FEED EFFICACY OF SILKWORM *BOMBYX MORI* (L.) LARVAE FED THE MR2 MULBERRY LEAVES FORTIFICATION WITH AMINO ACID L-SERINE IN RELATION TO GROWTH AND DEVELOPMENT

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Abstract

Nutrition is an important growth regulatory factor in silkworm like in any other organisms, the silkworm and the mulberry plant has a great partnership because the silkworm cannot thrive without the leaves of mulberry plants and the quality of leaves of mulberry plants influence greatly the biology of these worms. *Bombyx mori* silkworm is monophagous insect that feed mainly on mulberry leaves; it is an important economic insect and also converts the leaf protein into silk protein. Significant advances in the research of silkworm nutrition began with development of artificial diets. This study was to find out the feed efficacy parameters like food consumption, food utilization, digestibility, food consumption index rate, coefficient of food utilization and larval growth rate such as length, width and weight of silkworm *Bombyx mori* (III, IV and V instar larvae) fed the normal MR2 mulberry (*Morus sinensis*) leaves and different nutritional supplementary compound such as L-Serine, Aspartic acid, Arginine, Niacin, Retinol, Calciferol, Ascorbic acid and Glucose treated MR2 mulberry leaves. In the present study has been observed that the feed efficacy and growth rate of *Bombyx mori* (III, IV and V instar) larvae enhanced by 0.25% of α-amino acid L-Serine treated group than control and other treated groups. This study has been indicated that the α-amino acid L-Serine exhibit the presence of more growth stimulant activity and can be used to increase the silk yield in commercial silkworm rearing with reference to sericulture.

Keywords: *Bombyx mori*, *Morus sinensis*, MR2 mulberry, Feed Efficacy, Growth rate, L-Serine.

I. INTRODUCTION

Nutrition is an important growth regulating factor in silkworm. It has been reported that the vitamins of B-complex group and certain essential sugars, proteins, amino acids, minerals etc. are responsible for the proper growth and development of the silkworm, *B. mori* (Faruki, 1998). Recently, much research has been done on the diet supplementation of mulberry leaves fed to silkworms. These supplementations include vitamins such as ascorbic acid (Nirwani and Kaliwal, 1998), thiamin (Saha and Khan, 1996), niacin, folic acid, multi-vitamins (Etebari and Fazilati, 2003; Etebari *et al.*, 2004) Ascorpic acid (Vitamin C) (Ramesh *et al.*, 2017), silver nanoparticles, (Ganesh Prabu *et al*, 2012), Amoxicillin (Thilagavathi *et al*., 2013), natural dyes (Susithra *et al*., 2014), Spirulina powder (Valantina Sangamithirai, 2014), In addition to mulberry leaves feed supplements are also given to silkworm to enhance economic characteristics (Jeyapaul *et al*., 2003, Sheeba *et al*., 2006). Seki and Oshikane, (1959) have observed better growth and development of silkworm larvae as well as good quality cocoons when fed on nutritionally enriched leaves. Sengupta *et al.* (1972) have showed that *B. mori* requires specific essential sugars, amino acids, proteins and vitamins for its

normal growth, survival and also for the silk gland activity and growth. Ito, (1961) has recorded relationship of ascorbic acid supplementation and growth of silkworm. The absence of ascorbic acid in the diet of first and second instar larvae postponed growth and development of silkworm. There is enough Vitamin C in mulberry leaves and ascorbic acid content of growing larvae is dependent on amount of this vitamin in diet. Gomma *et al*. (1977) have observed that ascorbic acid significantly increased the weight of silkworm larvae.

Fe-PLUS® (Ferrus Fumarate + Folic acid) supplementation significantly increased larval, pupal and adult weight in comparison with controls with lowest and highest growths obtained at the concentrations of 0.32 and 0.64%, respectively (Khan and Saha, 1996). Horie and Ito, (1965) have showed that the required level of niacin for silkworm is highly regulated to the most appropriate level of 33 µg/l of dry weight and the increase of niacin reduced the larval weight. Horie, (1995) has showed a reduction of requirement pattern with increasing larval weight. Niacin caused significant deleterious effects on larval growth. Faruki, (1998) has reported that the thiamine derivative thianomin enhanced the growth of silkworm larvae, pupae and adults at all concentrations used (50, 100, 500 and 1000 ppm). Mulberry leaf enrichment with thianomin increased the growth indices such as larval, pupal and adult weight. The A*loe vera* tonic at 2.0% concentration resulted higher larval growth and increased the weight of cocoon (Manimuthu and Isaiarasu, 2010). The dietary supplements like protein, vitamins, lipids etc., evincing their specificity at specific dose for various metabolic activities of silkworm (Horie, 1980). Amino acids such as aspartic acid and glutamic acid are considered to be essential for silkworm growth (Ito and Inokuchi, 1981). Mulberry leaf supplemented with *Spirulina* as a feed to *B. mori* orally found to be effective in enhancing the larval and cocoon characters (Venkataramana *et al*., 2003). The silkworm larvae are attracted by three stimulants in mulberry leaves *viz.*, the attractant, biting factor and swallowing factor (Hamamura and Naito, 1961). Kafian, (1968) has observed that higher the quality of the given leaf, the lower is the quantity requirement for silkworm. Leaf consumption directly affects the silk producing capacity of the silkworm (Muthukrishnan *et al.*, 1978). Sumioka *et al.* (1982) have observed that the leaf consumption influenced the body weight which inturn influences the silk output. Therefore, a very simple and clear piece of logic to boost the production of the silk, improved quality of leaf or mulberry variety has to be used for silkworm rearing. Each instar, the increase in fresh and dry weights of the larvae, fresh and dry weights of food eaten and digested and dry weight of feces produced were recorded (Rath *et al.,* 2003).

Enrichment of mulberry leaves with vitamin E did not have significant effect on food consumption in silkworm larvae (Mosallanejad *et al.,* 2002). Shafique, (1993) has reported that dry matter consumed by silkworm was directly proportional to nitrogen contents of the leaves. Mahmood, (1989) has found that nitrogen increased the body weight of larvae and gave better cocoon production. He concluded that leaves dipped in 0.2% N solution produced the larvae with maximum weight as compared to the other doses Rehman, (1997) has concluded that optimum doses of minerals in various combinations, when used enhanced silk production and silkworm growth to a greater extent than control. During the entire larval life, mean food was converted into body matter was 74.55%. The A*loe vera* tonic at 2.0% concentration resulted higher larval growth and increased the weight of cocoon (Manimuthu and Isaiarasu, 2010). The amino acid plays an important role in glucose, tryptophan and organic acid metabolism. Few studies have been conducted on amino acids supplementation; their results improved the silk production (Etebari and Matindoost, 2005). Suprakash & Pal (2002) supplemented fresh mulberry leaves with 3 levels of vitamin B complex by dipping them in 0.5, 1.0 and 1.5% solution, and fed the dried leaves to larvae of various *Bombyx mori* races: the 0.5% level increased the weights of larvae and cocoons, and the shell ratio. Silk production basically depends on the *Bombyx mori* larval protein metabolism which in turn needs more energy generating events, spinning requires more muscular activity and silk is being produced by the silk gland. The quality of the leaves has a profound superiority of silk produced by the *B. mori* (Priyadharshini *et al*., 2008). Nutritional supplements include vitamins, amino acids, protiens and probiotics when added to larval feed tend to increase nutritional efficiency and economic traits of silkworm (Etebari and Matindoost, 2005; Amalarani *et al*., 2011; Singh *et al*., 2005). From the forgoing literature, it is evident that the impact of L-Serine on feed efficacy of *B. mori* is fragmentary. Therefore, it has been programmed in the present study to know the feed efficacy and larval growth rate to be noted in *B. mori* in relation to silk production. The studies on food preferences for larval growth promotion led to the development of an artificial diet. Today,

the silkworm can be raised entirely on the artificial diet from the first to the last larval instars. The present study explores the influence of mulberry leaves as a normal diet of silkworms as against the effect of the artificial diet on silkworm growth development.

II. MATERIALS AND METHODS

The first day of III instar of silkworm *Bombyx mori* L×NB_4D_2 (Local Bivoltine) race were reared simultaneously both in control and experimental groups separately on mulberry leaves dipped in nutritional supplementary solution in the laboratory. Proper environmental conditions provided to the silkworms with photoperiod of 12:12 h light and darkness as recommended by Krishnaswamy *et al.* (1973). The first day of III instar larvae were placed at ambient temperature of 25 ± 27ºC and relative humidity of 70 to 80%. The larvae were reared in card board boxes measuring 22×15×5 cms covered with nylon net and placed in an iron stand with ant wells (Govindan, *et al.*, 1981).

Morus sinensis (MR2) is one of the varieties of mulberry. This mulberry plant branches are simple, vertical, grayish leaves are light green, unlobed, elliptic palmately veined, leathery / smooth / wrinkled. It has good agronomic characters like high rooting ability. The *Bombyx mori* larvae were divided into two experimental groups; those are Control and Treated. Group 1 serves as the control this group larva to fed normal MR2 mulberry leaves. Group 2 larva to fed different nutritional supplementary compounds such as L-Serine (T1), Aspartic acid (T2), Arginine (T3), Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8) treated MR_2 Mulberry leaves in the concentration of 0.25%.

Only populations of larvae in synchronous growth were observed. During observations, each larva was placed in a plastic container facing a 3 cm^3 block of artificial diet. Larvae were spaced within the container so as not to disrupt the feeding behaviour of other animals. Larvae were observed for 6 h daily (Shinji Nagata and Hiromichi Nagasawa, 2006).

Feed Efficacy Analysis

The quantity of MR_2 mulberry leaf offered to the entire groups was similar and *B. mori* larvae were fed five times a day. The left over mulberry leaves and litter were weighed daily and recorded. Similarly, initial and final weights of the 5^{th} instar larvae were recorded in control (group 1) and nutritional supplementary compounds treated (group 2) groups. Fresh leaves were cut into two halves; one half was used to determine the initial water content. Three 5^{th} larvae in control and nutritional supplementary compounds treated groups were dried in a hot air oven to constant weight to determine the dry weights. Based on these weights, the physiological parameters like food consumption (FC), food utilization (FU), approximate digestibility (AD), Food consumption index (FCI) and coefficient of food utilization (CFU) were calculated (Arsenev and Bromlei, 1957).

Food Consumption was calculated by following formula

$$\mathbf{FC = Dry\ weight\ of\ leaves\ offered - Dry\ weight\ of\ residual\ leaves}$$

Food Utilization was calculated by following formula

$$\mathbf{FU = Weight\ of\ food\ consumed - Weight\ of\ faecal\ matter}$$

Approximate Digestibility was calculated by following formula

$$\mathbf{AD} = \frac{(E-F)}{E} \times 100$$

Where, E = Dry weight of food eaten, F = Dry weight of faeces produced

Food consumption index (FCI) was calculated by following formula

$$\mathbf{FCI} = \frac{E}{T \times A}$$

Where, E = Dry weight of food eaten, T = Duration of Experimental period, A = Mean dry weight of animal during experimental period

Co-efficient of Food Utilizaton (CFU) was calculated by following formula

$$\mathbf{CFU} = \frac{\mathbf{Dry\ weight\ of\ food\ consumed - Dry\ weight\ of\ faeces}}{\mathbf{Dry\ weight\ of\ food\ consumed}} \times$$

Morphometry analysis

Biological traits like larval (III, IV and V instars), length, width and weight were recorded for 6 larvae from control and nutritional supplementary compounds treated groups and mean values of 6 readings were recorded for observation. Larval length, width and weight were measured by using scales and digital balance respectively.

Statistical analysis

All the data were analyzed by one way analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT) using a commercially available statistics software package (SPSS® for Windows, V. 16.0, Chicago, USA). Results were presented as mean ± standard deviation (SD). $P < 0.05$ was regarded as statistically significant (Sokal and Rohilf, 1981).

III. RESULTS

Feed efficacy analysis

Feed efficacy characters like Food Consumption (FC), Food Utilization (FU), Approximate Digestibility (AD), Food Consumption Index (FCI) and Co-efficient of Food Utilization (CFU) data analysis of V instar larvae of *B. mori* fed with control MR2 mulberry leaves and different nutritional supplementary compounds such as amino acids L-Serine (T1), Aspartic acid (T2), Arginine (T3), Vitamins Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8) treated MR2 leaves (Table 1).

Table 1 shows that the food consumption (FC) data of V instar larvae of *B. mori* fed with control and different nutritional supplementary compounds treated MR2 mulberry leaves. The food consumption (gm) of group 'C' larvae (46.100±1.166gm), group T1 larvae (51.716±1.970gm), group T2 larvae (48.872±1.908gm), group T3 larvae (48.523±1.881gm), group T4 larvae (48.128±1.516gm), group T5 larvae (47.867±1.427gm), group T6 larvae (47.728±1.401gm), group T7 larvae (47.274±1.372gm) and group T8 larvae (46.572±1.210gm) respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated V instar larvae food consumption (gm) was significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Table 1 shows that the food utilization (FU) data of V instar larvae of *B. mori* fed with control and different nutritional supplementary compounds treated MR2 mulberry leaves. The food utilization (gm) of group 'C' larvae (44.457±1.051gm), group T1 larvae (48.983±1.849gm), group T2 larvae (46.536±1.651gm), group T3 larvae (46.233±1.120gm), group T4 larvae (46.108±1.070gm), group T5 larvae (46.007±1.040gm), group T6 larvae (45.834±1.017gm), group T7 larvae (45.503±1.011gm) and group T8 larvae (45.270±1.002gm) respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated V instar larvae food consumption (gm) was significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Table 1 shows that the Approximate Digestibility (AD) data analysis of V instar larvae of *B. mori* fed with control and different nutritional supplementary compounds treated MR2 mulberry leaves. The Approximate Digestibility (AD) of group 'C' larvae (85.197±0.660%), group T1 larvae (88.423±1.217%), group T2 larvae (87.893±0.839%), group T3 larvae (87.537±0.657%), group T4 larvae (87.279±0.310%), group T5 larvae (87.007±0.287%), group T6 larvae (86.821±0.216%), group T7 larvae (86.509±0.167 %) and group T8 larvae (86.227±0.026%) respectively. In these nine observations, 0.25% amino acid L-Serine (group T1)

treated V instar larvae Approximate Digestibility (%) was significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Table 1 shows that the Food Consumption Index (FCI) data analysis of V instar larvae of *B. mori* fed with control and different nutritional supplementary compounds treated MR2 mulberry leaves. The Food Consumption Index (FCI) of group 'C' larvae (36.415±1.020%), group T1 larvae (42.585±1.870%), group T2 larvae (40.467±1.612%), group T3 larvae (40.205±1.584%), group T4 larvae (39.828±1.527%), group T5 larvae (38.527±1.503%), group T6 larvae (38.109±1.481%), group T7 larvae (37.853±1.460%) and group T8 larvae (37.402±1.024%) respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated V instar larvae Food Consumption Index (%) was significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Table 1 shows that the Co-Efficient of Food Utilization (CFU) data analysis of V instar larvae of *B. mori* fed with control and different nutritional supplementary compounds treated MR2 mulberry leaves. The Co-Efficient of Food Utilization (CFU) of group 'C' larvae (84.380±0.191%), group T1 larvae (89.531±0.850%), group T2 larvae (87.706±0.672%), group T3 larvae (87.412±0.601%), group T4 larvae (86.739±0.581%), group T5 larvae (85.156±0.489%), group T6 larvae (85.071±0.342%), group T7 larvae (85.831±0.243%) and group T8 larvae (84.590±0.240%) respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated V instar larvae Co-Efficient of Food Utilization (%) was significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Morphometric Analysis

Morphometric data of length, width and weight of larval, pupal and cocoon parameters of *Bombyx mori* larvae fed with control MR2 mulberry leaves and different nutritional supplementary compounds such as amino acids L-Serine (T1), Aspartic acid (T2), Arginine (T3), Vitamins Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8) treated MR2 mulberry leaves (Tables 3, 4, 5).

Table 2 shows that the Morphometric data analysis of length, width and weight of larval parameters of *B. mori* fed with control MR2 leaves and different nutritional supplementary compounds such as amino acids L-Serine (T1), Aspartic acid (T2), Arginine (T3), Vitamins Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8) treated MR2 leaves fed III instar larvae of *B. mori*. The mean length, width and weight of III instar larvae of group 'C' were (1.702±0.1656cm, 0.327±0.0289cm and 0.124±0.0165gm), respectively. The mean length, width and weight of III instar larvae of group T1 were (1.893±0.1933cm, 0.369±0.0667cm and 0.137±0.0214gm), respectively. The mean length, width and weight of III instar larvae of group T2 were (1.721±0.1845cm, 0.356±0.0485cm and 0.135±0.0198gm), respectively.The mean length, width and weight of III instar larvae of group T3 were (1.737±0.1859cm, 0.334±0.0498cm and 0.126±0.0187gm), respectively.The mean length, width and weight of III instar larvae of group T4 were (1.731±0.1842cm, 0.341±0.0348cm and 0.129±0.0169gm), respectively.The mean length, width and weight of III instar larvae of group T5 were (1.747±0.1806cm, 0.332±0.0472cm and 0.132±0.0201gm), respectively.The mean length, width and weight of III instar larvae of group T6 were (1.735±0.1873cm, 0.327±0.0375cm and 0.127±0.0180gm), respectively.The mean length, width and weight of III instar larvae of group T7 were (1.724±0.1825cm, 0.348±0.0417cm and 0.136±0.0170gm), respectively.The mean length, width and weight of III instar larvae of group T8 were (1.715±0.1834cm, 0.328±0.0432cm and 0.129±0.0163gm), respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated III instar larvae length, width and weight were significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Table 3 shows that the Morphometric data analysis of length, width and weight of larval parameters of *B. mori* fed with control MR2 leaves and different nutritional supplementary compounds such as amino acids L-Serine (T1), Aspartic acid (T2), Arginine (T3), Vitamins Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8) treated MR2 leaves fed IV instar larvae of *B. mori*. The mean length, width and weight of IV instar larvae of group 'C' were (5.933±0.1422cm, 0.602±0.0616cm and 0.473±0.0341gm), respectively. The mean length, width and weight of IV instar larvae of group T1 were (6.561±0.2972cm, 0.678±0.0852cm and 0.565±0.0403gm), respectively. The mean length, width and weight of IV instar larvae of group T2 were (6.503±0.2860cm, 0.613±0.0794cm and 0.525±0.0413gm), respectively.The mean length, width and weight of

IV instar larvae of group T3 were (6.473±0.2673cm, 0.626±0.0633cm and 0.545±0.0473gm), respectively.The mean length, width and weight of IV instar larvae of group T4 were (5.485±0.2694cm, 0.619±0.0604cm and 0.543±0.0342gm), respectively.The mean length, width and weight of IV instar larvae of group T5 were (5.427±0.2217cm, 0.627±0.0675cm and 0.521±0.0334gm), respectively.The mean length, width and weight of IV instar larvae of group T6 were (5.418±0.2170cm, 0.645±0.0647cm and 0.542±0.0397gm), respectively.The mean length, width and weight of IV instar larvae of group T7 were (5.457±0.2346cm, 0.637±0.0543cm and 0.525±0.0342gm), respectively.The mean length, width and weight of IV instar larvae of group T8 were (5.405±0.2643cm, 0.617±0.0467cm and 0.536±0.0312gm), respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated IV instar larvae length, width and weight were significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

Table 4 shows that the Morphometric data analysis of length, width and weight of larval parameters of *B. mori* fed with control MR2 leaves and different nutritional supplementary compounds such as amino acids L-Serine (T1), Aspartic acid (T2), Arginine (T3), Vitamins Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8) treated MR2 leaves fed V instar larvae of *B. mori*. The mean length, width and weight of V instar larvae of group 'C' were (6.716±0.2483cm, 1.033±0.1011cm and 2.935±0.0940gm), respectively. The mean length, width and weight of V instar larvae of group T1 were (7.250±0.3870cm, 1.330±0.2016cm and 3.375±0.2740gm), respectively. The mean length, width and weight of V instar larvae of group T2 were (7.000±0.3781cm, 1.276±0.1614cm and 3.028±0.1260gm), respectively.The mean length, width and weight of V instar larvae of group T3 were (6.983±0.3448cm, 1.268±0.1616cm and 3.168±0.1375gm), respectively.The mean length, width and weight of V instar larvae of group T4 were (6.750±0.2178cm, 1.257±0.1538cm and 3.032±0.1741gm), respectively.The mean length, width and weight of V instar larvae of group T5 were (6.750±0.2275cm, 1.139±0.1374cm and 3.035±0.1870gm), respectively.The mean length, width and weight of V instar larvae of group T6 were (6.750±0.2174cm, 1.127±0.1385cm and 3.185±0.1450gm), respectively.The mean length, width and weight of V instar larvae of group T7 were (6.750±0.2359cm, 1.148±0.1279cm and 3.176±0.1845gm), respectively.The mean length, width and weight of V instar larvae of group T8 were (6.750±0.2256cm, 1.176±0.1157cm and 3.157±0.1240gm), respectively. In these nine observations, 0.25% amino acid L-Serine (group T1) treated V instar larvae length, width and weight were significantly increased than the other eight groups ('C', T2, T3, T4, T5, T6, T7, T8).

IV. DISCUSSION

In the present study, the feed efficacy and larval (III, IV and V) growth rate were significantly increased in some groups. Many researchers showed that the larval characters improve by different concentrations of complementary compounds such as ascorbic acid, folic acid, thiamin, vitamin B complex etc., (Nirwani and Kaliwal, 1996, 1998; Etaberi *et al*., 2004; Balasundaram *et al*., 2013). Muniandy *et al*., (1995) have showed that multi-vitamins and mineral compounds could increase the food intake, growth and conversion efficiency of silkworm. The total body weight gain on wet weight basis was significantly higher in Amino acids treated mulberry leaves followed by MR2 leaf variety. Among the mulberry leaves, Amino acids treated mulberry leaves has gained maximum body weight, cocoon weight and silk trait than the worms fed with MR2 leaf variety. The current findings are comparable with the results of Horie, (1978). In the present study, it has been observed that silkworms fed by the particular concentration (0.25%) of amino acid L-Serine have enhanced the feed efficacy and larval length, width and weight were concomitantly increased from III to V instars, suggested that amino acid L-Serine which were stimulate the silkworm to feed more amount of nutrients intake than the control. The weight of IV and V instar larvae were found to be increased when the worms were fed with Amino acids treated mulberry leaves followed by MR2 leaf variety. In silk worm, a gustatory stimulating activity has been observed to some extent (Ito, 1961). This work is corroborated with Nirwani and Kaliwal, (1996), suggested that this enhancement in feed efficacy and larval length, width and weight related to phagostimulation of folic acid. Several authors also reported these effects about ascorbic acid (Dobzshenok, 1974; Ito, 1978; Kl-Karkasy and Idriss, 1990). Since most of this multi-vitamin compounds is composed of ascorbic acid, it could be thought that the increase of larval weight is due to an enhancement of feeding activity in treated larvae although the vitamins as cofactors can

facilitate the metabolical pathway. In the present study, the Amino acids treated mulberry leaves may have helped the silkworm larvae in a beneficial way, leading to increase the conversion and silk synthesis. It is suggested that MR2 leaf variety influences the conversion of more food towards shell content as reported earlier (Radha *et al*, 1981; Tayade *et al.*, 1988 and Govindan *et al.*, 1990). Similar findings have also been observed in the present study that amino acid L-Serine (0.25%) act stimulate the feeding activity in the silkworms. Therefore, amino acid L-Serine can improve the food digestibility and increase the larval length, width and weight. In this study, cocoon parameters changed in different treatments. Previously, it was reported that enrichment of mulberry leaves by some vitamins could increase the growth rate of silkworm larvae. Haq and Saleem, (1985) who have investigated that when silkworm larvae were fed on 0.2% N treated mulberry leaves, increased the cocoon weight. Further, it has been revealed from the present study that the weight of cocoon was maximum in silkworm larvae when fed with Amino acids treated mulberry leaves than MR2 leaf variety. Evanglista *et al*. (1997) have also reported that the larval and cocoon length, width and weight increase under multi-vitamin treatment. Shivakumar, (1995) finding also incorporated with the food consumption has a direct relevance on the weight of larvae, cocoon, pupae and shell, the independent parameters of consumption and productivity vary depending upon the type of nutrition. The Amway protein supplemented (0.5%) mulberry leaf significantly improved larval growth and economic characters of silkworm (Amalarani *et al*., 2011). In sericulture, nutritional requirement and its conversion efficiency contribute directly or indirectly on the cost benefit ratio of silkworm rearing. It was considered as an important physiological criterion for evaluating the superiority of silkworm breeds. In silkworm, 97% of the total food intake during the last two instars and the feed utilization study confined to V instar larvae as 80-85% of the total leaves consumed in this instar as silkworm very active metabolically at this stage (Ramesh *et al.*, 2017). Javaid (1991) and Nadeem (1996) who have reported that silkworm larvae fed on mulberry leaves supplemented with mineral nutrients gave good food consumption and coefficient of utilization and low mortality and the larvae which were offered mulberry leaves treated with 0.2% N + 0.150% ascorbic acid showed lower mean values of body weight, body length, food consumption, coefficient of utilization and cocoon shell ratio but higher mortality rate. Verma and Atwal, (1963) have observed that feeding mulberry leaves supplemented with distilled water alone slightly increased the weights of larva, pupa and cocoon shell. Mulberry leaves with the combination of Nitrogen (0.2%) which enhances the growth and silk production (Javed and Gondal, 2002). According to Soo-Hoo and Frankel, (1966) the diminishing consumption rate of less preferred food was partially compensated by increased assimilation efficiency. Similar trend was observed by Udupa, (1986) and Tayade, (1987), Food ingestion and digestibility and growth in the larval stages are interrelated and the rate of digestion in silkworm increase with the advance of instar, which is highest, about 65% in the fifth instar (Ueda, 1982).The enrichment of mulberry leaves with amino acid L-Serine increase larval length, width and weight increase in these insects was related to metabolisms other than proteins. It is assumed that fortification of diet supports the metabolism of carbohydrates and lipids, in conclusion, L-Serine could increase some biological characteristics in silkworm, but this enhancement could economically improve the Sericulture goals. This finding clearly indicates quality and quantity of the food is needed to support optimal larval growth. The result obtained from the study revealed a highly significant variance on nutritional traits between the control MR2 leaf and amino acid L-Serine treated MR2. In the present study, the treatment of amino acid L-Serine at the concentration of 0.25% may have beneficial effects on the growth of the silkworm feed efficacy and larval length, width and weight and also increased the quantity of silk production by enhancing than control.

V. CONCLUSION

In the present study to be concluded that the feed efficacy parameters like food consumption, food utilization, digestibility, food consumption index rate, coefficient of food utilization and morphometric analysis larval (III, IV and V) growth rate was comparatively enhance by 0.25% concentration of amino acid L-Serine treated MR2 mulberry leaves than the control and other nutritional supplementary groups such as Aspartic acid (T2), Arginine (T3), Vitamins Niacin (T4), Retinol (T5), Calciferol (T6), Ascorbic acid (T7) and Glucose (T8).

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RESULTS TABLES

Table 1. Morphometric data analysis of III instar larvae of *Bombyx mori* fed with control and different nutritional supplements treated MR_2 mulberry leaves

Experimental Groups / Concentrations (0.25%)	Larvae length (cm)	Larvae width (cm)	Larvae weight (gm)
Control (C)	1.702±0.1656^{a}	0.327±0.0289^{a}	0.124±0.0165^{a}
L-Serine (T1)	1.893±0.1933^{b}	0.369±0.0667^{b}	0.137±0.0214^{b}
Aspartic acid (T2)	1.721±0.1845^{ab}	0.356±0.0485^{ab}	0.135±0.0198^{ab}
Arginine (T3)	1.737±0.1859^{ab}	0.334±0.0498^{ab}	0.126±0.0187^{ab}
Niacin (T4)	1.731±0.1842^{ab}	0.341±0.0348^{ab}	0.129±0.0169^{ab}
Retinol (T5)	1.747±0.1806^{ab}	0.332±0.0472^{a}	0.132±0.0201^{b}
Calciferol (T6)	1.735±0.1873^{a}	0.327±0.0375^{a}	0.127±0.0180^{b}
Ascorbic acid (T7)	1.724±0.1825^{a}	0.348±0.0417^{a}	0.136±0.0170^{b}
Glucose (T8)	1.715±0.1834^{a}	0.328±0.0432^{a}	0.129±0.0163^{ab}

Values are Mean ± Standard Deviation of six observations. Values in the same column with different superscript letters (a, b & c) differs significantly at P<0.05 (DMRT).

Table 2. Morphometric data analysis of IV instar larvae of *Bombyx mori* fed with control and different nutritional supplements treated MR_2 mulberry leaves

Experimental Groups / Concentrations (0.25%)	Larvae length (cm)	Larvae width (cm)	Larvae weight (gm)
Control (C)	5.933±0.1422^{b}	0.602±0.0616^{a}	0.473±0.0341^{a}
L-Serine (T1)	6.561±0.2972^{c}	0.678±0.0852^{c}	0.565±0.0403^{b}
Aspartic acid (T2)	6.503±0.2860^{ab}	0.613±0.0794^{b}	0.525±0.0413^{b}
Arginine (T3)	6.473±0.2673^{ab}	0.626±0.0633^{ab}	0.545±0.0473^{ab}
Niacin (T4)	5.485±0.2694^{ab}	0.619±0.0604^{ab}	0.543±0.0342^{ab}
Retinol (T5)	5.427±0.2217^{ab}	0.627±0.0675^{ab}	0.521±0.0334^{ab}
Calciferol (T6)	5.418±0.2170^{a}	0.645±0.0647^{ab}	0.542±0.0397^{ab}
Ascorbic acid (T7)	5.457±0.2346^{a}	0.637±0.0543^{a}	0.525±0.0342^{ab}
Glucose (T8)	5.405±0.2643^{a}	0.617±0.0467^{a}	0.536±0.0312^{ab}

Values are Mean ± Standard Deviation of six observations. Values in the same column with different superscript letters (a, b & c) differs significantly at P<0.05 (DMRT).

Table 3. Morphometric data analysis of V instar larvae of *Bombyx mori* fed with control and different nutritional supplements treated MR_2 mulberry leaves

Experimental Groups / Concentrations (0.25%)	Larvae length (cm)	Larvae width (cm)	Larvae weight (gm)
Control (C)	6.716±0.2483^{a}	1.033±0.1011^{a}	2.935±0.0940^{a}
L-Serine (T1)	7.250±0.3870^{c}	1.330±0.2016^{b}	3.375±0.2740^{b}
Aspartic acid (T2)	7.000±0.3781^{bc}	1.276±0.1614^{b}	3.028±0.1260^{b}
Arginine (T3)	6.983±0.3448^{bc}	1.268±0.1616^{b}	3.168±0.1375^{ab}
Niacin (T4)	6.750±0.2178^{bc}	1.257±0.1538^{ab}	3.032±0.1741^{ab}
Retinol (T5)	6.750±0.2275^{bc}	1.139±0.1374^{ab}	3.035±0.1870^{ab}
Calciferol (T6)	6.750±0.2174^{bc}	1.127±0.1385^{ab}	3.185±0.1450^{ab}
Ascorbic acid (T7)	6.750±0.2359^{ab}	1.148±0.1279^{ab}	3.176±0.1845^{a}
Glucose (T8)	6.750±0.2256^{ab}	1.176±0.1157^{ab}	3.157±0.1240^{a}

Values are Mean ± Standard Deviation of six observations. Values in the same column with different superscript letters (a, b & c) differs significantly at P<0.05 (DMRT).

Table 4. Feed efficacy data analysis of V instar larvae of *Bombyx mori* fed with control and different nutritional supplements treated MR_2 mulberry leaves

Experimental Groups / Concentration (0.25%)	Food Consumption (gm)	Food Utilization (gm)	Approximate Digestibility (%)	Food Consumption Index (%)	Co-efficient of Food Utilization (%)
Control (C)	46.100±1.166^{a}	44.457±1.051^{a}	85.197±0.660^{a}	36.415±1.020^{a}	84.380±0.191^{a}
L-Serine (T1)	51.716±1.970^{c}	48.983±1.849^{c}	88.423±1.217^{c}	42.585±1.870^{c}	89.531±0.850^{c}
Aspartic acid (T2)	48.872±1.908^{b}	46.536±1.651^{b}	87.893±0.839^{b}	40.467±1.612^{b}	87.706±0.672^{b}
Arginine (T3)	48.523±1.881^{b}	46.233±1.120^{bc}	87.537±0.657^{bc}	40.205±1.584^{bc}	87.412±0.601^{b}
Niacin (T4)	48.128±1.516^{b}	46.108±1.070^{bc}	87.279±0.310^{bc}	39.828±1.527^{bc}	86.739±0.581^{bc}
Retinol (T5)	47.867±1.427^{ab}	46.007±1.040^{bc}	87.007±0.287^{bc}	38.527±1.503^{bc}	85.156±0.489^{ab}
Calciferol (T6)	47.728±1.401^{ab}	45.834±1.017^{ab}	86.821±0.216^{ab}	38.109±1.481^{ab}	85.071±0.342^{ab}
Ascorbic acid (T7)	47.274±1.372^{ab}	45.503±1.011^{ab}	86.509±0.167^{ab}	37.853±1.460^{ab}	85.831±0.243^{ab}
Glucose (T8)	46.572±1.210^{a}	45.270±1.002^{ab}	86.227±0.026^{ab}	37.402±1.024^{ab}	84.590±0.240^{ab}

Values are Mean ± Standard Deviation of six observations. Values in the same column with different superscript letters (a, b & c) differs significantly at P<0.05 (DMRT).