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SILKWORM PUPA AS AN ALTERNATIVE TO SOYBEAN MEAL IN INDUSTRIAL POULTRY FARMING

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Abstract

The article covers the potential of using silkworm (*Bombyx mori*) pupa as an alternative protein source for industrial poultry farming in order to replace traditional soybean meal. A comparative analysis of the amino acid composition of pupa and soybean meal proteins was performed based on data from scientific publications and databases. It showed that pupa contain complete protein with high levels of lysine and methionine, amino acids that limit poultry growth when fed soybean meal. The results of studies show the positive effect of including silkworm pupa in the diet on growth, productivity and immune status of poultry, as well as improving the quality of meat and eggs. Environmental and economic benefits of using pupa, including reduced pressure on natural resources and a decrease in antinutrients in feed, are discussed. The article emphasizes the necessity of continued research and technological advancement to enable the widespread integration of silkworm pupae into poultry feed formulations.

Keywords: *silkworm pupa, soybean meal, industrial poultry farming, alternative protein, poultry feeding, environmental sustainability*

Ensuring balanced and cost-effective feeding of poultry is one of the key tasks in modern industrial poultry farming. Soybean meal traditionally occupies a leading position as the main source of vegetable protein.

Soybean meal (abbreviated SM) is a residual product after soybean processing, the dosage of which in the composition of compound feed for chickens reaches 7.0 ... 8.0% of the mass of compound feed. This raw material concentrates a significant amount of complete protein and a complex of minerals, which, with the correct dosage and constant feeding, make this product almost indispensable in poultry farming, where the main emphasis is on weight gain in young poultry.

The amino acid composition of soybean protein is the most perfect among all plant protein sources and resembles, with the exception of sulfur-containing amino acids (methionine), the composition of high-quality animal proteins. However, soy and its processed products, like many other legumes, contain anti-nutritional substances that have a negative effect on the health of poultry. These include trypsin inhibitors, lectins, saponins, soyin, as well as enzymes: urease, lipoxidase, trioses (raffinase and stachyose). Soy inhibitors inhibit trypsin activity by 60.0–70.0%, reducing protein digestion, accordingly, the growth and development indicators of poultry, and the presence of sulfur-containing amino acids in these enzymes can disrupt the balance of the amino acid composition. Most anti-nutritional factors of soy are heat-unstable, therefore, with moisture-heat treatment (toasting) and other technological methods, protein digestibility increases to 87.0–90.0% (Zenkova M. L. Ponomareva E. I., 2016; Simahina G. A., 2016).

At the same time, due to the high cost of SM, livestock producers prefer to use rapeseed or sunflower meal as a protein component of animal and poultry feed rations, since their cost is significantly lower. However, these raw materials are not produced in Uzbekistan. In this regard, the issue of finding our own high-protein raw materials and assessing their competitiveness with SM is relevant, which will most effectively solve the problem of feed protein deficiency in animal and poultry diet.

In accordance with the above, silkworm pupa (*Bombyx mori L.*) is very valuable raw material resource. This raw material is very effective due to large-scale work on the further development of the silk industry in Uzbekistan and increasing the volume of sericulture.

In the republic, sericulture remains one of the important branches of agriculture and ranks third in the production of silk cocoons after China and India, annually growing more than 21 thousand tons of live cocoons. According to the Decree of the President of the Republic of Uzbekistan No. DP-3910 dated August 20, 2018 “On measures for further effective use of existing opportunities of the silk industry in the Republic”, a further increase in their production is planned (Naumenko N. V., 2019).

Silkworm pupae (abbreviated SWP) are a valuable feed resource due to the high content of protein (up to 60.0%), essential amino acids (especially methionine and lysine), fat (high energy value) and minerals (calcium and phosphorus, necessary for the strength of bones and eggshells in birds). The presence of chitin in the shells of the pupae improves immunity and intestinal health of the poultry.

Traditionally, SWP, which produce significant amounts of biomass as a by-product of the silk industry, have been considered a waste product of silk production. However, in recent years, research has begun to explore their use in a variety of applications. This includes their role as additives or alternatives to traditional animal feed ingredients such as fishmeal, which is scarce and expensive, and their potential in cattle diets to reduce methane emissions. This shift in research highlights the adaptability of SWP as a resource for a variety of industries. A report on insects as a food and feed source noted that silkworm pupae are a high-quality and sustainable source of protein (P. van Hung P. 2012; Yi, L., Lakemond, C. M. M., Sagis, L. M. C., Eisner-Schadler, V., van Huis, A., & van Boekel, M. A. J. S., 2013; Ji, C., Zhang, J., & Wang, H., 2020; Wang, Y., Zhang, L., & Zhou, H., 2019).

The nutritional and biological value of silkworm pupae as a potential substitute for part of soybean meal in poultry feed was studied.

The objects of the research were silkworm pupae. The object of comparison was soybean meal. The quality of the raw material was assessed using modern generally accepted organoleptic (sensory) and physicochemical methods of analysis. The results of the study are presented in Fig 1, 2 and Tables 1, 2.

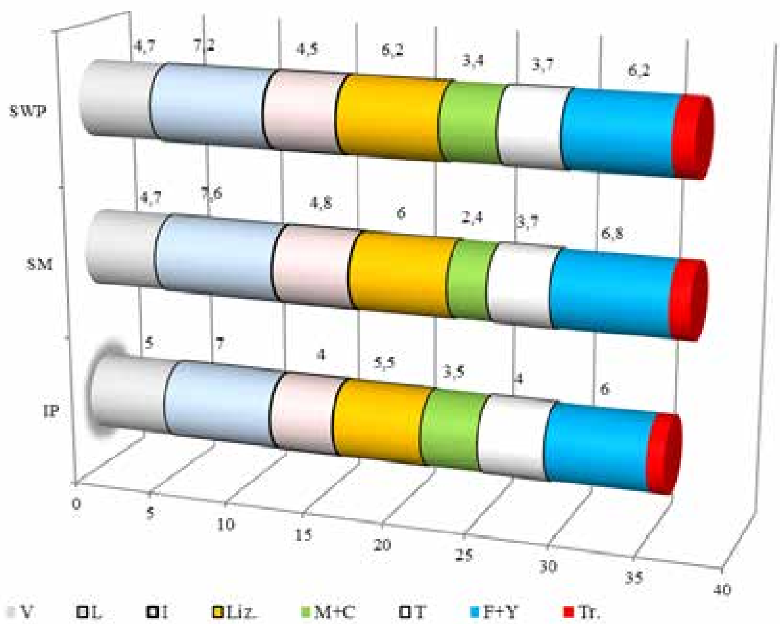
Comparative analysis of the nutritional value of SM and SWP showed that the content of crude protein in the SWP was 18.3%, crude fiber – 11.4 times, ME – 60.0%, lysine – 18.5%, methionine – 2.2 times, Ca and P, respectively, 2.3 and 1.8 times higher than similar values in SM. At the same time, the content of crude fiber and ash in the object of study decreased, respectively, by 10.0 and 23.1% relative to the data in the comparison sample, namely, in SM (Table 1).

Table 1. *Nutritional value of soybean meal (SBM) and silkworm pupae (SWP)*

Indicator	Content (% of dry matter)		±Δ relative to SM
	SM	SWP	
Crude protein	46.5± 3.5	55.0± 5.0	+ 18.3%
Crude fat	2.2± 0.8	25.0± 5.0	+ 11.4 times
Crude fiber	5.0 ± 2.0	4.5 ± 1.5	– 10.0%
Ash	6.5 ± 1.0	5.0 ± 1.0	– 23.1%
Metabolizable energy (ME), kcal/kg	2500 ± 200	4000 ± 500	+ 60.0%
Lysine	2.7 ± 0.3	3.2 ± 0.2	+ 18.5%
Methionine	0.6 ± 0.1	1.3 ± 0.2	+ 2.2 times
Calcium (Ca)	0.3 ± 0.1	0.7 ± 0.1	+ 133.3%
Phosphorus (P)	0.6 ± 0.1	1.1 ± 0.2	+ 83.3%

Analysis of the amino acid composition of the proteins of the studied raw materials did not reveal any fundamental differences in their quantitative composition. Thus, the total amount of essential amino acids (∑ EAA) in SM was 37.2, and in SWP was 37.0 g/100 g protein. Moreover, in terms of the content of these amino acids, the SWP protein was closest to the "ideal" protein in terms of biological value – 85.5% than SM – 65.0% (Fig. 1, Table 2).

Figure 1. *Amino acid composition of SM and SWP in comparison with the ideal protein: IP – ideal protein; V- valine, L- leucine, I- isoleucine, Liz. – lysine, M+C – methionine + cysteine, T – threonine, F+Y- phenylalanine + tyrosine, Tr. – tryptophan*



When studying the amino acid composition of the products under research, it was established that they contain almost all essential amino acids in significant quantities, exceeding their values in the "ideal" (reference) protein. It was established that in 100 g of SM and SWP protein, the mass fraction of the most deficient amino acid lysine on average exceeds the same value in the ideal protein by 9.0 and 24.0%, respectively. The limiting amino acids by amino acid score (AAS) in the SM protein are methionine + cysteine (68.0%), threonine (92.0%) and valine (94.0%), and in the SWP protein is mainly valine (94.0%).

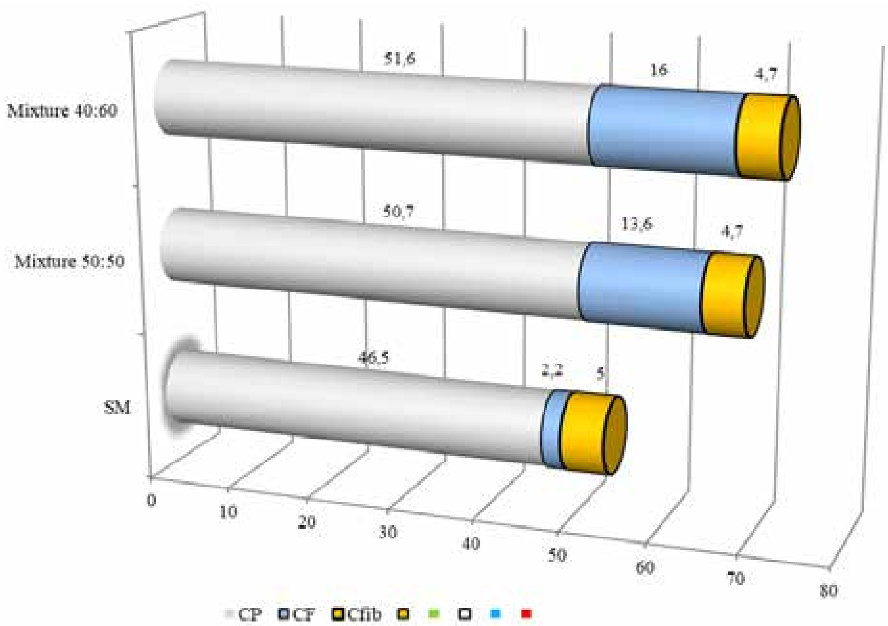
Table 2. *Content of essential amino acids in SM and SWP*

Amino acid	Protein according to FAO/WHO, in g/100 g protein	Mass fraction of amino acids in SM: in g/100 g protein	SM: *AAC, %*	SWP: in g/100 g protein	SWP: *AAC, %*
Valine	5.0	4.7	94	4.7	94
Leucine	7.0	7.6	108	7.2	103
Isoleucine	4.0	4.8	120	4.5	112
Lysine	5.5	6.0	109	6.8	124
Methionine + Cysteine	3.5	2.4	68	3.4	97
Threonine	4.0	3.7	92	4.0	100
Tyrosine + Phenylalanine	6.0	6.8	113	6.5	108
Tryptophan	1.0	1.2	120	1.3	130
∑ EAA	36.0	37.2	–	37.0	–
PDCAAS, %	–	35.0		14.5	–
Biological value (BV), %	100	65.0	–	85.5	–

It has been established that SWP are rich in lysine and methionine, which makes them a valuable supplement to SM, which, in turn, is poor in methionine. The combined use of these products will balance the amino acid composition of the feed, which will have a positive effect on the growth of young poultry and the productivity of poultry.

Let us consider the nutritional value of mixtures of SM and SWP in a ratio of 50:50 (for chickens) and 40:60 (for laying hens) by the main indicators, namely the content of crude protein, fat and fiber (Fig. 2).

Figure 2. *Nutritional value of mixtures of SM and SWP in the ratio of 50:50 and 40:60 in comparison with SM: CP – crude protein; CF – crude fat, CFib – crude fiber*



The analysis of the data presented in Fig 2 showed that with an increase in the proportion of SWP in the studied mixtures, the mass fraction of crude protein increased from 9.0 to 11.0%, crude fat – from 6.2 to 7.3 times relative to SM. At the same time, the content of crude fiber in both variants decreased by an average of 6.0%.

Therefore, the feasibility of combining SM and SWP in order to increase the nutritional and biological value of target-purpose compound feeds is substantiated. However, there are certain limitations to the use of SWP, namely, high fat content contributes to rancidity during long-term storage, heat treatment (roasting, drying) is required to reduce the likelihood of microbial contamination of this potential feed additive, as well as SM.

Therefore, the main arguments for using SWP instead of SM are:

1. *Nutritional value*: SWP protein has an amino acid composition comparable to or even superior to SM protein. Particularly important are the presence of lysine and methionine, i.e., amino acids that often limit growth in poultry.
2. *Environmental sustainability*: Silkworm production requires less land and water than soybean cultivation, and is also accompanied by lower greenhouse gas emissions.
3. *Reduced antinutrients*: SM contains trypsin inhibitors and phytic acid, which negatively affect the digestibility of nutrients. SWP are free of these substances, which increases the bioavailability of protein.
4. *Cost-effectiveness*: In regions with developed sericulture, pupae can be an accessible and inexpensive raw material, especially if a by-product of the silkworm industry is used.

Silkworm pupae are a promising alternative to soybean meal in industrial poultry farming due to their high nutritional value, environmental sustainability, and positive effect on poultry productivity. Their use can help reduce dependence on traditional plant proteins and increase the sustainability of the feed base. For successful integration further research, development of processing technologies and the formation of a regulatory framework are needed.

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