RELATIVE EFFICIENCY OF MULBERRY LEAF CONVERSION INTO SILK OF DIFFERENT *BOMBYX MORI* L. STRAINS

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Abstarct

Efficiency of mulberry leaf conversion into cocoons and cocoon shells was determined for seven exotic bivoltine pure lines of *Bombyx mori* L. strains (J-99, J-101, 205-MKD, 206-MKD, 206-PO, 207-PO and 208-PO) during spring and autumn seasons. Eight quantitative traits viz., total food ingestion (TI), Total food digestion (TD), cocoon weight, shell weight, efficiency of conversion of ingested food into cocoon (ECIC) & shell (ECIS), efficiency of conversion of digested food into cocoon (ECDC) & shell (ECDS) were measured. Rearing was carried out at 24±1 °C and 75±5%RH during spring and 28±1 °C and 75±5%RH during autumn. The strains J-99, J-101 and 205-MKD were the most efficient to convert ingested and digested food into cocoon and cocoon shell The mximum TI (4080.25 mg/larva), TD (2031.25mg/larva), single cocoon weight (1233.75mg), shell weight (291.5mg), ECIC (32.6%), ECIS (7.15%), ECDC (67.75%) and ECDS (15.03%) were recorded in J-101, J-101, J-99, J-101, J-99, J-101& 205-MKD, 205-MKD and 205-MKD, respectively during spring. Similarly minimum TI (3325.98mg/larva), TD (1543.93 mg/larva), cocoon weight (938.75 mg), shell weight (183.75 mg), ECIC (28.73%), ECIS (5.50%) and ECDS (11.98%) were found in 207-PO while ECDC (60.60%) was in 206-PO. During autumn the total ingestion and digestion of mulberry leaf were approximately the same as in spring however, cocoon and shell weights ECIC, ECIS, ECDC and ECDS were lower in all test strains. Based on these results it is recommended that more profitable and efficient strains like J-99, J-101, 205-MKD, etc. should be reared at 24±1 C° with 75±5% RH. In addition, training of mulberry plants should be carried out before the autumn rearing to get young nutritious leaves.

Key words: Silkworm, *Bombyx mori* , Rearing, Efficiency, Mulberry leaf.

Introduction

Sericulture is an intensive labour based cottage industry in Pakistan. It involves two distinct activities namely, mulberry leaf production and silkworm rearing. Mulberry leaf is a vital commodity for successful sericulture enterprise. It is not only a limiting factor for silkworm rearing activities (Hanjra, *et al.*, 1995) but also determines economic returns. About 60 percent of the total cost of silk production is incurred on mulberry leaf (Rangaswami, *et al.*, 1976). However, the quantity of leaf required depends on how efficient are the other activities of sericulture.

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The cocoon yield is the cumulative effect of many quantitative traits of silkworms. Selection of silkworm strains based on multiple traits is helful in judging the superiority of the strains and consequently to make this enterprise commercially viable. For instance, by reducing the larval duration, the quantum of leaf consumed can also be reduced which in turn lowers labour input in cocoon production resulting in increased net returns (Khawaja and Haq, 1991; Narayanaswamy *et al.*, 2002). Another important commercial property of silkworm is its efficiency of conversion of mulberry leaf into silk (Muniraju *et al.*, 1999). Rearing of silkworm strains/races having high efficiency of conversion of leaf to silk can enhance silk productivity per unit area and/or food. Various food consumption and utilization coefficients have been calculated for different silkworm strains (Rafique and Bajwa, 2004), but a dearth of studies still abounds on the quantification of conversion of mulberry leaf into silk by different silkworm strains.

Present study therefore, was aimed at assessing efficiency of conversion of mulberry leaf into cocoon and cocoon shell of different silkworm strains, vis-à-vis rearing seasons.

Materials and Methods

Efficiency of conversion of mulberry ingested and digested leaves into cocoon and cocoon shell was assessed for seven exotic bivoltine pure line *Bombyx mori* L. strains, namely; J-99, J-101, 205-MKD, 206-PO, 207-PO and 208-PO. Four hundred (400) disease free neonate for each strain were selected at random from the stock culture and weighed. They were fed weighed mulberry leaves (*Morus alba* var PFI-1) five times a day, i.e. at 0600, 1000, 1400, 1800, and 2200 hours throughout larval stage. The gravimetric method (Nath *et* al., 1990) was applied for studying the food ingestion, digestion and larval body weight gain. Fresh mulberry leaves were weighed, one half of it was given to the silkworms as food while other half was dried at 100°C to a constant weight which served as aliquot for calculation of amount of leaves given to the larvae on dry weight basis. Larval body weight was taken after and before each moult in a stadium. The formulae used for calculating different parameters were:

Total Ingestion = Total leaf supplied – leaf left over
Total Digestion = Total leaf ingested – Excreta

Efficiency of conversion of ingested mulberry leaf in cocoon

$$(ECIC) = \frac{\text{Weight of single cocoon}}{\text{Total ingestion / larva}} \times 100$$

Efficiency of conversion of ingested mulberry leaf in cocoon shell

$$ECIS = \frac{\text{Weight of single cocoon shell}}{\text{Total ingestion / larva}} \times 100$$

Efficiency of conversion of digested mulberry leaf into cocoon

$$(ECDC) = \frac{\text{Weight of single cocoon}}{\text{Total digestion / larva}} \times 100$$

Efficiency of conversion of digested mulberry leaf into cocoon shell

$$(ECDS) = \frac{\text{Weight of single cocoon shell}}{\text{Total digestion / larva}} \times 100$$

During spring season (March-April) indoor temperature kept was 24±1°C° with relative humidity of 75±5%. The experiment was carried out in a randomized complete block design with four replications. Same experiment was repeated in autumn season (September-October) at 28±1 °C with 75±5%RH. Mean data of various traits were analyzed statistically applying Two-way analysis of variance (ANOVA) and difference among individual silkworm strains was realized by least significant difference (LSD) test. In addition, difference between two rearing seasons was ascertained with the help of Pooled estimate of variance.

Results and Discussion

Data on different attributes of food conversion into silk, viz. total dry leaf ingestion (TI) and digestion (TD), cocoon & shell weight, efficiency of conversion of ingested leaf into cocoon (ECIC) and shell (ECIS) and efficiency of digested food into cocoon (ECDC) and shell (ECDS) are presented in Table 1 (spring rearing) and Table 2 (autumn rearing). In both the rearing seasons significant to highly significant difference was registered among the test silkworm strains for various parameters.

Spring Rearing

Overall difference among the seven silkworm strains was highly significant in TI, TD, Cocoon & shell weight, ECIS and ECDC while it was significant in ECIC and ECDS (Table-1). Almost a similar pattern of total leaf ingestion and digestion was found among the strains. Maximum (4080.25 mg larva^{-1}) and minimum (3325.98 mg larva^{-1}) total leaf ingestion was recorded in J-101 and 207-PO, respectively. However, there was non-significant difference among J-101, 206-MKD and 206-PO; J-99, 205-MKD and 208-PO. J-101 was also the most efficient to digest ingested food followed by 206-MKD, 206-PO, J-99, 208-PO, 205-MKD and 207-PO. J-99, 205-MKD, 206-PO and 208-PO did not differ significantly among them. Maximum cocoon weight did not correspond with TI and TD however; shell weight was positively related with them. The highest cocoon (1233.75 mg) weight was displayed by J-99 but that was statistically non-significant with J-101, 205-MKD and 206-MKD. Likewise, the difference among J-101, 205-MKD, 206-MKD and 206-PO; 205-MKD, 206-PO and 208-PO was non-significant. The least cocoon (938.75mg $cocoon^{-1}$) and cocoon shell (183.75 mg $shell^{-1}$) weight was recorded in 207-PO. Shell weight was maximum in J-101 (291.5mg) and was non-significant with 206-MKD. Whereas, the shell weight difference among J-99, 205-MKD and 206-MKD; J-99, 205-MKD, 206-PO and 208-PO was non-significant.

Maximum ECIC and ECIS was in J-99 (32.6%) and J-101&205-MKD (7.15%), respectively. ECIC was non-significant among J-99, J-101, 205-MKD and 206-MKD; J-101, 205-MKD, 206-MKD and 208-PO; J-101, 206-MKD, 206-PO, 208-PO and 207-PO. Similarly, comparison among individual strains for ECIS showed a non-significant difference among J-101, J-99, 205-MKD, 206-MKD and 208-PO; J-99, 206-MKD, 206-PO and 208-PO. ECIC (28.73%) and ECIS (5.50%) was the lowest in 207-PO. Maximum (67.75%) and minimum (60.3%) ECDC was given by 205-MKD and J-101, respectively. However, difference between 205-MKD and J-99; among J-99, 206-MKD and 208-PO; J-101, 206-MKD, 206-PO, 207-PO and 208-PO was statistically non-significant. Maximum (15.03%) and minimum (11.98%) ECDS was recorded in 205-MKD and 207-PO, respectively. There was statistically non-significant difference among J-99, J-101, 205-MKD, 206-MKD, 206-PO and 208-PO.

Autumn Rearing

The test silkworm strains maintained the same overall level of significance during autumn rearing for TI, TD, cocoon & shell weight, ECIC, ECIS, ECDC and ECDS. Maximum (4133.85 mg $larva^{-1}$) and minimum (3486.25 mg $larva^{-1}$) TI was found in 205-MKD and J-101, respectively. But the difference among J-99, 205-MKD, 206-MKD, J-99 and 208-PO; J-99, 206-PO, 207-PO and 208-PO; J-101, 206-PO and 207-PO was non-significant. The highest total digestion (2237.75mg/larva) was in 206-MKD. Similarly the lowest total digestion (1814.98 mg $larva^{-1}$) in 206-PO was non-significant with J-101. The difference among J-99, 207-PO and 208-PO was non-significant too. The heaviest and lightest cocoon with 864.0 and 549.75 mg weight was harvested in 206-mKD and 207-PO, respectively. Variation between J-99 and J-101; among 205-MKD, 206-PO and 208-PO was non-significant. On the other hand shell weight (163.75

mg/shell) was maximum in J-99. This shell weight did not differ significantly from J-101, 205-MKD and 206-PO. The minimum (89.25 mg) shell weight in 207-PO was also non-significant with 205-MKD and 208-PO. Variation in shell weight among J-101, 205-MKD, 206-MKD, 206-PO and 208-PO was also non-significant.

ECIC was maximum (21.33%) in J-101 while that was minimum (15.05%) in 207-PO. Difference between J-99 and 206-MKD; 206-PO and 208-PO; 205-MKD and 208-PO; 205-MKD and 207-PO was non-significant. Maximum (423%) ECIS was given by J-99, however this was non-significant with J-101 and 206-PO. Also variation in ECIS among J-101, 205-MKD, 206-mKD, 206-PO and 208-PO; 205-MKD, 206-MKD, 207-PO and 208-PO was insignificant. ECDC fluctuated between 40.90% (J-101) to 27.95% (207-PO). Difference in ECDC among J-99, J-101, 206-MKD and 206-PO; between 206-PO and 208-PO; 205-MKD and 208-PO was non-significant. The most efficient silkworm strain to convert digested mulberry leaf into shell was J-99 (8.28%) while in contrast was 207-PO (4.53%). Comparison among individual strains showed that difference among J-99, J-101, 206-MKD and 206-PO, T-101, 205-MKD, 206-MKD, 206-PO and 208-PO; 205-MKD, 206-MKD, 207-PO and 208-PO was statistically non-significant.

Eight quantitative parameters under study were compared for spring and autumn rearing. For this all the means of seven silkworm strains were Pooled and compared statistically by applying t-statistics. The outcome is presented in Table 3. Results revealed that there was non-significant difference for total ingestion and digestion between spring and autumn rearing. Rather ingestion and digestion was slightly more in autumn rearing however, it was statistically non-significant. On the other hand, cocoon and shell weight, ECIC, ECIS ECD, ECDC, ECDS were significantly high in spring rearing.

Table 1. Efficiency of conversion of mulberry leaf into cocoon and shell by different silkworm strains during spring rearing.

Strains	T.I (mg)	T.D (mg)	Cocoon (mg)	Shell (mg)	ECIC (%)	ECIS (%)	ECDC (%)	ECDS (%)
J-99	3787.43c**	1873.80bc**	1233.75a**	264.50bc	32.6a*	6.93ab**	65.83ab**	14.56a*
J-101	4080.25a	2031.25a	1224.0ab	291.50a	30.0abc	7.15a	60.30c	14.38a
205-MKD	3706.73c	1769.45c	1193.0abc	264.[illegible]bc	32.18ab	7.15a	67.75a	15.03a
206-MKD	4070.10a	1931.58ab	1226.0ab	277.50ab	30.15abc	6.85ab	63.50bc	14.38a
206-PO	3977.60ab	1887.10bc	1142.75bc	252.50c	28.73c	6.33b	60.60c	13.38ab
207-PO	3325.98d	1543.93d	938.75d	183.75d	28.73c	5.50c	61.30c	11.98b
208-PO	3812.15bc	1803.10c	1133.75c	253.75c	29.78c	6.65ab	63.03bc	14.08a
CD	182.97	122.48	87.70	23.79	2.75	0.67	3.95	1.77

* Significant at 95% level. ** Significant at 99% level.

- Figures in a coloumn sharing same alphabets are non-significant (P 0.05) among themselves.

Table 2. Efficiency of Conversion of mulberry leaf into cocoon and shell by different silkworm strains during autumn rearing.

Strains	T.I (mg)	T.D (mg)	Cocoon (mg)	Shell (mg)	ECIC (%)	ECIS (%)	ECDC (%)	ECDS (%)
J-99	3875.98ab**	1993.85c**	774.0b**	163.75a**	19.98b**	4.23a*	38.90a**	8.28a*
J-101	3486.25c	1820.55d	743.75b	132.25ab	21.33a	3.80ab	40.90a	7.25ab
205-MKD	4133.85a	2114.53b	673.25c	120.25bc	16.28de	2.93bc	31.90c	5.68bc
206-MKD	4100.18a	2237.95a	864.0a	143.0ab	19.98b	3.30bc	38.60a	6.38abc
206-PO	3714.48bc	1814.98d	679.0c	135.25ab	18.28c	3.60ab	37.55ab	7.43ab
207-PO	3648.68bc	1971.68c	549.75d	89.25c	15.05e	2.45c	27.95d	4.53c
208-PO	3869.38ab	1981.60c	673.25c	114.75bc	17.40cd	2.98bc	33.98bc	5.78bc
CD	278.47	116.89	48.02	35.03	1.28	0.90	3.74	1.97

* Significant at 95% level. ** Significant at 99% level.

- Figures in a coloumn sharing same alphabets are non significant (P 0.05) among themselves.

Table 3. Quantitative traits of different silkworm strains during two rearing seasons

Traits	Rearing Season		Difference	SED	T. Value
	Spring	Autumn			
T.I	3822.89	3832.69	-9.80	133.31	-0.074^{ns}
T.D	1834.32	1990.73	-156.41	81.48	-1.7196^{ns}
Cocoon	1156.0	708.14	448.86	54.13	8.273**
Shell	255.39	128.36	127.03	15.74	-8.07**
ECIC	58.88	18.33	40.55	28.50	-2.423*
ECIS	6.65	3.33	3.32	0.32	-10.506**
ECDC	63.19	35.68	27.51	2.03	-13.549**
ECDC	13.97	6.48	7.49	0.61	12.216**

* Significant at 95% level, ** Significant at 99% level, ns - non-significant

Nutritional background of the larval stage significantly influences the status of the resulting pupae, adult and production of silk (Hemavathi and Bharathi, 2003). However, food consumption and utilization depends upon many factors like feeding duration (Nath *et al.*, 1990; Mathavan *et al.*, 1987), temperature (Radhakrishna *et al.*, 2000) health of worms (Srikanth *et al.*, 1988), silkworm strains and rearing season (Rafique and Bajwa, 2004). Present study revealed that under similar conditions food ingestion and digestion varied with silkworm strains as well as with rearing season. These findings were in corroboration with Rafique and Bajwa (2004). Likewise, variation in cocoon and shell weight between spring and autumn rearing was supported by Khawaja and Haq (1991) and Muslim (1977). This seasonal impact on cocoon and shell weight might be due to inferior quality of leaf and high temperature in autumn. Qader *et al.* (1992) and Palit *et al.* (2003) have also observed this effect.

Efficiency of conversion of ingested mulberry leaf into shell layer during spring rearing showed that for 1 g shell layer at least 13.986 g (efficiency, 7.15%) dry mulberry leaves must be ingested (J-101, 205-MKD). ECDS ranged between 11.98-15.03%. It means 8.347-6.653g digested dry mulberry leaf produced 1 g shell layer. These coefficients (ECIS & ECDS) were remarkably low in autumn rearing. ECIS results of J-101 and 205-MKD were comparable to some extent with those of Ito and Kobayashi (1978), where they found that approximately 12 g dry mulberry leaf must be ingested for the production of 1 g of dry cocoon shell (efficiency, 8.26%). ECIS for the other test strains and ECDS for all the under trial strains were low. This discrepancy in results may be explained in terms of pure and hybrid silkworm strains. Our silkworm strains were pure lines while Ito and Kobayashi (1978) reared a hybrid of N115 x C108. Hybrids were more robust and have heavy cocoon/shell layer (Iqbal and Shahid, 1984). Low efficiency of conversion of ingested and digested leaves into silk during autumn showed a negative relationship of high temperature and maturity of leaf.

Conclusion

In nutshell it was concluded that efficiency of conversion of mulberry leaves into cocoon and cocoon shell varied with silkworm strains vis-à-vis rearing season. The strains 205-MKD, J-101 and J-99 were the most efficient for converting ingested and digested mulberry leaves into cocoon shell. Contrarily 207-PO was the least efficient ECIS and ECDS were remarkably low in all the silkworm strains during autumn rearing. Based on these results it is recommended that to maximize economic return, efficient strains like 205-MKD, J-99, J-101, etc. should be reared at 24±1 C° and 75±5%RH. For autumn rearing in addition to maintaining standard rearing conditions mulberry plants should be pruned to have fresh and nutritious leaves.

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