Research Article

Nutritional Effects of Three Mulberry Varieties on Silkworms in Torbat Heydarieh

Masoud Alipanah [iD],[1] Zabihollah Abedian,[2] Abdolazim Nasiri,[2] and Farid Sarjamei[2]

[1]*University of Torbat Heydarieh, Department of Plant Science, Torbat Heydarieh, Iran*
[2]*Sericulture Center of Khorasan Razavi, Torbat Heydarieh, Iran*

Correspondence should be addressed to Masoud Alipanah; m.alipanah@torbath.ac.ir

This research was conducted to evaluate and compare the performance of the silkworm hybrid $p31 \times p32$ reared with three varieties of mulberry leaves. In this study, the silkworms were fed with leaves from Kenmochi (*Morus bombycis*), native mulberry (*Morus alba* L.), and black mulberry (*Morus nigra* L.) trees and their influence on the leaf ingested, leaf digested, cocoon weight, efficiency of feed consumption to cocoon shell, efficiency of digested feed to cocoon shell weight, efficiency of digested feed to cocoon weight, and efficiency of feed consumption to cocoon weight was studied in the Torbat Heydarieh region. The results showed that silkworms that consumed leaves of Kenmochi had better performance. Also, they had better performance for traits of cocoon shell weight, feed efficiency to cocoon shell weight, and feed efficiency to cocoon weight. Therefore, Kenmochi tree is suggested for development of sericulture in the region.

1. Introduction

Silkworm is a very important economic insect which contributes substantially to the national economy and gross domestic production (GDP) of many countries such as China, India, and Thailand [1]. Iran has about 14,000 hectares of area under mulberry cultivation, and sericulture in these areas has provided employment and income generation for more than 60,000 households [2]; it is the fifth cocoon-producing country and the seventh silk-producing country in the world [3]. Mulberry leaves are the only food source for silkworms (*Bombyx mori* L.). Mulberry tree is grown under varied climatic conditions, ranging from temperate to tropical; hence, the growth and development as well the quality and quantity of cocoons produced are largely influenced by leaf quality [4]. Leaves with higher nutrient quality not only increase the quality of production but also help the insect to resist diseases. Due to climatic changes and droughts and decreasing tendency to plant and grow mulberry trees in different areas, there is a need to research the varieties adapted to new environmental conditions.

Differences in the performances of silkworms fed with different varieties of mulberry trees have been studied by a number of researchers [5–7]. In the present study, the effect of feeding of leaves from three varieties of mulberry trees including Kenmochi (*Morus bombycis* Kodiz), black berry (*Morus nigra* L.), and native mulberry (*Morus alba* L.) on production quality of silkworms (B. *mori*) has been considered.

2. Methodology

2.1. Animals and Experiment. The eggs of hybrid p31×p32 silkworms were obtained from Iran Silkworm Rearing Co. (Rasht, Iran) and reared in the Torbat Heydarieh sericulture center (Torbat Heydarieh, Iran) under a standard condition of $25 \pm 5°C$ with a RH of $80 \pm 5\%$ and a photoperiod of $16L : 8D$ as described by Hosseini [8]. The larvae were fed with mulberry leaves of Kenmochi variety up to the 5th instar. The first and second instar larvae were fed with chopped green leaves while for the remaining three instar larvae, whole leaves were fed.

After third instar, silkworms were reared on leaves of three mulberry varieties separately. Mulberry varieties included the following: Kenmochi (*M. bombycis*), native mulberry (*M. alba*), and black mulberry (*M. nigra*) trees. Fourth instar larvae were divided into 3 experimental groups, with three replicates in each group. Each replicate consisted of 300 healthy larvae of uniform size and age. To replace the dead and unequal larvae, a separate group of worms were maintained under identical conditions.

In order to determine nutritional parameters, leaf weight, residual leaf weight, excreta weight, cocoon weight, cocoon shell weight, and cocoon shell percentage were measured. All the weights noted in this study are based on dry weight. Nutritional parameters such as efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) by the larva were calculated by the method described Muniraju et al. [9].

Collected data were subjected to statistical analysis of variance for significant differences in the measured groups of parameters. For all analyses of variance, Duncan's multiple range test in general linear model (GLM) procedure of SAS 9.2 software was used.

3. Results and Discussion

The results of performances and nutritional indices of the silkworms are presented in Tables 1–3. Based on these results, the performance of ingested Kenmochi leaves was significantly lower than that of the blackberry and native tree leaves ($P < 0.05$). The results also showed that the excreta weight of silkworms that consumed the leaves of the black berry and native trees was the highest ($P < 0.05$). Based on the weight of the leaves consumed and the excreta weight, the digested feed weight was the highest in silkworms feeding on Kenmochi leaves ($P < 0.05$). According to the content of dry matter in the three varieties of mulberry, it is possible to observe that there is a relationship between dry matter content of leaves and digested weight of the leaf. The study of Rahmathulla et al. [10] indicated that nutritional parameters such as ingesta, digesta, approximate digestibility, reference ratio, and consumption index were significantly higher in silkworm that were fed with leaves of higher moisture content. Other researchers have emphasized the direct effect of mulberry leaf quality on food intake [11].

As expected, results presented in Table 1 show that ingestability (%) in Kenmochi experimental thesis was the lowest ($P < 0.05$), while digestibility of leaves of the Kenmochi variety being 54.79% was highest and digestibility for black berry leaves was very low, being only 37.10% ($P < 0.05$). These traits probably were affected by the moisture content of leaves; these results are consistent with previous result reports: for example, one previous research showed that up to 70% leaf moisture, all the nutritional indices increased progressively with an increase in the moisture level of leaves [11].

The survival of larvae up to the cocoon stage was in three experimental theses (Kenmochi, native, and black berry), respectively: 95.67, 90.00, and 88.67. Therefore, there were significant differences among treatments. There was a significant difference for total cocoon weight ($P < 0.05$); in fact, the Kenmochi treatment produced 152.09 g of cocoons showing the highest weight with respect to all the treatments, while the total cocoon weight for native and black berry tree was 135.13 g and 125.71 g, respectively. The best cocoon weight for 1000 larvae was observed ($P < 0.05$) when insects were fed with Kenmochi leaves while the lowest weight was recorded on black berry leaves (Table 2). Cocoon weight is one of the most important economic characteristics of silkworms, especially in Iran where product marketing is based on the cocoon weight. In general, mulberry varieties have to be modified and selected to produce the silkworm cocoons as heavy as possible [12]. Larval weight is another important trait in sericulture: larval weight is highly influenced by various environmental factors such as feeding and rearing environment and, on the other hand, larval weight has a significant correlation with cocoon weight, pupa weight, and silk shell weight [13].

Shell percentage was the highest in the treatments with Kenmochi and the native mulberry tree in comparison with black berry treatment ($P < 0.05$) (Table 3). The ECI for cocoon production and cocoon shell percentage significantly differs among treatments, and two traits were the highest in the Kenmochi treatment with 14.29 and 9.02, respectively. But native and black berry treatments were not different for shell percentage ECI and cocoon ECI. The research findings are in agreement with the work of [14, 15] who concluded that low nutritional indices in native tree leaves can be due to the low moisture content and harsh physical structure of their mulberry leaves.

The results of different researchers revealed that the content of mulberry leaves consumed caused differences in the performances of silkworm larvae. For example, in the study of Rajabi Kanafgorabi et al. [15], there was a significant difference in the yield of treatments fed with Kokuso and native mulberry varieties.

The cocoon weight was introduced as the best parameter to evaluate the nutritional effect of different varieties of mulberry [16]. Our results showed that the total cocoon weight was higher ($P < 0.05$) for silkworms treated with Kenmochi leaves ($P < 0.05$).

Motahari et al. [12] reported that the weight gained in silkworms that were fed with native leaves was the lowest in comparison to other tree leaves. In another study comparing different mulberry trees, it was found that mulberry variety had a significant effect on silkworm weight performance [17]. Comparison between performances of silkworm fed with different mulberry varieties showed that the highest number of cocoons was obtained when the leaves of Wasemidori and Kenmochi cultivars were used [12].

In general, it can be said that the variation in measured traits for silkworms fed with different tree leaves is due to different chemical compositions of the leaves. Differences in the performance of silkworms fed with different berry varieties have been documented in the results of many research studies [18–20].

Based on the results of the present study, it was observed that leaves of Kenmochi tree supported good growth and development of silkworm, which is reflected in higher

TABLE 1: Mean of leaf ingesta and digesta parameters of silkworm hybrid treated with three varieties of mulberry leaves.

Tree variety	Dry matter (%)	Leaf ingested (g)	Excreta weight (g)	Leaf digested (g)	Ingestability (%)	Digestibility (%)
Kenmochi	32	4.55[a]	2.06[a]	2.49[a]	61.91[a]	54.79[a]
Native	34	5.39[b]	3.22[b]	2.17[b]	69.03[b]	40.25[b]
Black berry	36	5.53[b]	3.48[c]	2.05[b]	68.84[b]	37.10[c]
Mean ± SE	34 ± 1.15	5.16 ± 0.11	2.20 ± 0.08	2.42 ± 0.06	66.59 ± 1.37	44.20 ± 0.78
CV	3.34	2.04	2.74	2.54	2.50	1.79
F	2.08	38.69	136.53	25.04	13.68	218.33
P	0.2115	0.0019	0.0002	0.0043	0.0133	0.0001

[a,b]Values in the same column with different superscripts differ significantly at $P < 0.05$.

TABLE 2: Mean of larvae and cocoon traits of a silkworm hybrid fed with three varieties of mulberry leaves.

Tree variety	Larvae (g)	Mortality (%)	Cocoon (g)	Number of cocoon (per liter)	Weight of a litter of cocoon (g)	Best cocoon weight per 1000 larvae (kg)
Kenmochi	1.62	4.33	0.63	112.67	181.63	1.521[a]
Native	1.59	10.00	0.64	111.00	176.31	1.361[ab]
Black berry	1.51	11.33	0.61	119.67	181.06	1.267[b]
CV	4.47	49.28	4.44	4.19	5.83	6.02
Mean ± SE	1.58 ± 0.83	8.56 ± 4.22	0.63 ± 0.03	114.44 ± 4.79	179.67 ± 10.47	1.38 ± 0.83
F	1.82	1.67	1.85	1.53	0.46	3.57
P	0.2882	0.3148	0.2836	0.3451	0.7659	0.1226

[a,b]Values in the same column with different superscripts differ significantly at $P < 0.05$.

TABLE 3: Mean of shell parameters and some of the nutritional indices of silkworm hybrid treated with three varieties of mulberry leaves.

Tree variety	Shell weight (g)	Shell percentage	Shell ECI (%)	Shell ECD (%)	Cocoon ECD (g)	Cocoon ECI (g)
Kenmochi	0.41	25.23[a]	9.02[a]	16.46	26.08	14.29[a]
Native	0.41	25.91[a]	7.66[b]	19.03	29.38	11.82[b]
Black berry	0.36	23.89[b]	6.54[b]	17.67	29.57	10.94[b]
CV	6.67	2.20	7.68	7.49	5.74	5.30
Mean ± SE	0.39 ± 0.03	25.01 ± 0.55	7.74 ± 0.59	17.72 ± 1.33	28.34 ± 0.65	12.35 ± 0.65
F	2.00	5.90	6.93	1.82	3.12	11.37
P	0.2593	0.057	0.0437	0.2888	0.1479	0.0186

[a,b]Values in the same column with different superscripts differ significantly at $P < 0.05$.

performance traits; therefore this variety can be recommended for rearing silkworm in the Torbat Heydarieh region.

Data Availability

All data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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