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Impact of turmeric on the protein and lipid metabolic profiles of silkworm, *Bombyx mori* L. and cocoon production

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ABSTRACT

Sericulture industry has played an important role in the economic life of man ever since its discovery (4000 years). It is being presently practiced in about 42 countries in the World. China and India occupies the first and second positions in the production of raw silk in the World. Mulberry cultivation, silkworm rearing and silk reeling are the three major components in the silk industry. Mulberry, being the only food plant for the silkworm, *Bombyx mori*., disease free mulberry leaf with high nutritive value and improved strains of silkworm have been considered as the two prime aspects for the development of this silk industry. The phenomenal health benefits of turmeric (*Curcuma longa*) were being explored since several hundreds of years. There's still a vast untouched potential on the miracle working power of curcumin in turmeric. In this context, mulberry leaves were treated with different concentrations of turmeric to check for its positive effect. This piece of study evaluated for the potential effect of Curcumin on protein and lipid metabolisms of the silkworm, *Bombyx mori*, the key enzymes involved in these metabolisms and treated batches are further taken up to study the energy metabolism through the levels of ATPase and Cytochrome-C activity levels. This study also tried to assess the state of cocoon yield from the turmeric fed *Bombyx mori* larvae. Throughout the study, the *Bombyx mori* larvae and cocoons were found to be disease free.

KEY WORDS: *Bombyx mori* L., cocoon yield, *Curcuma longa*, *Morus alba*

INTRODUCTION

Silk mesmerizes everyone by its customs, rich and royal touch, it imparts into one's mind. In the global silk production, India occupies the coveted second place. For our country, the Sericulture based activities rightly fit into the socio economic structure of our rural scenario and works as an effective tool for rural reconstruction to uplift the economy of down trodden sections of rural populace. Sericulture is spread over nearly 60,000 villages throughout the subcontinent but mostly concentrated in South India. Though, Indian sericulture was striving to evolve new races, the stable strains could be established only with the introduction of what is called 'New technology' of silkworm cocoon production. India is now in the threshold of producing international grade silk through this new technologies. Success of silk processing depends on quality of silk cocoons, which forms an integral part of raw silk production in sericulture. To harvest quality cocoons, disease free, nutritive mulberry leaf and improved strains of silkworm are primarily most important inputs to sustain this industry.

To this end, the impact of turmeric has been tried in this study, on silkworm to check for its efficacy on increasing the cocoon yield.

The rhizome of *Curcuma longa .L* (Family: Zingeberaceae) named turmeric is the perennial herb. The major constituents being curcumin, also contains curcuminoids, fats, minerals, fibers, vitamins, proteins and carbohydrates. Apart from being used in almost all Asian kitchens, it has also been used in indigenous systems of medicine in Asia during the past three decades. The curcumin (Diferuloyl methane) is one of the most active ingredients, which is responsible for its biological activity; antimicrobial (Lutomeski *et al.,* 1974), antileshmanial (Gomez *et al.,* 2002), Lepato protective (Kiso *et al.,* 1983), Anticancer (Kutton *et al.,* 1985). Curcumin has also been tried as a possible immune system stimulator (Agarwal *et al.,* 2006, Jagetia *et al.,* 2007) which modulates the activation of T-cells, B-cells, Macrophages, Neutrophils, Natural killer cells and Dendritic cells; and down regulates various proinflammatory cytokines and chemokines and enhance antibody responses M.D. Anderson Cancer centre, Texas (2007) researches also reported the curcumin's role in modulating the immune system. However, this has not been tried either as mulberry fortifying agent or silkworm health supplement for higher cocoon yield. Hence, the present study has been taken up to study the effects of turmeric on silkworm metabolism and cocoon production

MATERIALS AND METHODS

The study was carried out in the Division of Sericulture, Tirupati, A. P., India. Fine turmeric powder (*Curcuma longa*) commercially available was selected for the study. All other chemicals used were of technical grade from Sigma, St. Louis, USA, SDH, CDH (India).

A hybrid race PM X NB_4D_2 (Cross breed) of the silkworm *Bombyx mori* was used. The standard silkworm rearing method was followed, described by the Krishanswami (1978a). Mulberry constitutes the sole and satisfactory food of the silkworm *Bombyx mori* and mulberry cultivation is indispensable for silkworm rearing.

Biochemical analysis:

Total Proteins were estimated by using crystalline bovine serum albumin as the standard. The protein content was expressed as mg/g wet weight of the tissue or 1 ml of haemolymph.

The total FAA levels in control and experimental tissues and haemolymph of *Bombyx mori* larva were determined by the method of Moore and Stein (1954). The values were expressed as μM of tyrosine/gm. wet weight or 1 ml of haemolymph.

Protease activity was estimated by the method of Moore and Stein (1954), with 5% homogenate at 10000 rpm for 15 minutes. The proteolytic activity is expressed as μM of tyrosine /mg. protein/ hr or 1ml of haemolymph.

Serum transaminases:

In the colorimetric method, these enzymes catalyse the transfer of α-amino groups from specific amino acids to α-ketoglutaric acid to yield glutamic acid and oxalo acetic acid or pyruvic acid. The formed ketoacids were then determined colorimetrically by the method of Reitman and Frankel (1957).

Estimation of Aspartate Amino Transferase (AAT) (L-aspartate, 2-oxaglutarate amino transferase EC 2.6.1.1) activity:

0.2 ml of the homogenate was pipetted into a clean test tube. To this, 100μM of L-aspartate, 100μM of phosphate buffer (pH 7.5) and 2 μM of α-ketoglutaric acid were added. The reaction was carried out at 37° for 30 minutes. After incubation, 0.5 ml of 2, 4-DNPH was added to arrest the reaction. After keeping the tubes for 20 minutes at room temperature, added 5 ml NaOH (1N) and mixed thoroughly. The colour developed was read in a spectrophotometer at 505 nm against the reagent blank. Zero time controls were maintained. The colour intensity was proportional to the transaminase activity and was expressed as μM of pyruvate formed/mg. protein/hr or 1 ml of haemolymph.

Assay of anine amino transaminase (ALAT) (DL- alanine; 2-Oxaloglutarate Amino Transferase E C: 2.6.1.2) activity:

3% homogenates of control and experimental 4^{th} and 5^{th} instar *B.mori* larval intestine, silk gland, muscle and haemolymph were prepared in phosphate buffer and centrifuged at 1500 rpm for 10 min. 0.2 ml of the supernatant was pipetted into a clean test tube. To this 100 μM of L-alanine, 100 μM of phosphate buffer (pH 7.5) and 2 μM of α-ketoglutaric acid were added. Then the reaction was carried out at 37°C for 30 minutes. After incubation, 0.5 ml of 2, 4-dinitrophenyl hydrazine hydrochloride (DNPH) was added to arrest the reaction. After keeping the tubes for 20 minutes at room temperature, added 5 ml of NaOH (1N) and mixed thoroughly. The colour developed was read at 505 nm against a reagent blank in a spectro-photometer. Zero-time controls were also maintained. The colour intensity was proportional to the transaminase activity and was expressed as μM of pyruvate formed/mg protein/hr or 1 ml of haemolymph.

Measurment of glutamate dehydrogenase activity (GDH) (L-glutamate: NAD oxidoreductase, EC1.4.1.3):

The GDH activity was assayed by the method of Lee and Lardy (1965). The GDH activity was expressed as μ moles of formazan per mg protein per hour or 1 ml of haemolymph.

Estimation of Free Fatty Acids (FFA):

Lipids in control and experimental tissues and haemolymph were extracted in chloroform: methanol mixture (2:1 ratio) and FFA present were determined by suitably modifying the procedure of Schmidt *et al.* (1979) as given by Berg-Mayer (1974). The values of free fatty acids were expressed as μM of stearic acid/gm. wet weight of the tissue or 1 ml of haemolymph.

Determination of Lipase Activity (Lipase esterase E.C. 3.11.3):

The activity levels of lipase were estimated by the method of Bier (1957). The lipase specific activity was expressed as μ moles of paraphenol formed/mg protein / hr or 1 ml haemolymph.

Determination of ATPases activity (ATP phosphohydrolase: EC.3.6.1.3):

Total ATPase activity was measured by the method of Fritz and Hamrick (1966) and as modified by Desaiah and Ho (1979).

Total ATPases:

Total ATPase activity in control and experimental intestine, silk gland muscle tissues and haemolmph of 4^{th} and 5^{th} instar larvae was assayed by measuring the inorganic phosphate (pi) liberated from hydrolysis of ATP.

Cytochrome-C-Oxidase(cyt-C-oxidase) activity (Ferrocytochrome-C-Oxygen Oxidoreductase EC: 1.9.3.1)

In control and experimental tissues of intestine, silk gland, muscle and haemolymph cytochrome-c-oxidase activity was measured. The enzyme activity was expressed in μg of formazan formed/mg protein/hr or 1 ml of haemolymph.

Quantitative parameters of cocoons:

The quantitative parameters of cocoons viz., cocoon weight, shell weight, shell percentage, filament length and denier were determined by the methods given by Sonwalker (1993).

Cocoon weight:

A sample is drawn from each replication comprising around 20-25 cocoons, representing the entire quality of each replication. Individual cocoon weights were taken from each sample and the mean cocoon weight was found respectively for treatment and control batches. The weights were taken in gram units.

Shell weight and Shell percentage:

The shell weight and shell percentages are important economic characters. The shell ratio depends upon the silkworm race and is normally higher in male than in female. Shell percentage varies according to the variation in cocoon weight caused due to the loss of moisture present in the pupae. The weights were taken in gram units. Shell percentage = Weight of the cocoon shell/ Weight of the entire cocoon x 100.

Filament length:

The length of the silk filament was measured by subjecting the single cocoon to reeling in a mono-cocoon reeling machine called Eupprouvette. The total filament length was calculated as follows (Sonwalker, 1993). Total filament length in mts = No. of rotations x Circumference of the reel.

Denier:

The filament size was calculated for control and experimental batches by using the formulae as given by Sonwalker (1993). Variation in the denier of the cocoon silk filament will ultimately determine the uniformity and quality raw silk yarn reeled. Variations in thickness of the individual filament influence the size or thickness of the raw silk yarn. Denier = Weight of the filament/ Length of the filament x 9000.

RESULTS

Total proteins:

In the 4^{th} and 5^{th} instar 1% turmeric caused more percent elevation of larval tissue total proteins and was followed by 10% > 100 %. The increase in total protein content was found to be statistically significant for 1% and 10% turmeric fed larval tissues and haemolymph, over the control ($p<0.001$) in both 4^{th} and 5^{th} instar *B. mori* larvae (Table-1).

Free amino acids:

Turmeric sprayed mulberry leaf fed *Bombyx mori* larval tissues showed enhanced levels of their FAA contents was presented in table-2, and the changes were found to be statistically significant over the control ($p<0.001$) in both 4^{th} and 5^{th} instar larvae (Table-2).

Protease activity:

The intestine, silk gland, haemolymph and muscle tissues from turmeric fed 4^{th} and 5^{th} instar larvae showed elevated levels of their protease activity over the control and the changes were found to be statistically significant ($P<0.001$) over the control (Table-3).

AAT and ALAT:

The turmeric sprayed mulberry leaf fed 4th and 5th instar *Bombyx mori* larval intestine, silk gland, haemolymph and muscle tissues receiving 1 % & 10 % turmeric showed statistically (P<0.001) increased levels of their AAT and ALAT activity levels over the control.(Table-4&5).

Glutamate dehydrogenase:

The intestine, silk gland, haemolymph and muscle from turmeric fed 4th and 5th instar *Bombyx mori* larvae showed increased levels of their GDH activity (Table-6) and the changes were found to be statistically significant over the control in both 1 % and 10 % turmeric fed larvae (P<0.001).

Total lipids:

Turmeric fed 4th and 5th instar larval tissues and haemolymph showed decreased levels (Table- 7) of their total lipid content and the changes were found to be statistically significant over the control (P<0.001).

Free fatty acids (FFA):

Turmeric sprayed mulberry leaf fed 4th and 5th instar *Bombyx mori* larval tissues and haemolymph showed enhanced levels of their FFA content and the changes were found to be statistically significant over the control (Table-8).

Lipase activity:

Turmeric sprayed leaf fed larval intestine, silk gland, haemolymph and muscle lipase activity showed enhanced levels and the changes were found to be statistically significant over the control. More percent elevation of tissue and haemolymph lipase activity were observed in 1% turmeric fed larval tissue and haemolymph (Table-9) and was followed by 10% > 100% turmeric.

Total ATPase activity:

The data in Table 10 shows the control and turmeric sprayed mulberry leaf fed 4th and 5th instar *Bombyx mori* larval intestine, silk gland, haemolymph and muscle total ATPase activity levels. Turmeric treatment significantly (p<0.001) increased the *Bombyx mori* larval tissues and heamolymph total ATPase activity levels.

Cytochrome-c oxidase activity:

Turmeric sprayed mulberry leaf fed *Bombyx mori* larval intestine, silk gland, haemolymph and muscle showed enhanced cytochrome-c oxidase activity levels (Table-11) and all the changes were found to be statistically significant over the control (p<0.001).

Cocoon weight:

Cocoons from 1% turmeric fed larvae showed increased Cocoon weight and the percent increase was found to be 12.54% over the control and was followed by 10% (7.23%) > 100% (-2.62%) (Table-12). Cocoons from 5th instar (Table-13) larvae showed higher percent elevation over the control compared to the Cocoon weight from turmeric fed 4th instar larvae (Table-12).

Shell weight:

Cocoons from 1% turmeric fed larvae showed more percent increase of their shell weight; 24.50% and 39.92% in cocoons from 4th and 5th instar turmeric fed larvae respectively (Table 12 & 13) and was followed by 10%>100%.

Shell percentage:

More shell percentage was recorded in the cocoons from 1% turmeric fed 4th and 5th instar *B. mori* larvae (14.39% and 18.79% respectively) and the

increase in shell percentage was found to be statistically significant (Table 12 & 13) over the control ($p<0.001$).

Filament length:

From the data in table 12 and 13, it is evident that the silk from 1% turmeric fed *B. mori* larval cocoons showed increased filament length over the control ($P< 0.001$) compared to 10% and 100% turmeric concentration.

Denier:

The data in table 12 and 13 further depicts that the silk from 1% turmeric fed 4^{th} and 5^{th} instar *B. mori* larvae showed decreased denier (2.05 and 2.35 and 1% respectively) and the trends were followed by 10% > 100% turmeric.

DISCUSSION

The increase in the body weight of silkworm was accompanied by the accumulation of various biochemical constituents like protein, FAA and enzymes like AAT and ALAT etc (Lang *et al*., 1965; Church and Roberton, 1966; Kotby *et al.*, 1987; Dhinakar, 1988; Harihara Raju, 2001; Mamatha, *et al*., 2002). Tissue proteins undergo a continuous process of renewal, referred to as "turnover". Biochemical constituents like total and soluble proteins, FAA, ALAT and AAT, protease activity have been examined in tissues of silkworm with reference to its metamorphosis. The levels of amino acids show variations during metamorphosis and under stress conditions of the *Bombyx mori* (Harihara Raju *et al*., 2002; Mamatha *et al*., 2002). Amino acids are the most important constituents in silkworm nutrition (Bose *et al*., 1989).

The major transmission reactions are performed by alanine aminotransferase (Lehninger, 1993). Alanine aminotransferase recorded a higher activity compared to asparate aminotransferase all through the embryonic development in silkworms (Pant and Kumar, 1979). Proteases are the most commonly found digestive enzymes in insects (Ann Sorensen *et al*., 1983). Several factors responsible for the secretion of the proteolytic enzymes have been investigated by (Briegel and Lee, 1975; Mordue, 1967; Eguchi *et al*., 1972; Sarangi *et al* 1986). The total proteins (table-1) and free amino acid contents (table-2) were measured in the different tissues of both control and turmeric sprayed mulberry leaf fed larvae, with lowering percentage (1%)of turmeric an increase in both total protein and free amino acid contents were observed and the trend was followed by 10% > 100% fed larvae.

Elevation in the proteins in turmeric sprayed mulberry leaf fed larvae is an indication of high protein synthesis in *Bombyx mori* larvae. The lower the turmeric concentration the higher the protein and amino acid synthesis was observed. So different doses of turmeric may affect the protein synthesizing capacity of the larvae. The levels of free amino acids were estimated in both control and turmeric treated mulberry leaf fed larvae. Silkworm and other insects are known to contain usually large amount of free amino acids (Sinha *et al*., 1990; 1991). The larvae are metabolically more active as evidenced by the presence of increased levels of proteins and total free amino acids under turmeric stress. Increase in turmeric fed *Bombyx mori* larval tissue protease activity (table-3) reflect a state of breakdown of proteins resulting in the formation of total FAA which were recorded as increased in turmeric fed *Bombyx mori* larval tissues (table-2).

From the current study, it is evident that both transaminases are active in the control tissues. Based on the results

of table 4&5 it can safely be concluded that the above cited situation is pronounced more in 1 % turmeric fed larval tissues and less to the other concentrations of turmeric fed *B.mori* larval tissues and haemolymph. AAT at any time represent channeling of FAA directly into TCA cycle thus enhancing energy yield through aerobic metabolism.

The turmeric fed *Bombyx mori* larval tissues showed elevated activity levels of their GDH (table-6). Glutamate dehydrogenase is an enzyme of great importance in the intermediary metabolism of amino acids. Glutamate and GDH have a unique role in amino group transfer. It is through this enzyme that α- ketoglutarate is made available for the citric acid cycle, at the same time from ATP to release ammonia. The enhanced activity of GDH in the *Bombyx mori* larval tissues under turmeric stress indicates increased oxidation of glutamate (Sailaja, 1999).The role of α-ketoglutarate as a substrate for sperm mobility was demonstrated (Osanai *et al*, 1986, 1987a&b) in the silkworm *Bombyx mori.*

Total lipids were analyzed during developmental stages in silkworms such as *Bombyx mori* (Nakasone and Ito, 1967; Chinya and Ray (1976) and *Antheria mylitta* (Agarwal *et al*., 1981). Contradictory reports are available in the levels of total lipids during insect metamorphosis. The lipids such as glycerides and phospholipids have been shown to be essential for the oocyte maturation (Rajasekhar, 1993). Agarval *et al*. (1981) have reported a continuous decline in their levels from the first to fifth instar in Antheria. Gupta and Pathak (1984) observed an increase in their levels from the second to fifth instar. Further, it was reported that the fifth instar and mature spinning larvae contain the highest amount of total lipids and that they form the chief source of energy during prolonged cocoon spinning activity (Kercut and Gilbert, 1985; Inagaki and Yamashita, 1986; Dinakar, 1988).

To understand the rate of energy metabolism under turmeric stress, the author tried to measure two key enzymes namely ATPase and Cytochrome-c oxidase in the tissues and haemolymph of the *B. mori* larvae. The turmeric fed 4^{th} and 5^{th} instar *Bombyx mori* larval intestine, silk gland, haemolymph and muscle showed an increase in their total ATPase activity (Table-10) over the control. Increases in tissue cytochrome-c-oxidase under turmeric stress (Table -11) reflect increase in oxidative metabolism ultimately leading to the generation of more ATP to meet the energy demands of *B. mori* tissues under turmeric stress.

The major input in the manufacturing of raw silk in cocoon that plays an important role in the production and quality of raw silk. Cocoon lots contain varying proportions of defective cocoons, unreelable cocoons, the percentage of which need to be assessed accurately. The quality of cocoons and its quality should be ascertained for achieving optimum productivity and raw silk quality for an established process line.

The overall study confirms that turmeric sprayed mulberry leaf fed silkworm larvae (over a period of 48 hours) enhance the larval synthetic activities followed by improved metabolic functions. In addition, to assess the yield and quality of cocoons and silk from turmeric fed *B. mori* larvae, the author attempted to determine certain of the quantitative parameters like cocoon weight, shell weight, shell percentage, filament length and denier.

Interestingly, all the quantitative parameters excepting the denier of silk from turmeric fed larvae showed increasing trends over the control group

(table 12 and 13) and the trends were observed more for cocoons and silk from 1% turmeric fed 4th and 5th instar *B. mori* larvae. The decreased denier (table 12 and 13) in the silk from turmeric fed cocoons indicative of good quality of silk. The overall experimental data indicate that turmeric fed *B. mori* larvae enhance cocoon yield and the silk will be of quality type and this situation is exerted more by 1% turmeric and less for 10% and 100%. The disease-free state of larvae and cocoons throughout the study might be due to beneficial role of curcumin in boosting the immune system. (Agarwal *et al.*, 2006, Jagetia *et al.*, 2007).This is a much interesting and welcoming factor to explore further.

CONCLUSION

Based on the overall study, it is reported that turmeric treatment gears the overall protein, free amino acid and lipid metabolisms of the *Bombyx mori* larvae and the turmeric at concentrations tested, enhanced the biomass of the silkworm and this results in improving the cocoon yield. Of all he turmeric concentrations tested, 1% turmeric appeared to be more beneficial in improving the larval biomass and cocoon yield. Interestingly, throughout study *B. mori* larvae and cocoons were found to be disease free.

Table 1: Turmeric induced changes in the levels of total proteins in silkworm, *B. mori* larval tissues and haemolymph (Values expressed as mg / gm wet wt. of tissue or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	65.26	75.52	72.51	66.01	85.21	103.36	98.23	86.49
SD	± 1.02	± 0.927	± 1.36	± 0.825	± 0.793	± 1.72	± 1.44	± 0.653
PC		15.72	11.10	1.14^{NS}		20.12	15.27	1.50^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	
Silk gland								
Mean	97.37	118.08	115.25	98.30	115.53	153.61	146.43	116.60
SD	± 2.01	± 2.16	± 1.03	± 1.07	± 2.62	± 1.05	± 2.06	± 1.84
PC		21.6	18.36	0.95^{NS}		32.96	26.9	1.01^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	
Haemolymph								
Mean	49.52	56.82	52.25	50.01	62.44	73.07	72.07	63.50
SD	± 0.925	± 0.956	± 0.836	± 0.265	± 1.33	± 0.655	± 0.655	± 0.941
PC		14.74	5.51	0.96^{NS}		18.30	15.42	1.69^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	
Muscle								
Mean	71.44	85.00	79.56	72.32	85.34	102.00	98.91	86.53
SD	± 1.08	± 0.944	± 1.76	± 1.72	± 0.942	± 1.30	± 0.722	± 0.723
PC		18.98	11.36	1.23^{NS}		19.52	15.90	0.86^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	

Table 2: Turmeric induced changes in the Free Amino Acids (FAA) content in *B. mori* larval tissues and haemolymph (Values expressed mg / gm wet wt. of tissue or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	180.65	210.24	194.32	181.30	210.00	125.50	232.00	212.68
SD	± 1.62	± 2.32	± 1.981	±0.856	± 1.82	± 1.96	± 2.10	± 1.98
PC		16.37	7.56	0.58^{NS}		19.04	10.47	0.95^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	
Silk gland								
Mean	245.00	272.72	267.52	246.12	260.00	300.00	291.12	262.54
SD	± 2.00	± 2.981	± 2.56	± 3.01	± 2.20	± 2.96	± 3.00	± 2.13
PC		11.31	9.19	0.46^{NS}		15.38	11.96	0.68^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	
Haemolymph								
Mean	141.22	162.41	158.65	142.00	153.92	182.19	174.36	156.12
SD	± 1.580	± 2.892	± 3.760	± 1.87	± 2.00	± 1.962	± 1.78	± 1.02
PC		15.00	12.34	0.55^{NS}		18.36	13.27	1.42^{NS}
t		p<0.001	P<0.001			p<0.001	p<0.001	
Muscle								
Mean	240.80	258.19	249.11	242.23	268.41	295.52	286.15	270.85
SD	± 1.74	± 2.05	± 2.99	±2.86	±1.789	± 3.00	± 2.985	± 1.25
PC		7.22	3.45	0.59^{NS}		10.10	6.60	2.45^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	

Table 3: Turmeric induced changes in protease activity levels in *B.mori* larval tissues and haemolymph (Values expressed as moles of tyrosine equivalent /mg protein/ hour or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	0.493	0.685	0.584	0.514	0.524	0.700	0.625	0.539
SD	± 0.065	± 0.059	± 0.062	± 0.065	± 0.055	± 0.078	± 0.062	± 0.051
PC		38.94	18.45 ^{NS}	4.25^{NS}		33.58	19.27	2.86^{NS}
t		p<0.001				p<0.001	p<0.05	
Silk gland								
Mean	0.855	1.05	0.950	0.870	1.42	1.80	1.52	1.44
SD	± 0.092	± 0.044	± 0.084	± 0.509	± 0.023	± 0.051	± 0.045	±0.023
PC		22.80	5.26	1.75^{NS}		26.76	7.04	1.40^{NS}
t		p<0.001	p<0.001			p<0.001	p<0.001	
Haemolymph								
Mean	0.462	0.552	0.526	0.486	0.637	0.792	0.700	0.642
SD	± 0.073	± 0.048	± 0.035	± 0.042	± 0.045	± 0.089	± 0.075	± 0.056
PC		19.48	8.22	0.042^{NS}		24.33	9.89	0.78^{NS}
t		p<0.01	p<0.01			p<0.001	p<0.05	

Muscle								
Mean	0.910	1.05	1.02	0.926	1.59	1.92	1.68	1.62
SD	±0.0341	± 0.024	± 0.056	± 0.094	± 0.055	± 0.094	± 0.071	± 0.082
PC		15.38	12.08	1.75^{NS}		20.75	5.66^{NS}	1.88^{NS}
t		p<0.001	p<0.01			p<0.001		

Table 4: Turmeric induced changes in the Aspartate amino transferase (AAT) activity levels in *B. mori* larval tissues and haemolymph (Values expressed as moles of pyruvate formed/ mg protein/ hr or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	0.635	0.780	0.725	0.645	0.882	1.20	0.998	0.892
SD	±0.48	± 0.059	± 0.65	±0.042	±0.0624	± 0.056	± 0.093	± 0.074
PC		22.83	14.17	1.57^{NS}		36.05	8.84	1.13^{NS}
t		p<0.001	p<0.01			p<0.001	p<0.01	
Silk gland								
Mean	1.18	1.43	1.32	1.25	1.45	2.72	2.35	1.50
SD	± 0.074	± 0.096	± 0.054	± 0.083	±0.054	± 0.721	± 0.647	± 0.524
PC		21.18	12.00	5.93^{NS}		24.13	19.31	3.44^{NS}
t		p<0.05	p<0.01			p<0.001	p<0.01	
Haemolymph								
Mean	0.425	0.500	0.385	0.432	0.406	0.522	0.451	0.420
SD	± 0.044	± 0.421	± 0.079	± 0.036	±0.0824	±0.0472	±0.0709	± 0.364
PC	19.04	p<0.001	7.84	1.64		28.57	11.08	3.44
t			p<0.001	p<0.05		p<0.001	p<0.05	p<0.05
Muscle								
Mean	0.593	0.906	0.749	0.625	0.631	1.17	0.842	0.706
SD	± 0.063	± 0.507	± 0.093	± 0.044	±0.327	± 0.763	± 0.454	±0.0847
PC		52.78	26.30	5.39		85.41	33.43	11.88
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.05	p<0.05

Table 5: Turmeric induced changes in Alanine aminotransferase (ALAT) activity levels in *B. mori* (Values expressed as mole of pyruvate formed / mg protein/ hr or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	1.01	1.19	1.09	1.03	1.09	1.49	1.21	1.13
SD	± 0.041	± 0.031	± 0.060	±0.044	±0.061	±0.050	± 0.052	±0.0966
PC		17.8	7.92	1.98		36.69	11.00	3.66^{NS}
t		p<0.001	p<0.001	P<0.05		p<0.001	p<0.001	
Silk gland								
Mean	1.30	1.72	1.61	1.35	1.45	2.07	1.86	1.49
SD	± 0.050	± 0.067	±0.040	±0.036	±0.060	± 0.83	±0.0513	± 0.070
PC		2.30	23.84	3.84^{NS}		42.75	28.27	2.75^{NS}
t		p<0.001	p<0.001			p<0.001	P<0.001	

Haemolymph Mean SD PC t	0.524 ±0.086	0.635 ± 0.037 21.18 p<0.001	0.582 ± 0.061 11.06 p<0.001	0.540 ±0.082 3.05^{NS}	0.637 ±0.086	0.885 ± 0.090 38.93 p<0.001	0.820 ± 0.067 28.72 P<0.001	0.684 ± 0.042 7.37^{NS}
Muscle Mean SD PC t	0.605 ± 0.074	0.740 ± 0.042 22.31 p<0.001	0.700 ± 0.091 15.70 p<0.05	0.617 ±0.050 1.98^{NS}	0.724 ±0.093	0.952 ± 0.061 31.41 p<0.001	0.833 ± 0.052 15.05 p<0.01	0.741 ± 0.075 2.34^{NS}

Table 6: Turmeric induced changes in Glutamate Dehydrogenase (GDH) activity levels in *B. mori* larval tissues and haemolymph (Values expressed as mole of formazan formed /mg protein/ hr or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine Mean SD PC t	0.75 ±0.062	0.96 ±0.051 28.00 p<0.001	0.91 ± 0.036 21.33 p<0.001	0.77 ±0.046 2.66^{NS}	0.91 ±0.073	1.41 ± 0.53 64.94 p<0.001	1.28 ± 0.061 40.65 p<0.001	0.95 ± 0.038 4.39^{NS}
Silk gland Mean SD PC t	0.64 ±0.044	0.78 ± 0.032 21.87 p<0.001	0.75 ± 0.066 17.18 p<0.001	0.68 ± 0.051 6.25^{NS}	0.72 ±0.044	0.99 ± 0.041 37.50 p<0.001	0.92 ± 0.034 27.77 p<0.001	0.76 ± 0.044 5.55^{NS}
Haemolymph Mean SD PC t	0.32 ±0.065	0.65 ± 0.031 103.12 p<0.001	0.44 ± 0.055 37.50 p<0.001	0.41 ± 0.026 28.12$_{NS}$	0.35 ±0.025	0.78 ± 0.041 122.89 p<0.001	0.63 ± 0.035 80.00 p<0.001	0.39 ± 0.056 11.42^{NS}
Muscle Mean SD PC t	0.55 ± 0.067	0.75 ± 0.042 36.36 p<0.001	0.62 ± 0.054 12.72 p<0.001	0.59 ± 0.044 7.27^{NS}	0.61 ±0.035	0.87 ±0.065 42.62 p<0.001	0.75 ± 0.064 22.95 p<0.001	0.64 ± 0.041 4.91^{NS}

Each value is the mean ± SD of 10 samples

SD : Standard deviation, PC : Percent change over the control * P< 0.001; NS: Non Significant

Table 7: Turmeric induced changes in levels of total lipids in *B. mori* larval tissues and haemolymph (Values expressed as mg / gm wet wt. of tissue or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	120.05	105.76	112.14	110.66	137.08	102.31	109.26	120.49
SD	±3.22	± 0.345	± 1.75	±2.44	± 0.590	± 1.32	± 0.520	± 0.812
PC		-11.90	-6.58	-7.82		-25.36	-20.29	-12.10
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	p<0.001
Silk gland								
Mean	142.00	121.21	127.50	125.41	160.00	141.29	146.96	152.72
SD	±2.620	± 1.46	± 2.22	± 0.0590	±0.692	± 3.10	± 2.25	± 2.00
PC		-14.64	-10.21	-11.68		-11.69	-8.15	4.55
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	p<0.001
Haemolymph								
Mean	70.33	55.08	62.21	66.23	82.01	60.52	71.03	74.47
SD	±1.70	± 2.00	± 1.82	± 1.92	± 1.83	± 2.12	± 1.57	± 0.840
PC		-21.68	-11.54	-5.82		-26.20	-13.38	-9.19
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	p<0.001
Muscle								
Mean	99.00	72.33	81.44	84.07	103.94	85.30	96.62	99.73
SD	± 1.82	± 0.569	± 3.50	± 1.82	±0.850	± 0.940	± 0.984	± 1.42
PC		-26.93	-17.73	15.08		-17.93	-7.64	-4.0
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	p<0.0015

Table 8: Turmeric induced changes in the Free Fatty Acids (FFA) content in the silkworm (Values expressed as mg / gm wet wt. of tissue or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine								
Mean	158.64	175.79	172.03	165.44	175.62	199.04	192.04	179.22
SD	±2.26	± 3.74	± 2.609	±1.24	±2.967	± 2.24	± 2.02	± 2.98
PC		10.08	8.44	4.31^{NS}		13.33	9.34	2.04
t		p<0.001	p<0.001			p<0.001	p<0.001	p<0.001
Silk gland								
Mean	290.52	316.84	305.66	301.14	292.07	325.11	306.73	301.16
SD	±2.10	± 4.08	± 2.98	± 1.82	± 2.05	± 3.00	± 1.89	± 0.968
PC		8.71	5.21	2.66		11.31	5.02	3.11
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	p<0.001
Haemolymph								
Mean	270.29	290.26	285.50	274.54	278.31	308.36	291.26	280.49
SD	±3.02	± 2.20	± 3.752	± 2.886	± 3.74	± 2.66	± 3.02	± 1.87
PC		7.38	5.64	1.48		10.79	4.69	0.782^{NS}
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	
Muscle								
Mean	210.43	230.19	224.72	217.63	232.22	261.54	246.54	239.72
SD	± 9.98	± 0.844	± 1.82	± 0.982	± 4.10	± 1.92	± 1.980	± 2.16
PC		9.39	6.79	3.41		12.63	6.17	3.23
t		p<0.001	p<0.001	p<0.001		p<0.001	p<0.001	p<0.001

Table 9: Turmeric induced changes in the Lipase activity levels in the silkworm (Values expressed as moles of paranitrophenol formed / mg protein/ hr or 1 ml of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine Mean SD PC t	0.046 ±0.032	0.054 ± 0.001 17.39 p<0.001	0.0504 ± 0.003 8.69 p<0.001	0.049 ±0.008 6.52^{NS}	0.052 ±0.0050	0.068 ± 0.005 30.76 p<0.001	0.065 ±0.0090 25.00 p<0.001	0.059 ±0.0070 13.46 p<0.05
Silk gland Mean SD PC t	0.032 ±0.006	0.041 ± 0.007 28.12 p<0.01	0.035 ± 0.005 9.37 p<0.05	0.034 ± 0.004 6.25^{NS}	0.039 ± 0.0050	0.054 ± 0.008 38.46 p<0.001	0.047 ± 0.006 20.15 p<0.05	0.043 ± 0.003 10.25^{NS}
Haemolymph Mean SD PC t	0.022 ±0.026	0.028 ±0.0080 27.27 p<0.001	0.025 ± 0.005 13.63 p<0.001	0.023 ± 0.006 4.54 p<0.001	0.026 ± 0.004	0.038 ± 0.007 46.15 p<0.001	0.032 ± 0.006 23.07^{NS}	0.029 ± 0.005 11.53^{NS}
Muscle Mean SD PC t	0.031 ± 0.004	0.040 ± 0.023 29.03 p<0.001	0.036 ± 0.006 16.12 p<0.001	0.042 ± 0.007 3.22 p<0.001	0.037 ± 0.009	0.060 ± 0.005 35.13 p<0.001	0.044 ± 0.003 18.19^{NS}	0.041 ± 0.006 10.81^{NS}

Table 10: Effect of Turmeric on Total ATPase activity levels in the silkworm (Values expressed as moles inorganic phosphorus (Pi) formed/ mg protein /hr)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine Mean SD PC t	8.16 ± 0.309	14.00 ± 0.725 71.56 P<0.001	12.07 ± 1.62 47.91 p<0.001	10.62 ± 0.508 30.14^{NS}	10.07 ± 0.844	15.32 ± 2.39 52.13 p<0.001	12.15 ± 0.882 20.65 p<0.05	10.49 ± 1.34 4.17^{NS}
Silk gland Mean SD PC t	11.56 ± 0.961	15.06 ± 2.33 30.27 p<0.001	12.1 ± 884 10.81^{NS}	12.00 ± 1.77 3.80^{NS}	143.84 ± 0.901	16.35 ± 2.66 10.17 p<0.001	15.10 ± 2.31 1.75^{NS}	14.14 ± 2.08 4.71^{NS}
Haemolymph Mean SD PC t	9.42 ±0.463	11.44 ± 1.22 23.99 p<0.001	11.00 ± 2.05 16.77 p<0.001	9.65 ± 0.658 2.44^{NS}	12.49 ± 1.25	15.67 ± 1.08 25.46 P<0.01	14.71 ± 1.67 17.77 P<0.01	13.22 ±0.862 5.84^{NS}
Muscle Mean SD PC t	7.41 ±0.425	8.17 ± 0.440 23.75 p<0.001	8.00 ± 0.509 7.96^{NS}	7.33 ± 0.438 1.07^{NS}	8.36 ± 0.640	12.50 ± 0.917 49.52 P<0.001	10.33 ± 0.746 23.56 p<0.01	9.72 ± 1.77 16.26^{NS}

Table 11: Turmeric induced changes in Cytochrome- c oxidase activity levels in the silkworm (Values expressed moles of formazan formed/ m protein/hr /1of haemolymph)

Name of the tissue	4th Instar				5th Instar			
	Control	Percentage of the turmeric solution			Control	Percentage of the turmeric solution		
		1%	10%	100%		1%	10%	100%
Intestine Mean SD PC t	1.92 ± 0.035	2.63 ± 0.042 36.97 p<0.05	2.01 ± 0.036 4.68 p<0.05	1.99 ± 0.042 3.64 p<0.05	01.94 ± 0.092	2.86 ± 0.241 47.42 p<0.001	2.04 ± 0.210 5.15^{NS}	2.14 ± 0.212 10.30^{NS}
Silk gland Mean SD PC t	2.86 ± 0.048	4.08 ± 0.216 42.65 p<0.001	3.16 ± 0.210 10.48 P<0.001	2.92 ± 0.224 2.09 p<0.01	2.11 ± 0.224	3.75 ± 0.420 77.72 p<0.001	3.45 ± 0.324 63.50 p<0.001	2.90 ± 0.256 37.44 p<0.001
Haemolymph Mean SD PC t	0.89 ±0.024	1.44 ± 0.041 61.79 p<0.001	0.961 ± 0.069 7.97 p<0.05	0.885 ± 0.042 0.56 ^{NS}	0.85 ± 0.040	1.60 ± 0.096 88.23 p<0.001	1.22 ± 0.192 43.52 P<0.001	0.920 ± 0.026 8.23^{NS}
Muscle Mean SD PC t	1.62 ±0.038	2.33 ± 0.1790 43.82 p<0.001	2.33 ± 0.242 23.45 p<0.001	1.67 ± 0.172 3.08^{NS}	1.66 ± 0.056	2.72 ± 0.234 63.85 p<0.001	2.00 ± 0.180 20.48 p<0.001	1.68 ± 0.172 1.20^{NS}

Each value is the mean ± SD of 10 samples

SD : Standard deviation, PC : Percent change over the control * P< 0.001; NS: Non Significant

Table 12: The quantitative parameters of the cocoons from control and turmeric fed 4th instar silkworm

Name of the quantitative parameter	4th Instar			
	Control	Percentage of the turmeric solution		
		1%	10%	100%
Cocoon Weight (g) Mean SD PC t	1.562 ±0.024	1.758 ±0.04 12.54 p<0.001	1.675 ±0.094 7.23 p<0.001	1.521 ±0.059 -2.62^{NS}
Shell Weight (g) Mean SD PC t	0.253 ±0.044	0.315 ±0.012 24.50 p<0.001	0.297 ±0.025 17.39 p<0.001	0.237 ±0.035 -6.32 ^{NS}
Shell Percentage (%) Mean SD PC t	16.19 ±0.01	18.52 ±1.05 14.39 p<0.001	17.48 ±1.035 7.96 p<0.001	15.38 ±1.5 -5.00 ^{NS}

Filament length(mts)				
Mean	700.00	785.00	745.00	685.00
SD	±2.00	±25.68	±15.36	±18.45
PC		12.14	7.42	-2.14
t		p<0.001	p<0.001	p<0.001
Denier (d)				
Mean	2.39	2.05	2.19	2.32
SD	±0.120	±0.250	±0.040	±0.045
PC		-14.22	-8.36	-2.92 ^{NS}
t		p<0.001	p<0.001	

Table 13: The quantitative parameters of the cocoons from control and turmeric fed 5th instar silkworm, *B. mori*

Name of the quantitative parameter	**4th Instar**			
	Control	**Percentage of the turmeric solution**		
		1%	**10%**	**100%**
Cocoon Weight (g)				
Mean	1.682	2.158	2.052	1.560
SD	±0.102	±0.380	±0.45	±0.097
PC		28.29	25.99	-7.25^{NS}
t		p<0.001	p<0.01	
Shell Weight (g)				
Mean	0.273	0.382	0.363	0.249
SD	±0.045	±0.054	±0.12	±0.056
PC		39.92	32.96	-8.279^{NS}
T		p<0.001	p<0.01	
Shell Percentage (%)				
Mean	16.23	19.28	18.95	15.96
SD	±1.05	±1.07	±1.002	±0.972
PC		18.79	16.75	-1.66 ^{NS}
t		p<0.001	p<0.001	
Filament length (mts)				
Mean	700.00	823.00	760.00	670.00
SD	±25.36	±26.87	±24.45	±23.45
PC		15.49	7.04	-4.28 ^{NS}
t		p<0.001	p<0.001	
Denier (d)				
Mean	2.55	2.35	2.42	2.5
SD	±0.12	±0.25	±0.04	±0.045
PC		-8.20	-5.46	-2.34^{NS}
t		p<0.001	p<0.05	

Each value is the mean ± SD of 10 samples
SD : Standard deviation, PC : Percent change over the control * P< 0.001; NS: Non significant

REFERENCES

Agarwal, S.C., Jolly, M.S. and Benarjee, N.S. (1981). Lipid content in Silkworm, *Antheraea myilitta Indian. J. Ent.*, 43 (3): 294-296.

Agarwal. S, Ichikawa. H, Takada. Y, Sandur S.K, Shishodia. s, Aggarwal BB, 2006 "Curcumin (Diferulotlmethane) down regulates expression of cell proliferation and antiapoptotic and metastatic gene products through suppression of Ikappabalpha kinase and Akt activation" Mol Pharmacol. 2006, Jan; 69(1): 195-206

Ann Sorensen, A., Rosemary, S., Kamas and Bradleigh Vinson, S. (1983). The influence of oral secretions from larvae on levels of protein in colony members of Solenopsis invicts Buren (Hymenoptera: Formicidae). *J. Insect. Physiol*. 29:163 - 168.

Balavenkatasubbaiah, M., Datta, R.K., Naig, M., Nataraju, B. and Lengar, M.N.S. (1994a). Efficacy of bleaching powder against the pathogens of the silkworm, *Bombyx mori* L. *Indian J. Seri.*, 33 (1): 23 – 26.

Berg Mayer, H.V. (1974). Methods of Enzymatic Analysis: Academic Press, New York, Vol.1 4.

Bier, M. (1957). Lipase. In: Methods in enzymology. (S.P, Colowick and N.O. Kaplan, eds.) 1 New York.

Bose, P.C., Majumder, S. K. and Sengupta, K. (1989). Role of amino acid in silkworm, *Bombyx mori* L. Nutrition and their occurrence in haemolymph, silk gland and silk cocoons. *Indian. Jan. Seric***.** 28 (1): 17 - 31.

Briegel, H. and Lea, A.O. (1975). Relationships between protein and proteolytic activity in the mid gut of mosquitoes. *J. Insect. Physiol.* 21: 1597 - 1604.

Chinya and Ray (1976). Lipid and water contents during Metamorphosis in silkworm, *Bombyx mori* L. Nistari. *Indi. J. Seric.*, 25 (1): 31

Church, R.B. and Robertson, F.W. (1966). A biochemical studies on the growth of Drosophila melanogaster. *J. Exp. Zool.* 162: 337 - 352.

Desaiah, D. and Ho, I.K. (1979). Effects of acute and continuous morphine administration of catecholamine sensitive ATPase in mouse brain. *J. pharmacal. Exp. Ther*., 208: 80.

Dhinakar, G.M. (1988). Studies on the effect of favourable and unfavourable seasons on the growth, physiology and fecundity of silkworm, *Bombyx mori*, L., Ph.D., thesis, S. V. University, Tirupati, India.

Eguchi, M., Furukawa, S. and Iwamoto, A. (1972). Proteolytic enzyme in the mid gut of the pharate adult of the silkworm, *Bombyx mori*, *J. Insect. Physiol.*18: 2457 - 2467.

Fritz, F.R. and Hamrich, M.E. (1966). Enzymatic analysis of ATPases. *Enzymol. Acta Biocat.*, 30 : 57.

Gomez, D.C., L.V. Alegrio, L.L. Leon and M.E. Lima,(2002). Total synthesis and anti-leishmanial activity of some curcumin analogues. Arzneimittel-Forschung-Drug Research, 52: 695-698.

Gupta, S. and pathak, J.P.N. (1984). Correlation between lipid and water contents of bivoltine strain (NB_{18}) of

silkworm, *Bombyx mori*, L. during its different developmental stages. *Indian J. Seric*. 23: 42 - 45.

Inagaki,S. and Yamashita, O. (1986). Metabolic shift from lipogenesis to glycogenesis in the last instar larval fat body of the silkworm, *Bombyx mori*, L. *Insect. Biochem.* 16 (2): 327 – 331.

Iwashita and Zhou, C.Q. (1988). Inactivation by the treatment of a nuclear polyhydrosis virus of the silkworm, *Bombyx mori*, L., with calcium hydroxide solution. *J. Seric. Scin. Japn*., 57:511– 518.

Jagetia, Ganesh, Agarwal, Bharat (2007), Spicing up of Immune system by Curcumin. *J.Clinical Immunology*, 27(1): 19-35.

Kagawa, T. (1980). The efficacy of formalin as disinfectant of *Nosema Bombycis* spores. *J. Seric. Sci. Japan*., 57: 511 - 518.

Kawakami, K. (1970). Fungicidal activity of the iodine disinfectant. Sanski – Kenkyn,76:63 – 64.

Kerkut, G.A. and Gilbert, L. (1985). Comprehensive insect physiology, Biochemistry and pharmacology. In: Biochemistry. Ist edn. Carbohydrate metabolism. 10: 43 – 76.

Kiso, Y, Suzuki.Y, N. Watanbe, Y.Oshima and H.Hikino, (1983) Antihepatotoxic principles of *Curcuma longa* rhizomes. Planta Medica, 49: 185-187.

Kobayashi, H, Safo, F. and Ayuzawa (1968). On the disinfecting ability of the mixture of bleaching powder and formalin. *J. Seric. Sci. Jpn.*, 37 : 311 - 318

Kotby, F.A., Eid, M.A.A., Hosny, A. and Ibrahim, S. (1987). Effect of different temperature and relative humidity on growth rate of stages of *Philosomia ricini.* Boisd. *Indian. J. Seri.* 26 (1): 11 - 15.

Krishanswami, S. (1978). New Technology of silkworm rearing Bull. No.2, CSR&TI, Mysore, India.

Krishanswami, S. (1978). New Technology of silkworm rearing Bull. No.2, CSR&TI, Mysore, India

Kuttan, R., P. Bhanumathy, K. Nirmala and M.C. George, (1985). Potential anticancer activity of turmeric (*Curcuma longa*). *Cancer Letters*, 29: 197-202.

Harihara Raju, A (2001). Effect of turmeric on selected biochemical aspects of the silkworm *Bombyx mori* (L)., M.Phil., dissertation submitted to Sri Venkateswara University, Tirupati,India.

Lang, C.A., Lauod, H.Y. and Jeeferson, J. (1965). Proteins and nucleic acid changes during growth and ageing the mosquito. Biochem. J. 95: 372 – 377.

Lee, Y.L. and Lardy, II. A. (1965). Influence of thyroid hormones on phosphate dehydrogenase and other dehydrogenases in various organs of the rat. *J. Biol. Chem.* 240 : 1427 – 1432.

Lehningers, A.L. (1993). Biochemistry, IInd Edition, Kalyani Publishers, Ludhiana, New Delhi.

Lutomski, J., B. Kedzia and W. Debska, (1974). Effect ofan alcohol extract and of active ingredients from

Curcuma longa on bacteria and fungi. *Planta Medica*, 29: 9-19.

Mamatha, D.M., Raju, A.H.H., Reddy, K.G., Poornima, P.S.,and Rao, M.R. (2002).“A juvenile hormone fenoxycarb can be used to boost more productivity in Sericulture practice: A short report: NSERD-II. Environmental awareness, Education and Management for Sustainable rural development. Dept. of Env. Sci., S.V. University, Tirupati, A.P. India. ABS NO. Vol. 1: pp. 62.

Moore, S. and Stein, W. H. (1954). In: Methods in enzymology (Eds) colowick and Kaplan, Vol. II. Academic Press, New York. 501.

Mordue, W. (1967). The influence of feeding upon the activity of the Neuro endocrine system during oocyte growth in *Tenebrio molitor*. *Gen. Comp. Endocr.* 9: 406 - 415.

Nukasone, Schoichi and Ito, Toshio (1967). Fatty acid composition of the silkworm, *Bombyx mori*, L. *J. Insert. Physiol.*, B: 1237 – 1246.

Osanani, M., Aigak, T., Kosuga, H. and Yonezawa, Y. (1986). Role of arginase transferred from vesiculaseminalis during and changes in amino acid pool of the spermotophore after ejaculation in the silkworm *Bombyx mori. Insect Biochem.*, 16: 879 – 885.

Osanai, M. Aigaki, T. and Kosuga, H. (1987a). Energy metabolism in the spermatophore of the silkmoth *Bombyx mori*, associated with accumulation of alanine derived from arginine. *Insect Biochem.* 17: 71 – 75.

Osanai, M. Aigaki, T. and Kosuga, H. (1987b). Arginine degradation cascade as an energy yielding system for sperm maturation in the spermatophore of silkworm *Bombyx mori*. In new horizons in sperm cell research Edtd., by Mohr, pp. 185 – 195.

Pant, R. and Kumar, S. (1979). Changes occurring related to nitrogen metabolism during ontogeny to *Antherea mylitta* (Tasar silkworm). *Indian J. Exp. Biol.* 17 (7): 708 – 710.

Rajasekhar, R. (1993). Studies on the temperature induces mutilations on the growth and reproductive physiology of silkworm *Bombyx mori*, L. Ph.D thesis S.V.University, Tirupati, India.

Reitman, S., Frankel, S. (1957). Calorimetric method of the determination of serum oxaloacetic and glutamic pyruvic transaminases. *An. J. Clini., Pathology*, 28 : 53 - 56.

Sailaja, K. (1999). Effect of cobalt chloride on growth and cocoon crop production of silkworm *Bombyx mori*, L. Thesis submitted to S.P. Mahila Viswavidayalayam, Tirupati.

Sarangi, S.K. (1986). Alkaline protease in the mid gut of the silkworm, *Bombyx mori* changes during metamorphosis. *Proc. Indian Acad. Sci. Anim.* 94 (5) : 567 - 572.

Schmidt, R., Felix, H., Stork, H., and Katharina, V.D. (1979). Methods in Enzymatic Analysis, Ed. Bergmeyer, H.U. vol. II. Verlag chemic wein hein, Academic Press, Inc. New York, San Francisco, London. pp. 819.

Shinha, A.K., Sinha, U.S.P., Sinha, S.S. and Sengupta. (1990). Changes in free aminoacids in the haemolymph of pebrine infected larvae and pupae of *Antheraea mylitta*. D., *Ind. J. Seric.* 29 (2): 233 - 239.

Shinha, A.K., Shinha, U.S.P. Sinha, S.S. and Sengupta, K. (1991). Studies on free amino acids, proteins, carbohydrates and phosphorus compounds in the tissue extracts of healthy and pebrine infected moths of Tasar silkworm, *Antheraea mylitta*. D., *Ind. J. Seri.* 30 (2): 103 - 106.

Sonwalker, TN. (1993). Hand book of Silk Technology, Wiley Eastern Limited, New Delhi. pp. 14-25.

Sonwalker, TN. (1993). Hand book of Silk Technology, Wiley Eastern Limited, New Delhi. pp. 30-38.

Sonwalker, TN.(1993). Hand book of Silk Technology,Wiley Eastern Limited, New Delhi. pp.122-125.

Venkata Reddy, S. Singh, B.D. Baig, M. Sengupta, K. Giridhar, K. and Singal, B.K. (1990). Efficiency of Asiphor as a disinfectant against incidence of disease ofsilkworm *Bombyx mori*. L., *Ind. J. Seric.*, 29 : 147 - 148.

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