Research Article

Analysis of the Correlation Between Various Biological and Economic Indicators of Mulberry Silkworms (*Bombyx mori* L.) Introduced from Uzbekistan

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Abstract

In this study, eight mulberry silkworm (*Bombyx mori* L.) breeds imported from Uzbekistan were evaluated under laboratory conditions at the Sheki Regional Scientific Center of ANAS based on five key biological and productivity indicators: survival rate, viability, cocoon weight, feeding period, and silkiness. The results revealed significant differences among the breeds, with the highest productivity observed in the Marvarid and Markhamat breeds. Correlation analysis demonstrated positive and statistically significant relationships between survival rate and viability ($r = 0.788$; $p < 0.05$), cocoon weight ($r = 0.824$; $p < 0.05$), and silkiness ($r = 0.941$; $p < 0.01$). In contrast, negative correlations were identified between feeding period and survival rate ($r = -0.775$; $p < 0.05$), as well as silkiness ($r = -0.881$; $p < 0.01$). Overall, the survival rate showed a strong positive association with cocoon weight and silkiness, and a negative association with feeding period. These findings indicate that cocoon weight and silkiness are key productivity indicators, whereas a prolonged feeding period adversely affects productivity. Therefore, the Marvarid and Markhamat breeds are recommended as priority candidates for selection and breeding programs.

Keywords: mulberry silkworm, breed, hybrid, wet cocoon, silk, correlation

1. Introduction

In the history of the development of sericulture in Azerbaijan, the northwestern region, its craftsmen, and the local population have had a unique place and role. The sericulture industry plays an important role in improving socio-economic conditions. The location of the sericulture industry on the “Great Silk Road” has led to the formation and development of this sector in Azerbaijan, especially in the northwestern region, and has given impetus to the expansion of trade and economic relations with other countries. Breeding science plays a major role in the development of sericulture and the achievement of new achievements. As a result of the application of scientific methodological selection, it is possible to create new breeds and lines.

Determining the biological indicators of introduced breeds under local conditions is essential for breeding programs. Because the viability and productivity of hybrids created between breeds taken from different geographical environments are high.

The life cycle of the silkworm goes through four developmental stages: egg, larva, pupa (chrysalis), and butterfly (adult) (Figure 1).

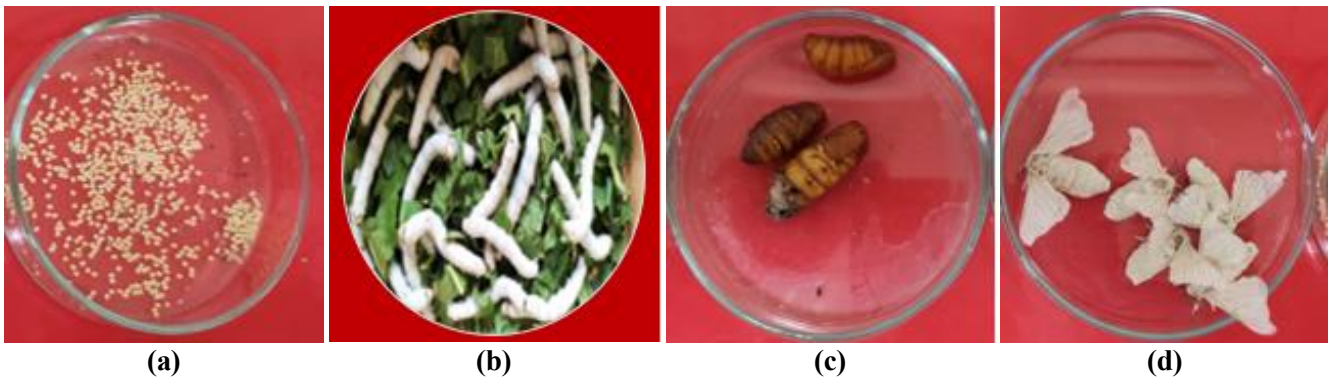

Figure 1. The life cycle of the silkworm: (a) egg, (b) larva, (c) pupa (chrysalis), (d) butterfly (adult).

The silkworm is considered an important source of raw material for the textile industry, and it is grown only in countries with favorable climatic conditions. The area where the production areas are located for the preparation of silk products using raw silk produced from the silkworm should also be selected according to the climatic conditions [1]. Azerbaijan is a country with such favorable climatic conditions, and the North-Western region is a region with the most favorable climatic conditions for the production of silk and silk products from the silkworm. This valuable wealth of the people, cultivated with hard work in the republic, should be used in such a way that the needs of the population are adequately met, and the population of the region is provided with employment. The former glory of Azerbaijani silk should be restored, and it should take its rightful place in the world market.

The "Azad" breed created by Professor R. A. Huseynov played a significant role in the republic's sericulture and had a significant positive impact on the economy of Azerbaijan with its good adaptation to local conditions, endurance, high productivity, and technological quality of the silk, etc., positive features. In the past, the Azad, Sheki-1, and Sheki-2 breeds in their pure form constituted 40-50% of the republic's total forage. However, considering the superiority of hybrids over pure breeds and the fact that only hybrids are currently used in forage farms, to further increase the productivity of these breeds, the most important issue of the day was to identify worthy components for the breeds existing in the republic and ensure their use in hybridization [2].

During family breeding, which is widely used in the selection and breeding of mulberry silkworms, 3 types of phenotypic variability of quantitative traits are observed in the selection material (in populations, lines, or breeds): intra-family, inter-family, and general variability. However, these have not been studied by anyone so far [3]. B. H. Abbasov's studies showed that among the 3 phenotypic variability parameters of 5 biological and 8 technological quantitative traits of the mulberry silkworm, the general variability parameters have the largest values, and the interfamily variability parameters have the smallest values [1], [2]. He determined that the heritability coefficient of the mass of the live cocoon and silkiness decreases in the summer and autumn seasons compared to the spring season. Based on three-year experiments conducted at the Ganja breeding sericulture station on the elite material of the Azad and Ganja-1 breeds, which are regionalized in our republic, the heritability coefficient of the mass of the live cocoon and silkiness, as well as the mass of the cocoon in the cocoon, was determined by 3 methods [3].

A positive correlation was found between temperature and wet cocoon shell weight (r=0.383), yield per box (r=0.357), cocoon undrawn portion (r=0.345), dry cocoon weight (r=-0.217), cocoon width (r=-0.238), silk richness (r=-0.255) and silk yield (r=-0.256); and a positive correlation was found between humidity and cocoon width (r=0.213), fiber thickness (r=0.271) and drawable yarn weight (r=0.201) (P>0.05). A negative correlation was found between humidity and silk richness (r=-0.287) (P>0.05). A negative correlation was observed between light and cocoon width (r=-0.385), filament negation (r=-0.317) and removable part weight (r=-0.410), wet cocoon weight without chrysalis (r=-0.237), cocoon length (r=-0.246), cocoon width (r=-0.385) and filament negation (r=-0.317); a negative correlation was observed between carbon dioxide and silk richness (r=-0.560) and the percentage of cocoons with silk (r=-0.350) (P>0.05). A negative correlation was found between carbon dioxide

and silk richness ($p<0.05$). A positive correlation was found between carbon dioxide and the weight of the non-removable part of the cocoon ($r = 0.289$) ($P>0.05$) [4].

Sharma et al. (2020) reported that temperature and humidity showed a negative correlation with cocoon yield, with values of -0.72 and 0.52, respectively [5].

In the study conducted by Safarali Khudjamatov et al., the correlation between the duration of the larval period and egg-laying traits of 6 breeds and 4 silkworm breeding lines was studied. Breeds and lines were divided into grades according to the speed of development, and a comparative assessment of the indicators in the grades was carried out. Based on the analysis of the results obtained, a negative correlation was established between the speed of the larval period and reproductive characteristics [6].

In studies conducted by Hemmatabadi et al., the interaction between the genetic potential of silkworm species and the environment determines the silkworm's production capacity [7].

Elite and industrial seeds imported from abroad are superior to local varieties and hybrids in terms of quality, hatchability, biological and technological indicators, and most importantly, the short larval period of caterpillars. Therefore, reducing the larval period and creating highly productive varieties and hybrids are urgent tasks in sericulture. Scientists believe that an increase in productivity indicators is observed in populations with a long life cycle. However, foreign experience shows that it is possible to create rapidly growing and developing, as well as highly productive breeds and hybrids, using special selection methods. Based on this, at the current stage of development of the silkworm industry, the creation and application of breeds with a short life cycle and rapid cocoon collection in production is a priority task for genetic and selection researchers [8].

According to the selection results of the Guzal and Marvarid silkworm breeds, cocoons are divided into large, medium, and small cocoons in terms of size. The technological indicators of medium-sized cocoons are considered the best technological indicators. The existence of an inverse correlation between cocoon size and selection traits has been proven [9]. Pearson correlation was used to test the correlation between larval and cocoon parameters. A strong, positive, and highly significant correlation was observed between larval weight and length ($R = 0.82$) and cocoon and pupa weight ($R = 0.981$), and a moderate, highly significant correlation was observed between larval and silk gland weight ($R = 0.601$), silk gland and shell weight ($R = 0.622$), cocoon and shell weight ($R = 0.694$), and shell and pupa weight ($R = 0.552$) [10].

In a study conducted by Ridvan Yakisan and Ayhan Yilmaz, the relationship between some environmental measurements and cocoon productivity and quality characteristics was investigated. A positive correlation was found between temperature and wet cocoon shell weight ($r=0.383$), productivity per box ($r=0.357$), non-removable part of cocoon ($r=0.345$), dry cocoon weight ($r=-0.217$), cocoon width ($r=-0.238$), silk richness ($r=-0.255$) and reza ($r=-0.256$); and a positive correlation was found between humidity and cocoon width ($r=0.213$), filament negation ($r=0.271$) and removable yarn weight ($r=0.201$) ($P>0.05$). A negative correlation was found between humidity and silk richness ($r=-0.287$) ($P>0.05$). There was a negative correlation between light and cocoon width ($r=-0.385$), filament denier ($r=-0.317$) and retractable part weight ($r=-0.410$), wet cocoon weight without chrysalis ($r=-0.237$), cocoon length ($r=-0.246$), cocoon width ($r=-0.385$), filament denier ($r=-0.317$); carbon dioxide ratio was found to be negatively correlated with silk richness ($r=-0.560$) and percentage of cocoon with fiber ($r=-0.350$) ($P>0.05$). A negative correlation was found between carbon dioxide and silk richness ($p<0.05$). A positive correlation was found between carbon dioxide and non-retractable part weight of cocoon ($r=0.289$) ($P>0.05$). Sharma et al. They reported in their study (2020) that temperature and humidity were negatively correlated with cocoon productivity, with values of -0.72 and 0.52, respectively [4].

In recent decades, *Bombyx mori* L. has been successfully used as an alternative invertebrate model organism in various scientific fields. These applications include human disease modeling, environmental monitoring, epigenetic studies, as well as microbial drug testing and discovery [11].

2. Materials and Methods

The research work was carried out at the "Mulberry Silkworm Breeding Department" of the Sheki Regional Scientific Center of ANAS. The research was conducted in different seasons. Seeds of different breeds were incubated in both spring and summer. Different breeds were fed by families, and their biological indicators were determined.

The influence of weather and climate conditions on silkworms, especially on the efficiency of mass breeding, is one of the main factors. It shows the importance of a comprehensive study of the problem of genotype interaction and the need for targeted research. The following breeds were imported from the Institute of Sericulture of Uzbekistan in 2023.

1. Gulshan
2. Orzu
3. Yulduz
4. Asaka
5. Guzal
6. Markhamat
7. Marvarid
8. Nafis

The above breeds were fed in the spring and summer of 2023. The scientific research work was carried out in the "Selection of Mulberry Silkworm" department of the Sheki Regional Scientific Center. The following work was carried out in accordance with the methodology for the years.

In order to create a highly productive mulberry silkworm breed, the biological indicators of breeds imported from Uzbekistan were determined, and parental forms were determined to create new productive hybrids. The above breeds were fed by families, worms were counted after the third age, and fed in four repetitions with 200 worms each. The biological indicators of mulberry silkworms were studied.

In conducting the work, the Gulshan, Orzu. Yulduz, Asaka, Guzal, Markhamat. Marvari and Nafis mulberry silkworm breeds introduced in the selection work were used as the research object.

3. Statistical Analysis

The aim of the study is to determine the correlation between viability, cocoon weight, and silkiness.

The correlation coefficient between the biological and economic characteristics of the silkworm is calculated using the following formula:

$$r = \frac{\sum(X - \overline{X})(Y - \overline{Y})}{\sqrt{\sum(X - \bar{X})^2 \cdot \sum(Y - \bar{Y})^2}}$$

Here, r is the correlation coefficient, X and Y are the variables, and $\bar{X}$ and $\bar{Y}$ are the mean values of the variables. The correlation coefficient was also calculated using SPSS, and the "r" table was used to determine the statistical significance of the results.

The degree of freedom is calculated by the formula:

$$df = n-2$$

Here: df-degree of freedom, n-number of samples

3. Results and Discussion

The experimental results indicate that adaptation to local conditions significantly affects productivity. The biological indicators of the breeds in the experiment were determined. The biological indicators of the breeds brought from Uzbekistan are given in Table 1 and Figure 2.

Table 1. Biological and economic indicators of mulberry worm breeds imported from Uzbekistan.

S.N	Name of breed	Hatching of eggs, %	The survival of worms, %	Weight of one wet cocoon, g	Feeding period of silkworms, days	Silk yield of a wet cocoon, %
1	Gulshan	96.5	96.5	2.0	29	21.7
2	Orzu	96.0	96.0	1.9	30	19.5
3	Yulduz	96.0	96.0	1.9	30	19.5
4	Asaka	96.0	96.5	1.9	29	20.3
5	Guzal	96.0	96.0	1.9	30	19.5
6	Markhamat	96.5	96.5	2.2	29	21.2
7	Marvarid	96.5	97.0	2.4	29	22.2
8	Nafis	96.0	96.0	1.9	30	19.5

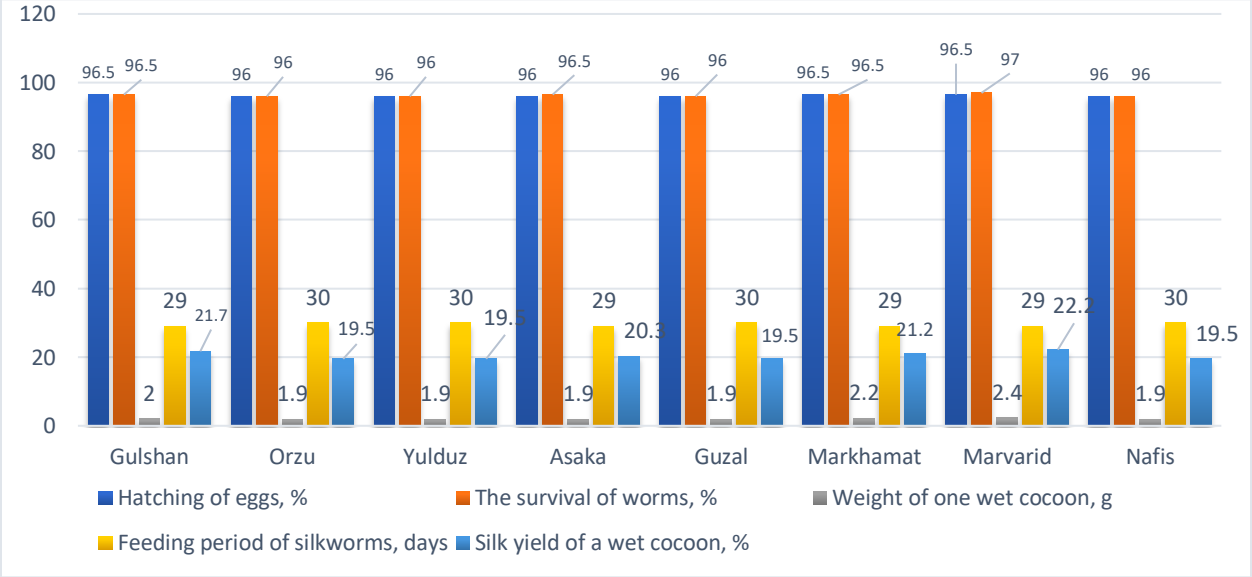

Figure 2. Various biological and economic indicators of mulberry silkworm breeds.

Table 1 shows the results of the study of 5 main biological and economic indicators of 8 breeds imported from Uzbekistan in the Sericulture Laboratory of the Sheki Regional Scientific Center of ANAS. It is clear from the table that the highest indicator for the revival of mulberry silkworm seeds was 96.5% in the Gulshan, Markhamat, and Marvarid breeds. However, it was relatively low in the Orzu, Nafis, Yulduz, Asaka, and Guzal breeds, 96.0%.

Viability is a key indicator directly affecting productivity and yield quality. If the viability of mulberry silkworms is low, the yield and quality will decrease. Among the breeds imported from Uzbekistan, the highest indicator for the viability of mulberry silkworms was 96.5 - 97.0% in the Marvarid, Markhamat, Asaka, and Gulshan breeds.

However, a relatively low indicator among the breeds was observed in the Orzu, Yulduz, Guzal, and Nafis breeds, 96%.

Wet cocoon weight is an important productivity indicator. Among the breeds in the experiment, the highest indicator in terms of cocoon weight was 2.0-2.4 g in the Marvarid, Gulshan, and Markhamat breeds. However, it was 1.9 g in the Orzu, Yulduz, Asaka, Nafis, and Guzal breeds.

The feeding period is a significant factor influencing production cost. It is clear from the table that the feeding period was 29 days in the Gulshan, Asaka, Marvarid, and Markhamat Guzal and Marvarid breeds in the

experiment. However, during the research work, it was determined that the feeding period in the Orzu, Yulduz, Guzal, and Nafis breeds was relatively long, 30 days.

The silkiness of the wet cocoon was determined among the breeds imported from Uzbekistan. As a result of the research work, it was determined that in the Marvarid, Markhamat, Asaka, and Gulshan breeds, it was 20.3-22.2%. However, the silkiness of the wet cocoon in the Orzu, Yulduz, Nafis, and Guzal breeds was -19.5%.

Overall analysis shows that the Marvarid breed demonstrates superior performance across key productivity traits. Therefore, cocoon weight and silkiness should be considered primary criteria in breeding programs. The Markhamat breed also dominates in terms of productivity and quality. Gulshan has high viability and silkiness, but its cocoon weight is slightly lower. Other breeds - Orzu, Yulduz, Guzal, and Nafis, although good in terms of viability, are average in terms of cocoon weight and silkiness.

As a result, the main criteria in selection and breeding should be cocoon weight and silkiness; therefore, the Marvarid and Markhamat breeds should be selected as a priority.

In order to determine the mutual influence of various indicators and the strength of their relationship with each other, correlation coefficients between traits were calculated using the SPSS program, and the results are shown in Table 2 and a heatmap (Figure 3).

Table 2. Correlation coefficient between biological and economic indicators.

Indicator	Hatching of eggs, %	The survival of worms, %	Weight of one wet cocoon, g	Feeding period of silkworms, days	Silk yield of a wet cocoon, %
Hatching of eggs, %	1	0.788*	0.824*	-0.775*	0.941**
The survival of worms, %		1	0.853**	-0.898**	0.937**
Weight of one wet cocoon, g			1	-0.638	0.842**
Feeding period of silkworms, days				1	-0.881**
Silk yield of a wet cocoon, %					1

Note: * and ** are statistically significant at 5% and 1% probability.

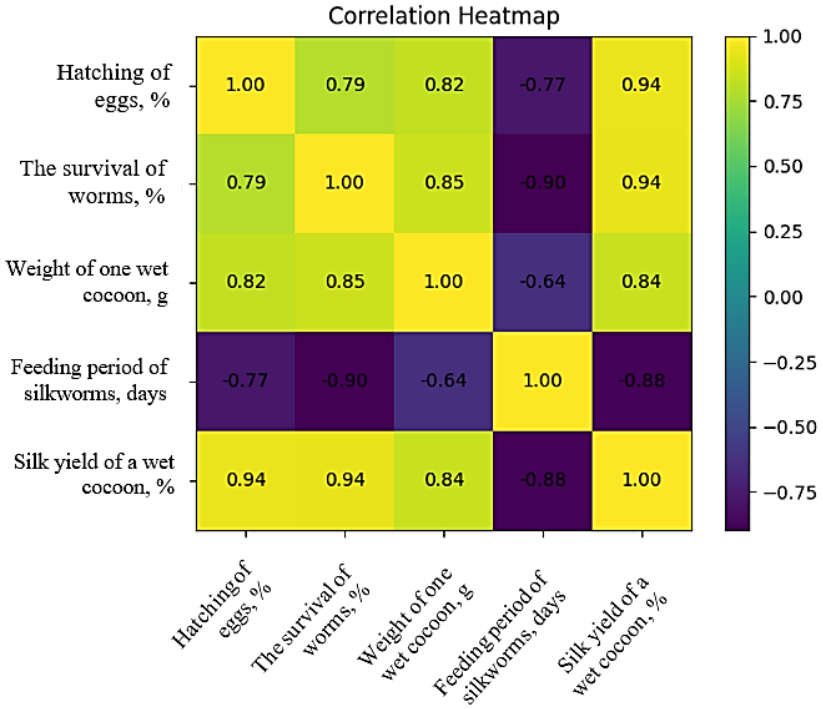

Figure 3. Heatmap for correlation between indicators.

Correlation analysis revealed relationships of varying strength and direction among the studied traits.

As a result of the conducted correlation analysis, it was determined that there are relationships of different directions and different strengths between the main biological and productivity indicators studied in the silkworm species. The results obtained show that there is a positive and statistically significant relationship ($r=0.788$; $p<0.05$) between the revival rate and viability. This confirms that individuals with a high revival rate also show higher viability.

Positive and reliable relationships were also determined between the revival rate and wet cocoon weight ($r=0.824$; $p<0.05$) and silkiness ($r=0.941$; $p<0.01$). In particular, the very strong correlation with silkiness indicates that this indicator is one of the main indicators in terms of productivity. At the same time, a negative relationship ($r=-0.775$; $p<0.05$) was observed between the revival rate and feeding period, which indicates that an increase in feeding period has a negative effect on revival indicators.

The relationships between viability and other parameters are also noteworthy. Thus, there are strong positive relationships between viability and cocoon weight ($r=0.853$; $p<0.01$) and silkiness ($r=0.937$; $p<0.01$). These results indicate that individuals with higher viability produce cocoons with heavier and higher silk yield. In addition, a strong negative relationship was observed between viability and feeding time ($r=-0.898$; $p<0.01$), which indicates that the extension of the development time negatively affects the overall sustainability of the organism. The strong positive relationship found between cocoon weight and silkiness ($r=0.842$; $p<0.01$) indicates that these two parameters are closely related to each other and confirms the possibility of their complex selection. On the other hand, a negative but not statistically significant relationship ($r=-0.638$; $p>0.05$) was found between cocoon weight and feeding period, which indicates that this relationship may be of a random nature.

A strong negative relationship ($r=-0.881$; $p<0.01$) was observed between the feeding period and silkiness. This result indicates that an increase in the feeding period leads to a decrease in silk productivity. Overall, the results obtained show that silkiness and viability act as the main indicators of productivity, and the feeding period is one of the factors that negatively affects these indicators.

4. Conclusion

The study demonstrates that biological and productivity indicators differ among the studied breeds imported from Uzbekistan. The Marvarid and Markhamat breeds are distinguished by high productivity and silk quality, while the Gulshan breed has a high survival rate and silkiness, but its cocoon weight is slightly lower. Other breeds - Orzu, Yulduz, Guzal, and Nafis - show satisfactory results in terms of viability, but are average in terms of cocoon weight and silkiness.

Correlation analysis showed that there are strong positive and statistically significant relationships between survival rate and viability, cocoon weight, and silkiness. At the same time, feeding time has a negative effect on these indicators. The strong positive correlation observed between cocoon weight and silkiness confirms the importance of a comprehensive assessment of these two indicators in the selection process.

Thus, cocoon weight and silkiness should be prioritized, and the Marvarid and Markhamat breeds are recommended for breeding.

5. Suggestions

Silkiness and viability should be prioritized in breeding programs.

1. Silkiness and viability should be given priority in breeding programs.
2. Technological and management measures should be implemented to shorten and optimize the feeding period.
3. Complex selection approaches covering several traits should be applied in order to increase productivity.

Thus, these strategies can contribute to increasing productivity and silk yield in silkworm breeding.

Author Contributions

Gudurat M. Bakirov, Ramiz G. Bakirli, and Dursun M. Adigozalova conducted the experiments and performed the research. Safarli Kh. Khuzhamatov provided the species/materials. Ayaz M. Mammadov performed the statistical analysis, prepared the graphs and statistical data, and reviewed the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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