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Dynamics of Nutritional Indices in Fifth Instar Silkworm *Bombyx Mori* L. Parasitized with *Beauveria Bassiana*

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Abstract

Silkworm Bombyx mori is a small economically significant insect. Due to domestication for centuries, silkworms have become very gentle and subtle to the environmental conditions and micro-pathological agents which affect its metabolism, the food intake, dietary utilization, dietary efficiency, morpho-nutritional parameters such as olfactory organs and gene expression in the silkworm. Hence, the present research was focused to comprehend the dynamic changes in the nutritional parameters amalgamating the effects of infection of Beauveria bassiana in 5th instar silkworm compared to untreated silkworms. For the current investigation, the popular silkworm race bivoltine double hybrid (CSR2 X CSR27) X (CSR6 X CSR 26) was chosen. Various nutritional parameters such as ingestion of mulberry leaf, digestion, excretion, approximate digestibility, consumption index and reference ratio were estimated based on the dry weight of mulberry. The results indicated that food consumption, digestion of food ingested and excreta decreased in Beauveria bassiana parasitized silkworms. No significant variation was noticed in approximate digestibility and reference ratio from the first day to the fifth day of the instar, but on the sixth day, a significant drop in these two parameters was noticed compared to unparasitized worms. The consumption index was recorded higher in the experimental batch.

Keywords: *Ingesta, Digesta, Excreta, Approximate digestibility, Reference ratio, Consumption index*

1. Introduction

Sericulture is the sustainable multipurpose agro-based industry which chiefly aims at production of silk. Naturally available silk fiber is the end product of silkworm farming. It involves a series of activities starting from mulberry cultivation, feeding these mulberry leaves to the rearing silkworms, procuring cocoons, weaving, dyeing and marketing silk and silk products. Thereby it covers various sectors of agriculture, research, innovation, art and design of textiles. It not only provides employment opportunities to many but also helps in improving the economic status of the people and country at large. Cocoon production is the most valuable outcome of silkworm rearing as it provides the raw material for silk industries. In addition to cocoons, silkworm proteins, moths and silkworm wastes are processed and used as animal feeds. Globally, modern economies of different states have been benefited from the silkworm farming through the social uplift due to employment opportunities especially women empowerment. Silk production boosts the environmental conservation (Gamble, 2011), employment opportunities (Benchamin and Jolly, 1986), social benefit and serves as main occupation for a self-reliant living.

The mulberry silkworm is a commercially significant insect that contributes to the economic development of the country. Silkworm is a very sensitive monophagous insect that forages only on mulberry and obtains all nutrients and water from the mulberry leaves to form its body, grow, endure, synthesize silk proteins and spin cocoons. The success of silkworm farming depends on the provision of nutritive mulberry leaves apart from other factors. Nourishment is a vital physiological factor that impacts the growth and development of silkworms and production of silk. The fifth instar is a voracious feeding stage of the silkworm, which warrants progressive changes in its biology and physiology. Biotic and abiotic factors influence the rate of ingestion and utilization of mulberry leaf by the silkworm. The capability of silkworms to consume mulberry leaf, digest, absorb, assimilate and convert it to silk fiber differs depending on environmental factors and health conditions. Consumption of suitable mulberry leaves influences the silkworm growth, survival, sustenance and reproductive performance (Slansky *et al.*, 1985). The silkworm performance relies on the nutritional value of the mulberry leaves (Morohoshi *et al.*,1976, Koul *et al*.,1979, Kumar *et al.*, 2000) and the quantity of food ingested (Takano *et al.*,1978). Pathological infections influence the conversion efficiency of the mulberry leaf into the body biomass, silk synthesis and spinning of the cocoon.

Food provides the nutrients an organism needs to function, survive, and maintain health, making it essential for survival. Nutrition is one of the most vital factors in silkworm rearing. It is the basic and fundamental aspect of silkworm rearing for its proper growth and development. The quantity of nutrients acquired by silkworm varies depending upon their body size, metabolic rate, stress induced by the biotic and abiotic factors and host-pathogen interaction. Improper nutrition due to diseases affects growth, development, body weight, fecundity, longevity and other physiological activities. Insects respond to imbalanced diet in any of the three ways either by altering the total amount of ingested food; or by switching on to other food with a different nutrient balance or regulate the effectiveness of the nutrients (Dadd, 1985). Silkworm digests the ingested food for absorption and supply of essential nutrients for its growth and development (Shamsuddin, 2009). Studies on feed utilization are generally confined to 4th and 5th instar of silkworm as they consume 80% of total leaf intake in these instars.

Food utilization studies in silkworm were well investigated ever since the pioneering work of Hiratsuka (1920) and various studies with regard to food consumption and utilization by *Bombyx mori* is reviewed by Legay (1958). The studies on food consumption were confined to V instar as the maximum quantity (80-85%) of mulberry leaves are used up in this stage of the silkworm life cycle and the silkworms are metabolically very active at this stage (Ueda, 1965). Feed utilization efficiency of temperate strains of silkworm has been extensively studied by Matsumara *et al.*, (1955), Takeuchi *et al.*, (1964), Ueda *et al.*, (1967). Later methodological changes were made by Nakano *et al.*, (1968), Horie *et al.*, (1976). The relationship between cocoon productivity and mulberry leaf intake has been reported by Takano *et al.*, (1978). Scriber *et al.*, (1981) stated that understanding the food consumption pattern of insects is essential to gaining knowledge of their comprehensive metabolic and physiological activities. Nutritional quality as well as environmental conditions and stress caused by any biotic or abiotic factors have a greater influence on the quantity of intake of mulberry leaf, breakdown and digestibility of food in silkworm *Bombyx mori* (Ito, 1972). Therefore, in the present study, an attempt has been made to assess the various nutritional parameters influenced by *Beauveria bassiana* infestation.

2. Materials And Methods

The current investigation has been carried out on the commercially popular bivoltine double hybrid (CSR2 X CSR27) X (CSR6 X CSR26). The stock of silkworms has been maintained by following the standard protocol as suggested by Dandin (2003). Silkworms were reared by careful synchronization of several factors such as maintenance of a mulberry garden to provide suitable mulberry leaves for the silkworms, strict maintenance of hygiene in the rearing house and its surroundings, manipulation of required environmental conditions, procurement of good quality chawki worms etc. in the silkworm rearing laboratory of Department of Biosciences and Sericulture, Sri Padmavati Mahila Visvavidyalayam, Tirupati.

Simultaneously pure *Beauveria bassiana* culture was maintained by using Potato Dextrose agar medium. Conidia were collected from the 3-week-old *Beauveria bassiana* pure culture and prepared sterile inoculum in a beaker that contained 50 ml of sterile double distilled water and a drop of tween-20. LD50 value was calculated for the 5^{th} instar silkworms by following the probit analysis (Leora software, 1987). Then the silkworms were inoculated immediately after passing the fourth moult, with sub-lethal concentration (2.15×10^4 conidia/ml) and untreated silkworms were treated with double distilled water and used as control. Four replications were kept for the experiment with hundred silkworms in each replication.

After induction of the myco-pathogen, *Beauveria bassiana,* the larvae were taken for experimentation to scan the dynamic daily changes occurring in the nutritive indices. A specific quantity of mulberry leaf was weighed and fed to the silkworms from the 1^{st} day to the 6^{th} day of the 5^{th} instar, the quantity of leftover leaves and excreta were weighed every day as recommended by Waldbauer(1968), Kogan(1981) and the data was recorded for the nutritive components like ingestion, digestion, excretion, approximate digestibility, reference ratio and consumption index in the 5^{th} instar silkworm. The weight of fresh mulberry leaves and simultaneously the same quantity of dry leaf weight was recorded.

Ingesta:

The day wise ingested dry weight of mulberry leaves by silkworm throughout the fifth instar i.e., from immediately passing 4th moult to the ripening stage was calculated with the help of the formula as given below and expressed in grams per larva.

Ingesta/day = Total leaf supplied – leaf leftover/day

Digesta:

Day wise assimilated dry food was calculated from the ingesta of mulberry leaves and leftover leaves in dry weight by silkworm larva from starting of the 5th instar until ripening. It is estimated using the formula furnished below and expressed in grams per larva.

Digesta/day = Dry weight of leaf ingested – Dry weight of litter/day

Excreta:

Excreta is non-utilized leaves of mulberry in the form of litter from the ingested mulberry leaves of a silkworm. It is estimated by using the following formula and expressed in grams per larva.

Excreta/day = (Ingesta – Digesta)/day

Approximate digestibility:

Approximate digestibility denotes the amount of nutrients assimilated. It directly signifies the assimilation competence of food by the individual. In the first instar of the silkworm, the approximate digestibility is the highest but the food intake of this instar is less but in the fifth instar the situation is reverse.

Approximate Digestibility (AD) =

$$\frac{\text{Dry weight of leaf ingested} - \text{Dry weight of litter}}{\text{Dry weight of leaf ingested}} \times 100$$

Reference Ratio (RR):

The ratio between the dry weight of food ingested divided by the dry weight of excreta is called the reference ratio and higher values of the reference ratio indicate a high rate of digestion and absorption of food and it was calculated by using the below-mentioned formula

$$\text{Reference ratio (RR)} = \frac{\text{Dry weight of food ingested}}{\text{Dry weight of excreta}}$$

Consumption index:

The consumption index is related to the ratio of food ingested to the mean weight of the silkworm and it measures the rate at which nutrients enter the digestive system. The consumption index was estimated in healthy and inoculated silkworms by employing the formula mentioned below

$$\text{Consumption Index} = \frac{\text{Ingesta}}{\text{Fresh larval weight (g)} \times \text{larval duration (days)}}$$

Statistical Analysis

The data were collected from the four replications of the experiment and control batches and analyzed the data by using Analysis of Variance (ANOVA) and presented in the tables.

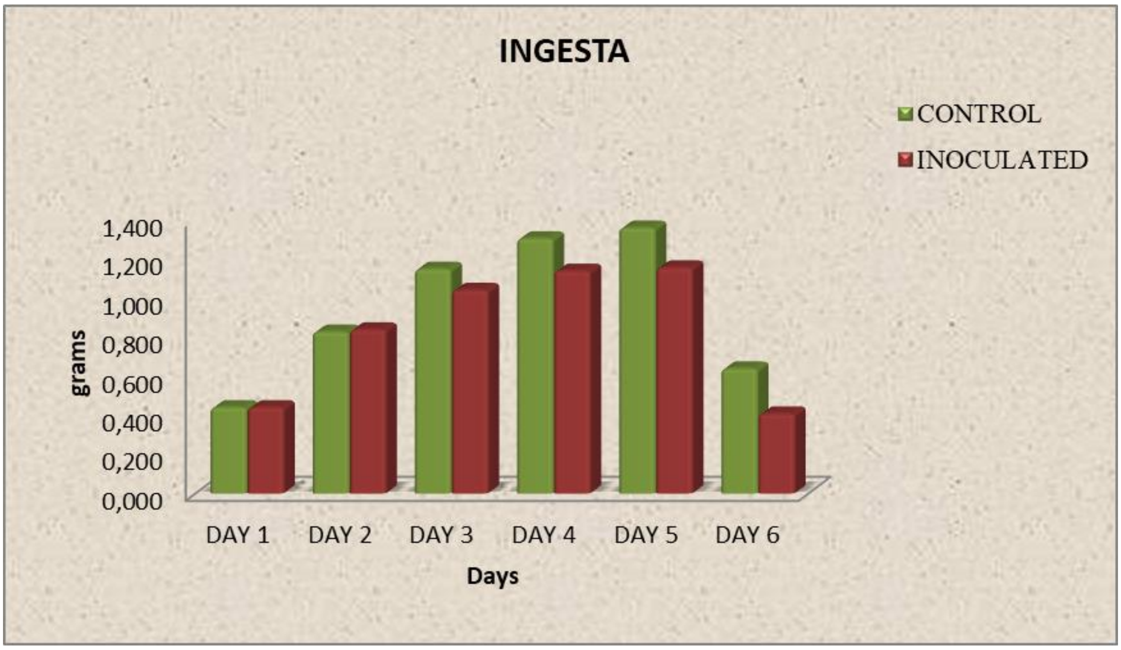
3. Results and Discussion

The data recorded on nutritional indices of the silkworms are presented in Tables 1 - 6.

Table 1 and Fig 1: Everyday changes in ingesta of silkworm ***Bombyx mori*** L. inoculated with fungal pathogen ***Beauveria bassiana*** (Bals.) Vuill. with reference to control during 5th instar.

Ingesta/larva(g)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Control	0.441 ± 0.030	0.827 ± 0.008	1.148 ± 0.019	1.304 ± 0.013	1.359 ± 0.011	0.639 ± 0.025
Inoculated	0.441 ± 0.029	0.839 ± 0.017	1.041 ± 0.011	1.139 ± 0.015	1.156 ± 0.015	0.409 ± 0.018
P value	1.000	0.154	0.000	0.000	0.000	0.000
Sig	NS	NS	***	***	***	***

NS = Not Significant; *** = p< 0.001 (Highly Significant)

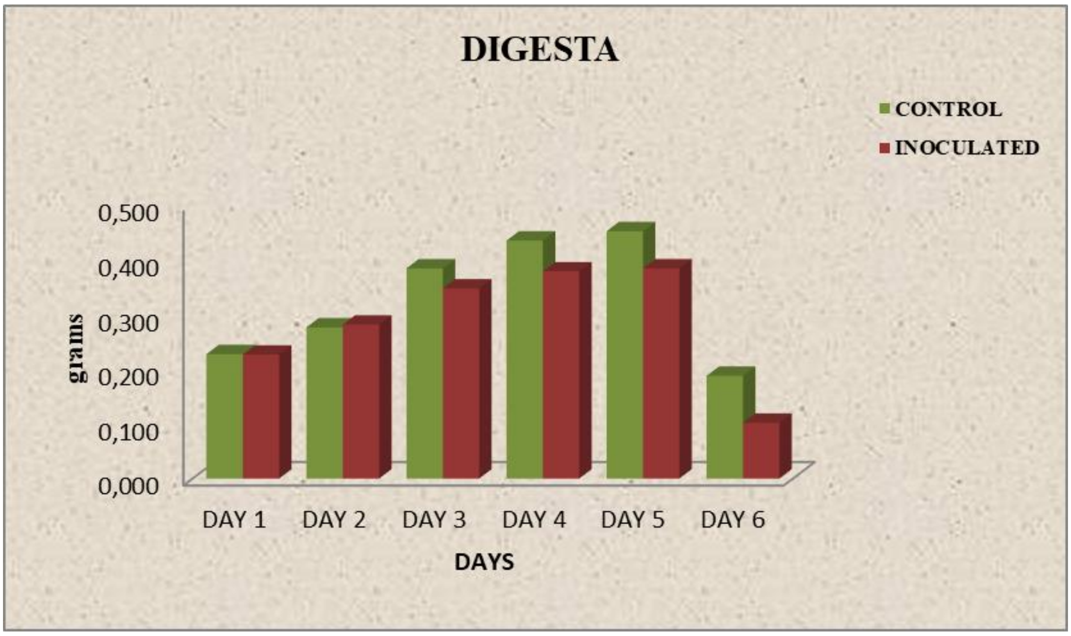


The food intake was high after 24 hrs of infection. Gradual elevation of intake of the mulberry leaf has been noticed in both healthy (0.441 g/larva to 1.359 g/larva) and *Beauveria bassiana* parasitized silkworm (0.441 g/larva to 1.156 g/larva) but compared to healthy silkworm no significant variation has been noticed in the ingestion of mulberry leaf on 1st and 2nd day of the instar. But, on the second day, the intake of feed was higher in infected silkworms compared to the untreated silkworm. Third day onwards the ingestion of food was significantly low in experimental animals until the end of the instar.

Table 2 and Fig 2: Day to day changes in digesta of silkworm *Bombyx mori* L. inoculated with fungal pathogen *Beauveria bassiana* (Bals.) Vuill. with reference to control during 5th instar.

Digesta/larva (g)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Control	0.227 ± 0.011	0.276 ± 0.007	0.383 ± 0.008	0.434 ± 0.011	0.451 ± 0.011	0.187 ± 0.009
Inoculated	0.226 ± 0.022	0.281 ± 0.008	0.347 ± 0.018	0.378 ± 0.010	0.383 ± 0.009	0.102 ± 0.014
P value	0.936	0.263	0.001	0.000	0.000	0.000
Sig	NS	NS	***	***	***	***

NS = Not Significant; *** = p<= 0.001 (Highly Significant)



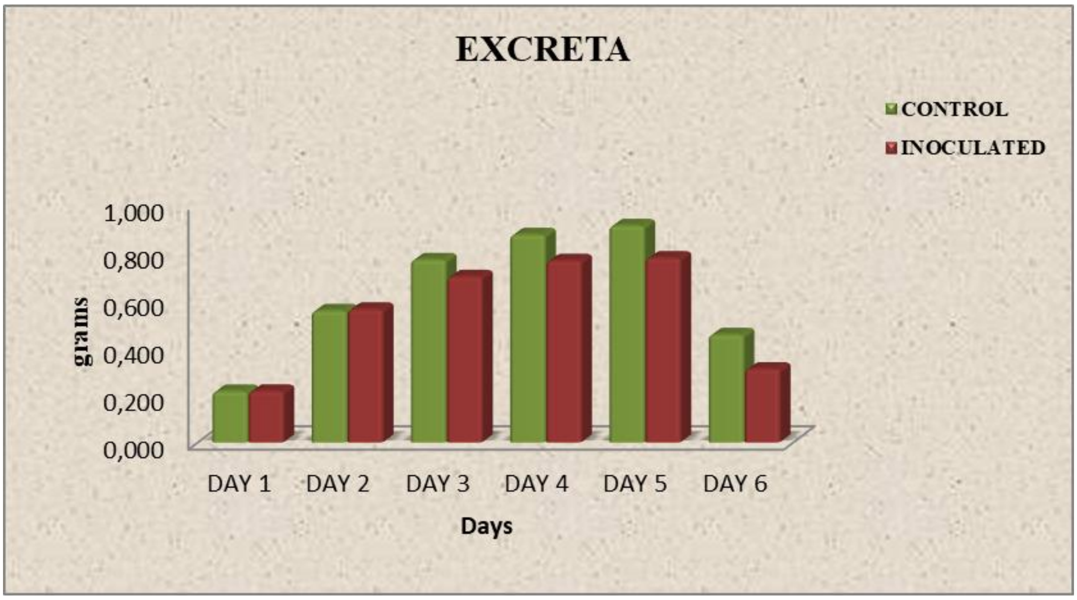
A similar trend was noticed in digestion as in ingestion of food i.e., steady enhancement of digestion of food was noticed from 1st day to 5th day of the 5th instar in treated (0.226g to 0.383g/larva) and untreated

(0.227g to 0.451g/larva) batches, on 6th day drastic decline of digestion has been noticed in both the batches i.e., treated (0.102g/larva) and untreated (0.187g/larva). Compared to healthy silkworms, a reduction in digesta was noticed from the third day to the sixth day and a slight elevation of digesta was noticed on the second day in treated worms.

Table 3 and Fig 3: Every day changes in excreta of silkworm *Bombyx mori* L. inoculated with fungal pathogen *Beauveria bassiana* (Bals.) Vuill. with reference to control during 5th instar.

Excreta/larva (g)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Control	0.214 ± 0.024	0.552 ± 0.013	0.765 ± 0.022	0.870 ± 0.007	0.908 ± 0.019	0.451 ± 0.023
Inoculated	0.215 ± 0.017	0.558 ± 0.020	0.694 ± 0.027	0.762 ± 0.021	0.773 ± 0.016	0.307 ± 0.029
P value	0.946	0.506	0.001	0.000	0.000	0.000
Sig	NS	NS	***	***	***	***

NS = Not Significant; *** = p<= 0.001 (Highly Significant)

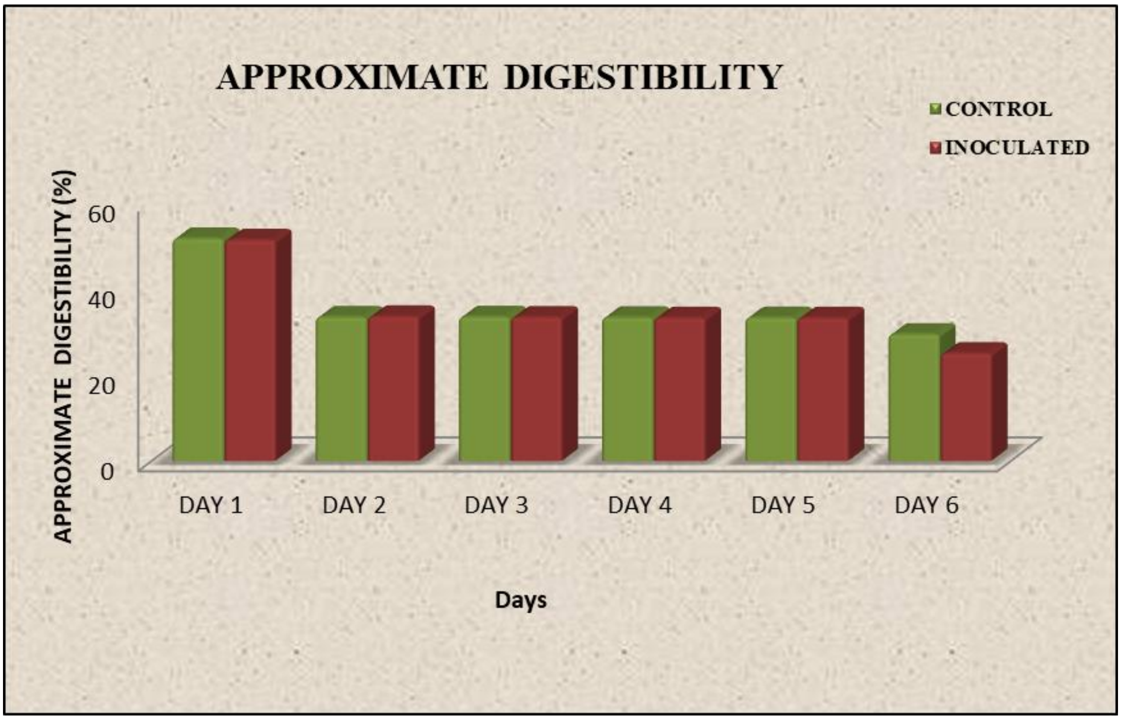


Excreta ranged from 0.214 g/larva to 0.908 g/larva in the healthy batch and in the experimental animal it ranged from 0.215 g/larva to 0.773 g/larva from the 1st day to the 5th day of the instar. Then decline in excretion was observed on the 6th day of treated (0.307 g/larva) and untreated (0.451 g/larva) batches. With reference to healthy silkworms, the decline of excretion was recorded in infected worms except on the 2nd day of the instar.

Table 4 and Fig 4: Everyday changes in approximate digestibility of silkworm *Bombyx mori* L. inoculated with fungal pathogen *Beauveria bassiana* (Bals.) Vuill. with reference to control during 5th instar.

AD (%)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Control	51.521 ± 2.561	33.319 ± 1.011	33.363 ± 1.016	33.254 ± 0.587	33.170 ± 0.950	29.333 ±1.440
Inoculated	51.204 ± 2.719	33.461 ± 1.239	33.304 ± 1.963	33.152 ± 1.155	33.130 ± 0.860	24.94 ± 4.181
P value	0.840	0.832	0.950	0.851	0.941	0.035
Sig	NS	NS	NS	NS	NS	*

AD = Approximate digestibility; NS = Not Significant; *= p< 0.05

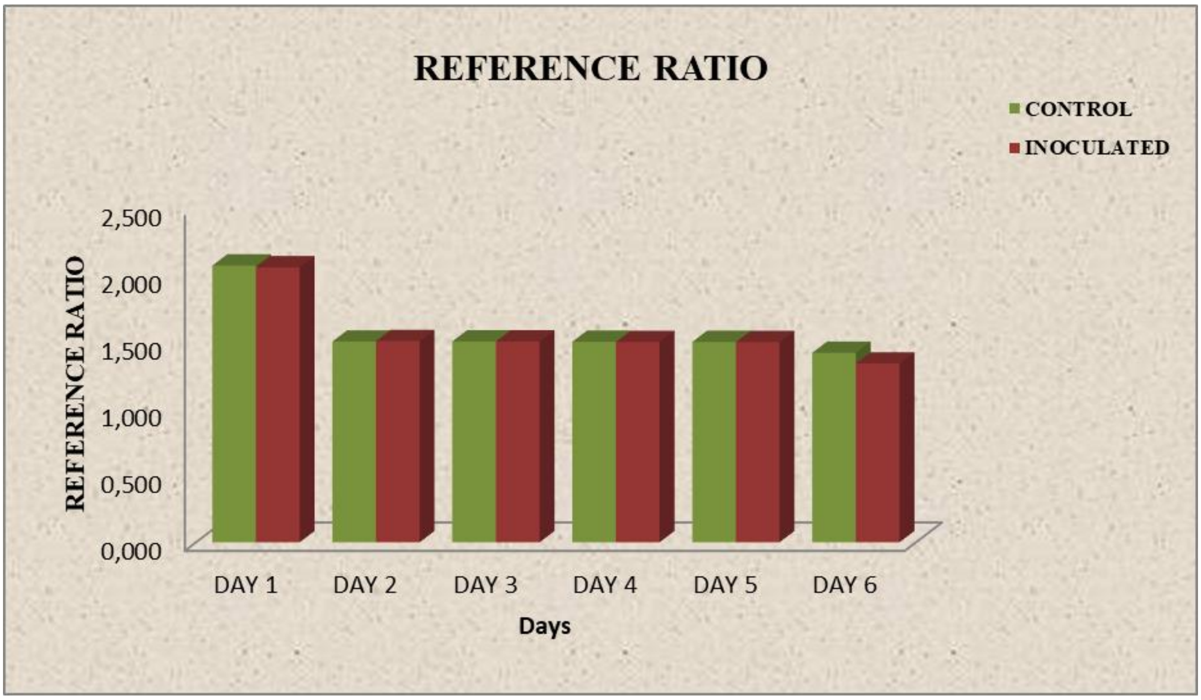


A sudden drop in approximate digestibility was noticed on the second day (33.46%) compared to the first day (51.20%) in inoculated and (33.32% and 51.52%) in untreated silkworms and then a gradual decline of approximate digestibility has been recorded from third day in healthy silkworms (33.36% to 29.33%) and treated batch (33.3% to 24.94%) upto the end of the instar. A significant reduction of approximate digestibility was noticed on the 6th day in *Beauveria bassiana* inoculated batch compared to healthy silkworms.

Table 5 and Fig 5: Every day changes in reference ratio of silkworm *Bombyx mori* L. inoculated with fungal pathogen *Beauveria bassiana* (Bals.) Vuill. with reference to control during 5th instar.

RR	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Control	2.067 ± 0.105	1.499 ± 0.023	1.501 ± 0.023	1.498 ± 0.013	1.497 ± 0.021	1.416 ± 0.029
Inoculated	2.055 ± 0.115	1.503 ± 0.028	1.500 ± 0.044	1.496 ± 0.026	1.496 ± 0.019	1.336 ± 0.072
P value	0.844	0.806	0.981	0.871	0.945	0.029
Sig	NS	NS	NS	NS	NS	*

RR=Refence ratio; NS = Not Significant; *= p< 0.05; ** = p<0.01

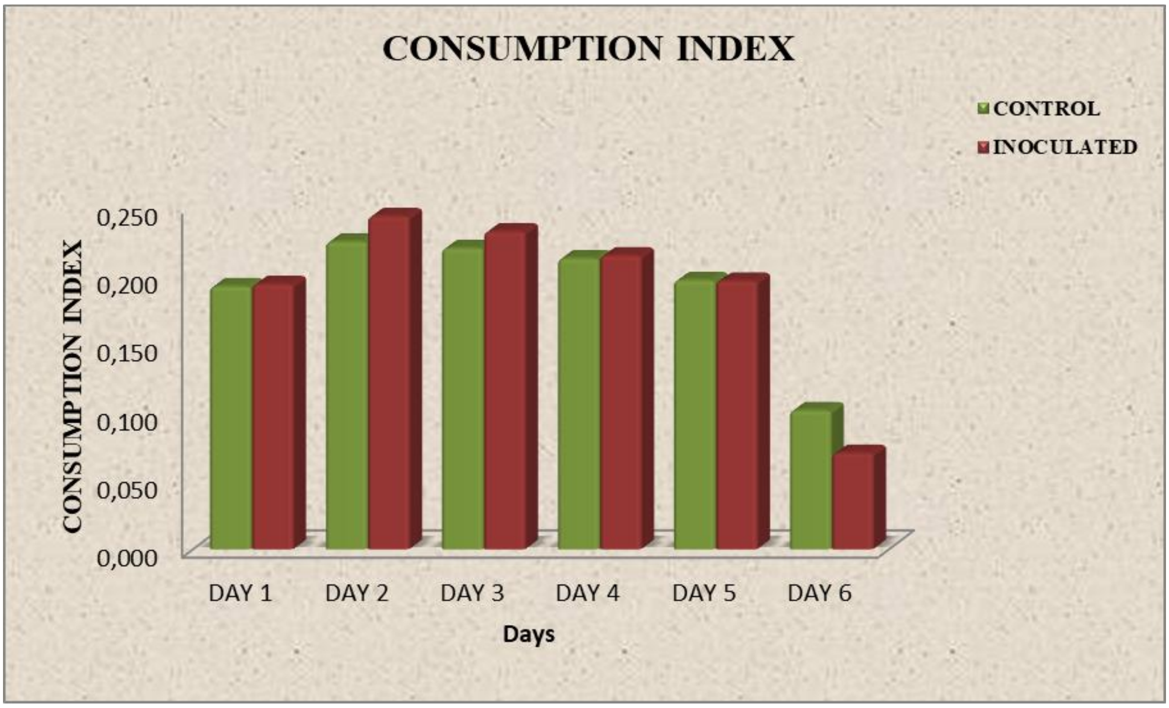


The reference ratio decreased from the first day to the sixth day in both the inoculated and healthy batches. In the healthy batch, it varied from 2.067 to 1.416 from the first day to the sixth day and in the experimental batch, it ranged from 2.055 to 1.336 from the first day to the last day of the instar. The highest reference ratio was recorded on the first day of both batches i.e., healthy (2.067) and treated (2.055) then onwards decline in reference ratio was noticed. Significant variation was observed on the sixth day in inoculated batch (1.336) compared to the control (1.416). Reference ratio is inversely proportional to food absorption and assimilation.

Table 6 and Fig 6: Every day changes in consumption index of silkworm *Bombyx mori* L. inoculated with fungal pathogen *Beauveria bassiana* (Bals.) Vuill. with reference to control during 5th instar.

CI	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Control	0.192 ± 0.015	0.224 ± 0.014	0.219 ± 0.005	0.212 ± 0.002	0.196 ± 0.003	0.101 ± 0.005
Inoculated	0.193 ± 0.022	0.243 ± 0.007	0.232 ± 0.013	0.214 ± 0.004	0.196 ± 0.008	0.070 ± 0.005
P value	0.883	0.014	0.066	0.206	0.894	0.000
Sig	NS	*	NS	NS	NS	***

CI=Consumption index; NS = Not Significant; * = p< 0.05 (Significant); *** = p< 0.001 (Highly Significant)



On the contrary, the consumption index was more in the inoculated batch than in healthy ones till the fourth day. The consumption index in healthy silkworms ranged from 0.192 to 0.212 and in inoculated worms the consumption index was recorded from 0.193 to 0.214 from the first day to the fourth day. There was a reduction in the consumption index on the fifth and sixth days in healthy (0.196 and 0.101) and inoculated (0.196,0.07) batches.

Physiological alterations especially nutritional parameters such as ingesta, digesta, excreta, approximate digestibility, reference ratio and consumption index are useful in understanding the host and pathogen interaction. In the process of the interface of the pathological agent with the host organism, they lose their individual characters and form a new entity with distinctive physiological characteristics. Bergold (1963), Benz (1963), Maertignoni (1964) noticed many physiological adjustments in insects.

The food intake and digestion were high on the 2nd day of the 5th instar. Higher consumption of mulberry leaf in the inoculated worm is to meet the energy requirement for the augmented metabolism as a result of infection by the fungal pathogen *Beauveria bassiana* and to overcome the stress created by the pathogen. The decline of intake and digestion of mulberry leaf from 3rd day onwards might be due to an increase in the severity of infection of the pathogen *Beauveria bassiana.* Takano *et al*., (1978) and Ahamed *et al*., (1999) reported that mulberry leaf consumption is dependent on the silkworm's ability to assimilate and transform digested material into body mass. Nath *et al*., (1990) made similar observations with silkworms infested by Uzi fly. This observation is consistent with Horie and Watanabe (1983), Ramakrishnan *et al*., (1974) past observations. The current findings are consistent with those of Gururaj *et al*., (2001), who found that control batches consumed more food and assimilated more nutrients than *Bm*NPV infected batches. Food ingestion recorded in the study is in contrast to those studied by Hadimani *et al.,* (2019) who found that food ingestion is more in *Bm*NPV infected larvae. Zhang *et al*., (2016) studied the epigenetic regulation of response in silkworms due to *Bombyx mori* cypovirus infection and stated that when the host is attacked by pathogens, gene expression is regulated because of the changes in DNA methylation levels which may activate or suppress the relevant signaling pathways and trigger a series of immune responses against viral invasion. Song *et al*., (2021) identified the expression of UGT46A1 gene and its effect on silkworm nutrition and stated that silkworm Bombyx mori depends on a complex olfactory system to detect its food. Due to the production of endotoxins by *Beauveria bassiana* the expression of UGT46A1 gene might have been suppressed, so the diseased worms consume less quantity of mulberry leaves. Silkworm feeds on mulberry leaves depending on its olfactory and gustatory stimuli. Qiu (2018) noticed that the olfactory system of an insect is a highly specific chemical detector which is sensitive and plays a significant role in feeding. It is mainly responsible for the sense of smell. Nagata and Nagasawa (2016) reported that the insect's frontal ganglia promote feeding behaviour through the contraction of the foregut and regulation of other neural networks. The pathological condition of the inoculated worms might have impaired the olfactory senses of the silkworms and so they consumed less quantity of leaves.

The digestion of food was high after 24 hrs of infection in the infected silkworms and is to meet the increased energy requirement for the amplified metabolism as a result of inoculation by the fungal pathogen *Beauveria bassiana* to overcome the stress created by the pathogen. The decrease in digesta from the third day onwards may be due to less consumption of food by the infested silkworm and increase in the severity of the pathogen *Beauveria bassiana* infection. According to Takano and Arai (1978) and Aftab Ahamed *et al.,* (1999), digestion of mulberry leaf is dependent on the assimilation and conversion efficiency of the silkworm. Nath *et al.,* (1990) made similar observations with silkworms infested by Uzi flies. This observation is similar to Ramakrishnan *et al.,* (1974), Horie *et al.,* (1983) past observations. The current findings are in confirmity with those of Gururaj *et al.,* (2001), who found that control batches assimilated more nutrients from the food they consumed than *Bm*NPV infected batches. Hadimani *et al.,* (2019), reported that food digestion was higher in *Bm*NPV-infected larvae. The gut microbiota present in silkworm may secrete enzymes important in digestion. Raman (1994) observed the affiliation between the bacteria of the gut and digestion and reported that the gut microbiota directly influences the nutrient uptake and metabolism in *Bombyx mori*. The endotoxins released by *Beauveria bassiana* in the diseased silkworms may affect the gut microbiota and may influence the digestion in the silkworms.

Gradual reduction of excretion during the progress of myco-pathogen interaction may be due to reduced consumption of mulberry leaf by the host organism, fluctuations in metabolism, improper discharge of the excretory materials and also impairment of Malpighian tubules caused by the penetration of the pathogen into the malpighian tubules in infected silkworms. Ramakrishnan *et al.,* (1974) reported that excretion was maximum in control batches of the tobacco caterpillar, *Spodoptera litura* than infected with *Bm*NPV. The production of fecal matter also depends on the amount of food intake and digestibility (Remadevi, 1992).

Based on the pace at which the food passes through the alimentary canal, approximate digestibility indicates the effectiveness of digestion and assimilation of mulberry leaf in silkworms based on the passage rate of food through the alimentary canal. A slight decline of approximate digestibility may be due to stress created by the myco-pathogen during its development and also gradual blockage of the passage of food in the alimentary canal due to the spread of the mycelia in the host organism resulting in the slow movement of the food through the gut. Waldbauer (1964) observed that the digestibility was influenced by nutritional deficiency, improper diet, imbalanced diet, high content of crude fiber or deficiency of water deficiency in food. Increased food cosumption does not always imply higher digestibility, according to Magadum *et al*., (1996).

The ingesta that is required for the formation of a unit of excretion is expressed as the reference ratio, which is inversely proportional to food absorption and assimilation. A higher reference ratio designates a faster rate of digestion of food taken, its absorption and increased retention efficiency of food. Impaired malpighian tubules and less amount of food intake in the infested silkworms decreases the reference ratio.

The pace at which the nutrients enter the alimentary tract is known as the consumption index. According to Trivedy (1999), the consumption index was low when food passed quickly through the gut, leaving less time for digestion. On the other hand, when food passed slowly through the intestines, the consumption index was high, allowing time for more digestion and assimilation. For the first four days, the consumption index in the experimental batch was marginally higher than in the control batch, but it became substantial on the second day. This may be due to the slow transit of ingested mulberry leaves in the alimentary canal because of the influence of disease which makes the organism lethargic. Less consumption of food suggested the decreased accumulation of organic constituents in the digestive tract.

Miao (2002) reported that different stress and disease results in substantial decrease in alkaline phosphatase (ALP) activity. An upsurge in ALP activity significantly specifies a better physiological situation and reflects the absorption, digestion and positive transportation of nutrients in the midgut. Decreased consumption index in inoculated worms may also be due to altered ALP activity due to pathological stress.

4. Conclusion

Silkworm requires nutrients for its proper growth and development which influences body weight, reproduction, egg production, silk gland weight, cocoon weight which are the most important economical parameters. Nutritional parameters like ingesta, digesta, excreta, approximate digestibility, reference ratio and consumption index are obviously influenced by the metabolic conditions of the organism. Appropriate nourishment is a vital factor for silkworm rearing as the silkworm is the biological protein factory that synthesizes silk proteins in silk glands for the production of silk. Biotic factors such as pathogenic microorganisms affect the metabolism and physiology that influence the growth and development of the silkworm due to **a** lessening in the intake of food and other nutritional factors. As nutrition is the crucial factor for successful silkworm farming, the researcher focused on comprehending the effect of myco-pathogen on various nutritional parameters that influences the economic characteristics of cocoon crop yield. Further, more studies on these lines are necessary to understand the relation between digestive parameters, morphology in terms of olfactory and gustatory stimuli, gene expression, gut microbiota and the interaction of the pathogen with the host comprehensively.

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