kg/10000 larvae)	10.83	10.35	8.16	5.07	HS	0.57	1.02
Cocoon wt. (g)		1.19	1.19	1.13	1.01	HS	0.08	0.13

Note: HS-Significant at 1%.

intake was maximum in T4c (400.44 mg/larva) (Table 5) while it was minimum in T1a (267.87 mg/larva) (Table 2). However, during 5th instar the food intake decreased with the increase in temperature and the results were significant ($P > 0.01$).

Conversion

Food conversion increased with temperature for first 3 instars. However, during 4th and 5th instars it decreased (Table 2, 3, 4, 5). For instance, the conversion for 1st instar is 0.39 mg/larva for T1a and it increased to 0.43 mg/larva for T4a. It is 1.48 to 1.58 and 6.16 to 7.42 mg/larva for 2nd and 3rd instars, respectively for the same treatments (Table 2 and 5). Conversion decreased with increase in temperature during 4th and 5th instars. Larvae reared at T1a exhibited conversion of 33.55 mg/larva while larvae reared at T1d showed 31.53 mg/larva. Same trend of decreased conversion was recorded for other temperature levels and also for 5th instar (Table 2, 3, 4, 5).

Cocoon production

Cocoon production by yield by number and by weight was maximum in T1a and it decreased with increased temperature. The minimum yield was recorded in T4d the highest constant rearing temperature. The same trend of treatment differences was recorded for cocoon weight.

Rearing performance

The larval duration in T1a recorded was maximum (658 hrs) and the duration decreased with increased temperature. The minimum larval duration of 499 hours was recorded at T4d, the highest constant rearing temperature. The larval weight recorded positive relation up to 4th instar and negative relation during 5th instar for temperature. Same trend of treatment differences was recorded for cocoon weight, shell weight and shell ratio.

Maximum effective rate of rearing by number was recorded in T1a (94.44%) followed by T2b, T2c, T3b, T1b, T3a, T1c and T4a (94.33 to 92.13%) which did not differ significantly among themselves in respect of the ERR by number. Progressive decrease in the ERR was recorded from a to b to c to d in respect of T1, T2, T3 and T4 the differences being significant in majority of the cases (Table 2).

Maximum fecundity (eggs laid by a moth) was recorded for T3b with 459 eggs and poor fecundity was recorded for T3d and T4d batches (381 and 315 eggs, respectively).

The fecundity decreased with increase in temperature and the intensities were temperature dependent (Table 2,3,4,5).

Discussion

The lepidopteran insects like *Bombyx mori* are known to adopt themselves to the changing environmental conditions so as to pupate, emerge and reproduce successfully (Delvi and Nayak, 1984). Among the environmental factors, temperature is known to have a predominant influence on growth, development and productivity in silkworm (Shivakumar *et al.,* 2000). In the commercial rearing of silkworms, studying the effect of temperature in combination was found more relevant than considering constant temperature throughout. The parameters of food consumption, conversion, productivity and larval duration vary with temperature combination (Muniraju *et al.,* 1999), silkworm breed, season and larval instars (Maribashetty *et al.,* 1999).

The amount of dry food consumed exhibited an increasing trend up to 4th instar and suddenly decreased during 5th instar for the same temperature leading to greater demand for energy to meet the metabolic activities (Hochachka and Somero, 1973). However, the decrease in food intake during 5th instar contributes to the temperature with the increased larval size (Bartholomew, 1981; Casey, 1981). These responses clearly indicate the predominant role of temperature influencing the rates of food transportation in the gut (May, 1979). In the tested silkworm race Pure Mysore increased consumption with temperature up to 4th moult, the rate of passage of food through its gut may increase allowing less time for digestion and thus leading to lower food assimilation (Mathavan and Pandian, 1975). Similar observations were recorded in the present study. On the contrary a prolongation of food passage in the gut may bring about an increase in assimilation efficiency (Slansky and Scriber, 1985). In the present study it is evident that Pure Mysore silkworm larvae are continuous feeders and require the amount of energy gained through intake to spend on lower oxidation and convert more or on par with control through faster conversion rate leading to higher biomass accumulation in all the treated batches. However, from the commercial point of view a silkworm breed, which consumes minimum with shortened larval duration and utilizes the food to the maximum extent for the body weight should be considered more productive than the others (Remadevi *et al.,* 1992). The differences in consumption and conversion between the races were also observed by earlier workers and considered to be an important parameter while evaluating new races both in temperate and tropical countries (Takano and Arai, 1978; Chandrakala *et al.,* 1999). The conversion of food-ingested depends on digestibility and leaf moisture content (Narayan Prakash *et al.,* 1985). In the present study the consumption of food and utilization parameters among different temperatures indicated that the conversion is more in higher temperatures in spite of low food consumption. This observation clearly indicates that the larvae under low input manage to accumulate more of nutrients by increasing the efficiency and feeding periods in order to maintain critical level of growth limiting nutrients such as nitrogen and water (Slansky and Feeny, 1977). It is known that the rearing temperature has a direct relation with the rates and efficiencies of physiological activities of the insects (Benchamin and Jolly, 1986). These compensatory responses of enhanced conversion efficiencies are adoptive mechanisms by which the insect strives to attain optimal body weight for fitness and synchrony in life cycle. It is known that the attainment of minimum body size or biomass is a prerequisite for successful metamorphosis in insects (Engelmann, 1966). However, the altered response of better food transformation capacities at higher rearing temperature could not be appreciated from the economic point due to the expression of poor biomass accumulation apart from its negative influence on cocoon characters. It is often found logical that in insects particularly in silkworms the effect of environment at one stage of life cycle will be reflected in the subsequent stages (Ullal and Narasimhanna, 1994). For instance the lower biomass perpetuates into lower cocoon weight leading to lower pupal weight and so on. It is evident that the combination of higher temperature affected the silkworm by adopting its efficiency of conversion of food to larval biomass, cocoon, shell and fecundity. This indicates that the lower temperature (26 and 28°C) during young age and 28 to 30°C during late age will not affect the silkworm production potential though it alters the food intake and utilization efficiencies resulting in higher cocoon parameters. Based on the different food budget parameters and cocoon characters the performance of multivoltine silkworm in the rearing temperature of 26 and 28°C (in combination) stood first when compared to the remaining combinations of temperature. This study confirms the relationship of abiotic (rearing temperature) and biotic (food intake and conversion) factors responsible for cocoon production. In addition it also confirms the above recommended rearing temperature which could be used to improve the growth and development of silkworm through nutritional indices (efficiencies) and ultimately to improve the cocoon yield.

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