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Impact on Augmentation of *Zea mays* Flour on Growth and Monetary Traits of the Silkworm, *Bombyx mori*

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ABSTRACT: Sericulture is dependent on silkworm rearing and silk output is directly tied to larval growth and development. The goal of this study was to ascertain the effects of various maize flour dosages on the biological, economic and biochemical characteristics of the silkworm *B. mori* using 2 %, 4 %, 6 %, 8 % and 10 % concentrations of *Zea mays* flour. Lowry's method was used to quantify protein levels in samples taken from both *Zea mays* supplemented and control silkworm larvae of FC1 × FC2 hybrid strain. When compared to various concentrations of oral administration of *Zea mays* flour on the influence of the silkworm, *B. mori,* 4 % showed an increase in all the features investigated, while 10 % indicated a decrease in all the studied parameters. Following the oral administration of *Zea mays* flour, the bivoltine hybrid of FC1 × FC2 had a greater protein concentration of 312.89 µg/ml and a lower protein content of 250 µg/ml from 4 % and 10 %, respectively. However, the effect of 4 % increased practically all of the traits evaluated, while the effect of 10% decreased all of the characteristics but increased against control.

Keywords: Augmentation, *Zea mays*, flour, growth, *Bombyx mori*.

INTRODUCTION

Sericulture is a technology-based art and science, primarily a village-based and welfare-oriented industry that contributes significantly to our national economy. With its agricultural and forestry foundation, Industrial superstructure, and labor-intensive nature, it is the quintessential cottage industry (Singh *et al*., 2005). Sericulture is based on the rearing of silkworms on mulberry leaves, and silk production is directly proportional to larval growth and development on mulberry leaves. Mulberry leaf output, both in terms of quality and quantity, varies owing to environmental circumstances and field techniques. India is the second largest producer and also the largest consumer of silk in the world due to development of innovative technologies in mulberry cultivation as well as in silkworm rearing. The greatest silk quality comes from cocoons of mulberry silkworm *Bombyx mori* larvae raised in captivity (sericulture). The silkworm (*B. mori*) is a lepidopteran insect that has a long history of breeding for silk production. Natural fibre, which is secreted by silkworms, is the queen of textiles, symbolising richness, elegance, class, and comfort. India is the world's second largest producer of silk and also its greatest consumer. The silkworm is a monophagous insect that relies on the mulberry for its entire life cycle. Silkworms, as a result, require variable leaf quality at different phases of their growth, emphasizing the importance of mulberry production practices. One of the most important characteristics of the silkworm is its capacity to convert plant protein into silk protein (Ude *et al*., 2014). Silk proteins can be found in a wide range of medical and commercial uses (Khyade, 2016; Ageitos *et al*., 2019). The silkworm (*B. mori* L.) is a monophagous insect that is crucial to the sericulture industry. Silkworm larvae commonly feed on mulberry leaves, which contain morin. The food quality or appetite (or both) of silkworm larval instars must be enhanced for higher silk production performance. Legay in 1958 revealed that silk production is based on mulberry larval feeding and nutritionally valuable leaves, which play a key role in the development of high-quality cocoons.

Silkworm growth and development, as well as the production of silk proteins, require proteins. Free amino acids in bod fluid and amino acids produced in the posterior silk gland cells provide the amino acids, required for survival. The silk worm requires all ten essential amino acids for growth and development (Ito, 1978). Fibroin and sericin are two proteins that make up silk. Fibroin is at the centre, surrounded by sericin. These two proteins have different characteristics and are secreted from different parts of the silk gland. The silk gland's posterior section secretes fibroin, whereas the middle section secretes sericin. Fibroin is made up of amino acids made by the cells of the posterior silk gland. Sericin quality is one of the most important characteristics of cocoon. Between *B. mori* strains, the amount of sericin in the cocoon varies. The quality of mulberry leaves determines the amounts of these biomolecules. Proteins in the haemoly mph are more concentrated throughout development and can be used to make silk proteins. The purpose of this study was to determine how different amounts of maize flour affected the biological, economic and biochemical aspects of the silkworm *B. mori*.

MATERIALS AND METHODS

Materials

Silkworm strains: The UT Sericulture Department in Mendher, Jammu and Kashmir, provided the first instar silkworm larvae (first moult) silkworm hybrid strain of FC1 × FC2 for this investigation. The larvae were raised on mulberry leaves according to conventional practises (Krishnaswami, 1978).

Composition of *Zea mays*: Maize has the moisture content ranging from 9.201 to 10.908%, ash (0.7-1.3%), lipids (3.21-7.71%), protein (7.71-14.60%), crude fibre (0.80-2.32%) and carbohydratess (0.80-2.32%).

Food supplements for 5th instar silkworm, *Bombyx mori.* Using commercial *Zea mays* flour purchased from the market, several concentrations of *Zea mays* flour suspensions were made in distilled water. A known quantity of mulberry leaves (1 kg) were dipped in maize flour suspension, air-dried and fed to the experimental groups from the first day of the 5th instar until the end of the 5th in star. In each treatment, 150 (50 larvae each replication) were fed leaves dusted with flour at concentrations of 2%, 4%, 6%, 8% and 10%, respectively. One batch of silkworm larvae (150 larvae) was fed with regular mulberry leaves in three replications (control). Supplementing mulberry leaves with *Zea mays* flour was studied to improve the silkworm.

Analysis of biological and commercial traits:

Effective rate of rearing (ERR). The following formula was used to determine ERR,

$$\text{ERR} = \frac{\text{Number of good cocoons spun}}{\text{Number of larvae brushed}} \times 100$$

Larval weight. On day 6 of the fifth instar, approximately 6 larvae were randomly selected from each replication and their weights were recorded.

Cocoon weight. On day 6, after spinning, about 6 cocoons were randomly selected from each replication and weighed.

Pupal weight. The pupae retrieved from randomly selected cocoons (6) of each replication were used to calculate pupal weight.

Shell weight. After removing the pupa from the randomly selected 6 cocoons from each replication, the cocoon shell weight was recorded.

Shell ratio. Shell ratio was calculated using the formula,

$$\text{Shell ratio} = \frac{\text{Shell weight}}{\text{Cocoon weight}} \times 100$$

Protein extraction. On the third day of the fifth instar, *Zea mays* supplemented and control larvae were homogenised separately in extraction solution (50 mM Tris buffer - pH 6.8) at 4^{o}C. The homogenate was centrifuged for 20 minutes at 4°C at 4000 rpm, and the supernatant was collected for protein estimation.

Protein estimation. Lowry's method was used to measure protein in samples taken from both *Zea mays* supplemented and control larvae of different silkworm strains (Lowry *et al*., 1951). The colour generated was measured at 660 nm after 30 minutes of incubation at room temperature.

Data analysis. Using one-way ANOVA and SPSS version 20, all data from three replications of different treatments were utilized to calculate mean values, standard deviations and significant variations.

RESULTS

Changes in the larval growth due influence of corn flour. The findings concerning larval weight were considered to be extremely significant (Table 1). 4% flour (3.49 g) had the highest larval weight, followed by 2 percent flour (3.47 g), 6% (3.29 g), 8% (3.04 g), 10% (2.87 g), and control (3.33g). Treatment 2 with 4 percent corn flour showed the most significant increase in larval weight, followed by treatment 1 with 2% corn flour (Fig. 1).

Changes in the ERR due influence of corn flour. Table 1 shows the effect of mulberry leaves enrichment with *Zea mays* flour treatment on the average ERR. The ERR stands for the larvae that successfully spin cocoons. Surprisingly, the population formed from 2% corn flour showed a 92% improvement in ERR. However, the ERR was enhanced by 93.33% in the control, and the ERR was 90% from 4% corn flour, 87.33% from 6% corn flour, 86.67% from 8% corn flour, and 85% from 10% corn flour (Fig. 2), which is significant at $P< 0.01$.

Changes in the larval mortality due influence of corn flour. The effect of mulberry leaves enrichment with *Zea mays* flour treatment gave lower larval mortality of 7.33% from 4% corn flour which on par with 6% corn flour which showed 8.67 %, 12.67% from 2% corn flour, 17.33% from 8% corn flour, 25.33% from 10% corn flour and against control (4%). The sensitivity of different instars larvae of FC1 × FC2 to different temperatures of corn flour is quite significant (Fig. 3, Table 1).

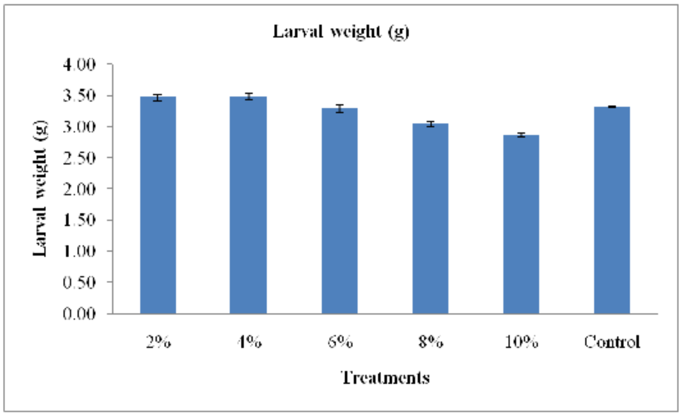

Fig. 1. Influence of corn flour on larval weight.

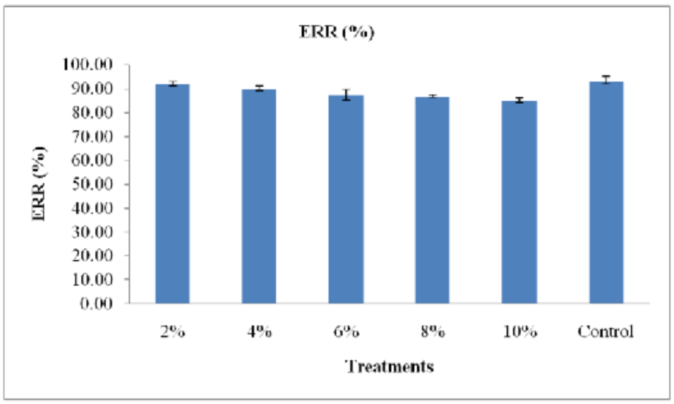

Fig. 2. Influence of corn flour on ERR.

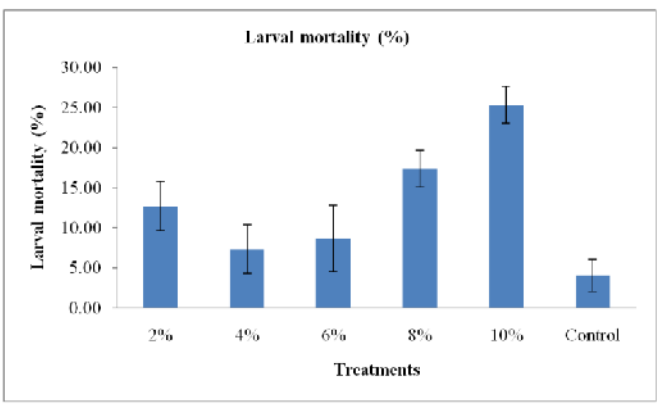

Fig. 3. Influence of corn flour on mortality.

Changes in the cocoon characters due to influence of corn flour

Cocoon weight. The cocoon weights also varied with the dosage of corn flour following oral administration. The highest cocoon weight of 1.69 g was observed from 4% corn flour while as least cocoon weight of 1.54 g was observed 10% corn flour. The cocoon weight of 1.63, 1.62, 1.54 and 1.51 g was observed from 2, 6, 10 % and control of corn flour following oral administration that is significant at $P< 0.01$ (Table, 2, Fig. 4).

Table 1: Effect of *Zea mays* flour on biological traits of the silkworm, *Bombyx mori* bivoltine hybrid FC1 X FC2.

	Larval weight (g)	ERR (%)	Larval mortality (%)
Treatments	**Mean±S.E.**	**Mean±S.E.**	**Mean±S.E.**
2%	3.467±0.03	92±0.577	12.667±1.764
4%	3.49±0.032	90±0.577	7.333±1.764
6%	3.287±0.032	87.333±1.202	8.667±2.404
8%	3.043±0.03	86.667±0.334	17.333±1.333
10%	2.87±0.021	85±0.577	25.333±1.333
Control	3.313±0.009	93.333±0.882	4±1.155
C.D.	0.084	2.322	5.227
SE(m)	0.027	0.745	1.678
SE(d)	0.038	1.054	2.373
C.V.	1.431	1.45	23.145
F-value	82.65	19.073	21.437
Significance	0	0.00002	0.00001
DF	17	17	17
Sum of Squares	0.916	178.944	1,006.44
Mean Squares	0.178	1.667	181.002

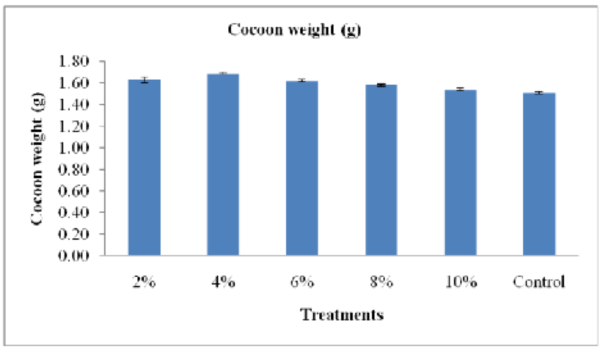

Fig. 4. Influence of corn flour on cocoon weight.

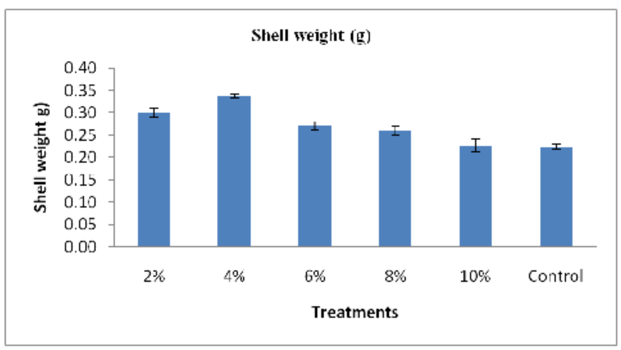

Fig. 5. Influence of corn flour on cocoon weight.

Shell weight. The cocoon shell weight was also unequivocally affected as that of cocoon weight in control due to fluctuated environmental condition in the rearing house. As a result, the cocoon shell weight in control was 0.22 g. But, significant improvement in the shell weight was noticed from 4% corn flour. The cocoons spun by form oral administration of 2, 4, 6, 8, 10% of corn flour and control had shell weight of 0.30, 0.34, 0.27, 0.26, 0.23 and 0.22 g respectively (Table 2, Fig. 5).

Pupal weight. Interestingly, weight of the pupa, as an index of its growth, showed highest weight 1.35 g derived from the population from 4 and 6% corn flour while as least pupal weight of 1.31 g was observed from the 10% corn flour, respectively. Whereas, 1.33, 1.32 and 1.29 g of pupal weight was observed 2%, 8% and control larvae of FC2 X FC1 (Table 2, Fig. 6).

Shell ratio. The cocoon shell weight ratio was also correspondingly affected as that of cocoon and shell weight due to influence of corn flour on fifth instar larvae in FC1 × FC2. The cocoon shell ratio recorded as

14.79% in control, highest of 19.92 and 18.44% was recorded in the population derived from larvae of FC1 × FC2 HS due to influence of corn flour of 4 and 6% on fifth instar larvae respectively. Concomitantly, 16.67, 16.46, 14.72 and 14.79 % of shell ratio was observed from 6, 8, 10% and control respectively (Table 2, Fig. 7).

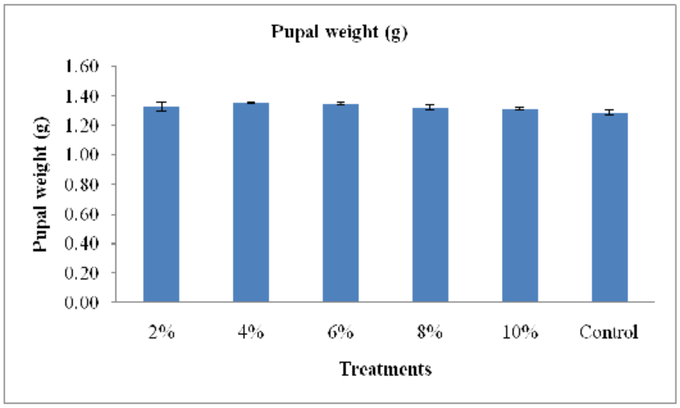

Fig. 6. Influence of corn flour on pupal weight.

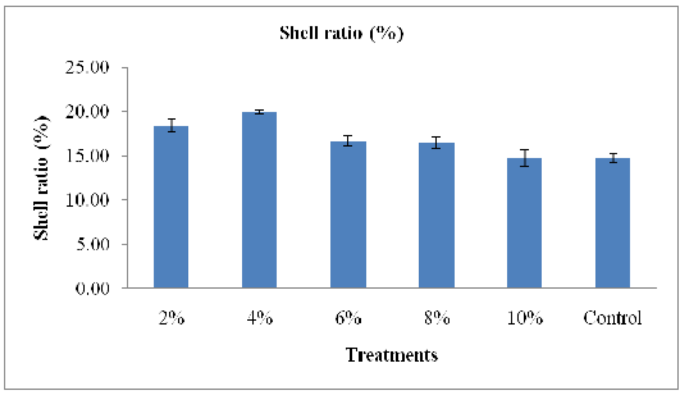

Fig. 7. Influence of corn flour on shell ratio.

Table 2: Effect of *Zea mays* flour on cocoon traits of the silkworm, *Bombyx mori* bivoltine hybrid FC1 X FC2.

Treatment	Cocoon weight (g)	Shell weight (g)	Pupal weight (g)	Shell ratio (%)
	Mean±S.E.	Mean±S.E.	Mean±S.E.	Mean±S.E.
2%	1.627±0.015	0.3±0.006	1.327±0.018	18.45±0.442
4%	1.69±0.006	0.337±0.003	1.353±0.003	19.920.144
6%	1.620±0.006	0.27±0.006	1.35±0.006	16.667±0.33
8%	1.58±0.006	0.260.006	1.32±0.01	16.457±0.402
10%	1.54±0.006	0.227±0.006	1.313±0.003	14.717±0.517
Control	1.51±0.006	0.223±0.003	1.287±0.009	14.79±0.272
C.D.	0.025	0.018	0.03	1.157
SE(m)	0.008	0.006	0.01	0.372
SE(d)	0.011	0.008	0.013	0.525
C.V.	0.862	3.711	1.245	3.823
F-value	67.08	56.988	6.751	30.381
Significance	0	0	0.00326	0
DF	17	17	17	17
Sum of Squares	0.066	0.03	0.012	67.867
Mean Squares	0.013	0.006	0.002	12.581

Protein concentration in silkworm eggs at 35°C. The higher protein concentration of 312.89 µg/ml and the minimum protein content of 250 µg/ml was observed from 4% and 10% from the bivoltine hybrid of FC1 × FC2 following the oral administration of *Zea mays* flour. The protein content of 306.14, 291.86, 285.52 and 221.46 µg/ml was recorded from 2, 6, 8% and control larvae of FC1 × FC2 following the oral administration of *Zea mays* flour (Table 3, Fig. 8).

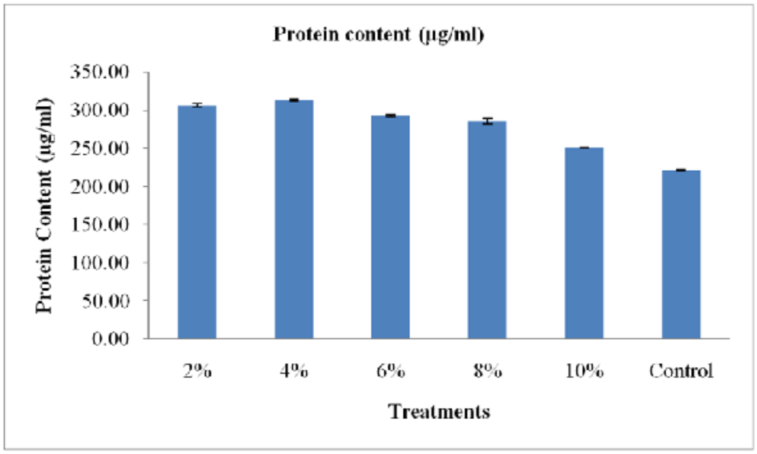

Fig. 8. Influence of corn flour on total protein content

Table 3: Effect of *Zea mays* flour on the total protein content of the silkworm, *Bombyx mori* bivoltine hybrid FC1 × FC2.

Treatments	Protein content (µg/ml)
	Mean±S.E.
2%	306.143±1.213
4%	312.887±0.67
6%	291.857±0.799
8%	285.517±2.262
10%	250.433±0.321
Control	3.98
SE(m)	1.247
SE(d)	1.764
C.V.	0.746
F-value	381.227
Significance	0
DF	14
Sum of Squares	7161.259
Mean Squares	1778.651

DISCUSSION

These findings are important and necessary from the view point of silkworm rearing for commercial cocoon production as larval weight, ERR and pupal weight increases the cocoon weight thereby add revenue while transacting the cocoons in market. The results pertaining to larval weight was found to be highly significant. The maximum larval weight was recorded in 4% flour (3.49 g) followed by 2% flour (3.47 g), 6% (3.29 g), 8% (3.04 g), 10% (2.87 g) and control (3.33 g). Highly significant gain in larval weight was observed in treatment 2 with 4% corn flour followed by treatment 1 with 2% corn flour. The increase of body weight in treatment 2 may be due to the fortification of leaf with the feed corn flour supplement. These findings corroborated earlier research that suggested lactic acid bacteria could aid in the development of fruit flies' immune systems as well as their growth and development (Nishida *et al.*, 2016; Li *et al.*, 2017). Similar results were reported by Mahmoud, 2013 indicated that the 5th instar larval fed on diet contained mulberry leaves with Corn flour gave the highest significant weights of larvae, silk glands and pupae. Significantly high larval weight (3.49 g), ERR (92%), cocoon weight (1.690 g), shell weight (0.34 g), pupal weight (1.35 g), shell ratio (19.92%) and total protein content of (312.89 µg/ml) were recovered in treated batches indicating influence of *Zea mays* on biological and commercial traits of the silkworm FC1 × FC2. Mihai Bentea *et al*. (2012) studied the effect of zinc supplementation and reported that the use of Zinc in silkworms has improved larval weight, serigene gland weight, cocoon weight and shell weight. The maximum dose of administration did not have any negative effects. Geetha *et al*. (2017) conducted the combined foliar spray of micronutrients ($ZnSO_4$, $FeSO_4$, $MnSO_4$ and citric acid) on 5th in star larvae. Significant increase might be due to increased DNA synthesis in the silk gland or may be due to the general growth stimulatory effect of those chemicals on silk glands as indicated by Manimala (1995). The importance of these elements were indicated by Ito and Niminura (1966) as well as Horie *et al*. (1967) where they reported that it accelerated the growth of larvae. Hugar *et al*., (1999); Ashfaq *et al*. (2000) reported that Zn increases the weight of the larvae and sericine gland and reduced the mortality rate and the larval duration. During present study increase of larval weight was observed in treated batches compared to control batches. The data showed significant difference between treatments and their interaction in all the parameters. From the data it is evident that the larvae fed with the oral administration of *Zea mays* has got a profound influence on the growth of silkworms and inturn on cocoon parameters as well as in protein content which is proved by improvement in cocoon weight, pupal weight, shell weight etc., compared to feeding of worms on normal mulberry leaves. He *et al*. (2021) observed that adding lactic acid at levels of 0.01, 0.1, and 1% improved growth and the quality of female cocoons, resulting in greater larval weight and female cocoon shell weight than in the control group. On the other hand, 10% lactic acid killed the larvae by poisoning them and substantially slowed their growth. The cocoon shell as such contains silk proteins namely fibroin and sericin which are inturn made up of polypeptide chain of amino acids, particularly sericin, alanine and glycine. These amino acids are perhaps assimilated by the worms in the course of supplemented feeding with protein aceous source in the form of flour can be exploited to enhance shell ratio and shell weight. According to Vanderstoep (1981) germinated mungbeans, common beans (Matki) are associated with turnover of protein and amino acids with the greatest increase in glutamic and aspartic acids. These amino acids are necessary in silk synthesis. The *Zea mays* utilized in present study perhaps optimize quantity of nutrient assimilated which is channelized for maximum silk production by silkworms. Silkworms feeding on mulberry shoots fortified with the palatable nutrient rich source *viz*., protein, fats, carbohydrates, minerals and amino acids enhanced the cocoon characters. The total protein content of experimented. The feeding efficiency of the Spirulina supplemented group was significantly lower than that of the control group, according to Kumar *et al*. (2019). However, compared to the control group of silkworms, the experimental group's cocoon yield was noticeably higher. The results of this inquiry advance our understanding of enhanced silkworm nutrition and its practical commercial use in the sericulture sector. The higher protein concentration of 312.89 µg/ml and the minimum protein content of 250 µg/ml was observed from 4 % and 10 % from the bivoltine hybrid of FC1 × FC2 following the oral administration of *Zea mays* flour. The protein content of 306.14, 291.86, 285.52 and 221.46 µg/ml was recorded from 2, 6, 8 % and control larvae of FC1 × FC2 following the oral administration of *Zea mays* flour. The present findings are in agreement with the findings of Vanisree *et al*. (1996); Raj *et al*. (2000a and 2000 b); Manimsegalai *et al*. (2002) who reported higher cocoon parameters on soyabean protein supplement. Artificial diet containing wheat bran increased female cocoon weight of two multivoltine breeds (Nistari and BSRI-85/3) as reported by Sarkar and Absaram (1995); Nagesh (1998) reported similar trend on 'Sericare', and on cereal flour by Ganga and Gowri (1990); Vanitha (2006); Andal (2006); Sumathi (2007) respectively. According to Senthamarai Selvi *et al*., 2014, the silk worm *B. mori* dramatically increased morphometric parameters such larval length, width, and weight when exposed to MR2 mulberry leaves treated with a 25% concentration of *Spinacia oleracea*.

CONCLUSION

The present study suggests that the oral administration of *Zea mays* flour to *Bombyx mori* significantly showed uprise almost in all biological and commercial traits as well as in the biochemical constituent of protein content. Decisive increase in monetary characters was observed in treatment with corn flour powder. The analysis demonstrates the viability of corn flour treatment in silkworm rearing. As these materials are modest and matter-of-fact, they can be suggested for the farmers use.

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