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STATUS AND PROSPECTS FOR THE USE OF INSECTS IN COMPOUND FEED PRODUCTION

Abstract

Due to the rapid growth of the population and the growing consumption of meat products, the issue of finding alternative sources of animal protein in feed production is more acute than ever. Insects are a promising protein component in feed production today. The article examines the state and prospects for the use of insects that have a high nutritional value, consume less resources and are environmentally friendly. The volumes of protein production obtained from fly larvae, flour worms and other insect species are given. The distribution of the use of insects for different types of animal husbandry, poultry farming and aquaculture in recent years is given. The main world leaders companies engaged in the cultivation of larvae and breeding of worms are presented. A comparative analysis of the content of crude protein and fat in various types of insects and traditional protein sources such as fish and soy meal is presented. A literature review of the results of the use of insects in the feeding of pigs and poultry by the world's leading scientists is presented. Insect-based animal feeds have been shown to have advantages over grain-based feeds. Test results are shown showing that crickets, black soldier flies and worms have the same protein digestibility as soy and provide more lipids, vitamins and minerals. The inclusion of insects in compound feed is one of the strategies for finding alternatives to create conditions for animal feeding that would be consistent with the concept of sustainable development. Data from a study on the effect of insects on egg production is also presented, which showed that yolk color, shell tear strength, and shell thickness were significantly increased by the addition of black soldier fly larvae. The results of studies on the use of insects in feeding fish are analyzed. The use of protein-chitin concentrate of Hermetia illucens larvae in feeding tilapia showed that it almost completely corresponds to fishmeal in terms of nutritional value.

Keywords: insects, processing, protein, feed, livestock, poultry, aquaculture.

Introduction

Global population growth, wealth growth and urbanization are leading to changes in global consumption patterns, lifestyle and food preferences, which leads to an increase in the need for animal protein [1, 2]. According to FAO estimates, the world's population will exceed 9 billion by 2050 and, accordingly, food production will have to increase by 70 % in order to be able to feed the world. It is expected that the production of meat products (beef, poultry and pork) will need to be doubled [3]. At the same time, it will be necessary to increase the production of fodder for farm animals, poultry, and fish. An increase in demand leads to protein deficiency and the search for alternative sources of animal protein [4-6]. While in agriculture, its main sources are fish and meat and bone meal. After thinking about alternative sources of animal protein, the researchers turned their attention to insects. There are more than 90 thousand species of insects on the planet, and each of them feeds on certain waste: vegetable, manure / litter, food waste, etc. [7].

To date, the volume of insect production in the world, of course, does not yet fully cover the shortage of fodder protein. However, it is expected that in 2050 the share of industrially cultivated insect protein could be more than 15% of the total amount of protein produced in the world [8]. The use of insects in feed production can make a significant contribution to climate protection, as their production is much safer for the environment. Insects are a source not only of valuable protein, but also of nutritious fatty acids, biologically active substances, macro- and microelements and antioxidants [9]. From an ecological point of view, the use of insects as an alternative source of animal protein makes sense. They consume fewer resources and provide an excellent supply of protein [10].

Purpose and objectives of the analysis.

The purpose of this article is to study the state and prospects for the use of insects in the production of feed products for farm animals, poultry and fish.

Results and its discussion

Today, mealworms, dipterous larvae, as well as crickets, grasshoppers, and cockroaches are used for industrial protein production. The most "exotic" protein is obtained from fly larvae – 52.6 %, mealworms account for 33.7 %, and other types of insects – only 14 %.

Due to the peculiarities of protein production from insects, it is most widely used in aquaculture, pig farming, and poultry farming (Table 1 and Fig. 1).

The main production of protein from insects is

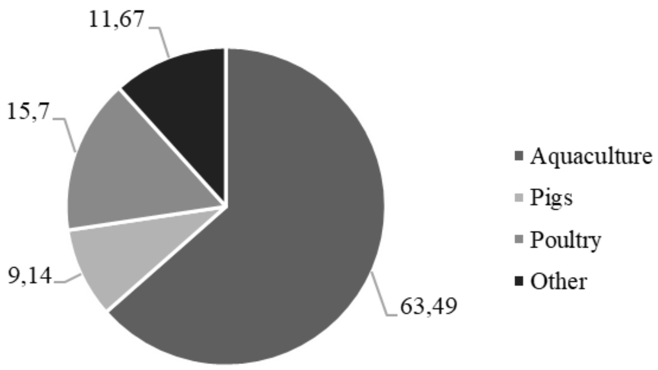

Fig. 1 - Distribution of the use of insects for different types of livestock, poultry and aquaculture

Table 1. Main consumers of insect feed

Consumer	2012	2016	2022	Market share (%), 2022	Cumulative average annual growth rate (%), (2016-2022)
Aquaculture	57.2	300.5	583.8	63.24	9.95
Pigs	8.9	43.3	81.8	8.86	9.53
Poultry	14.1	74.3	146.5	15.87	10.19
Other	10.3	55.2	111.1	12.03	10.50
Together	90.5	473.2	923.2	100	10.02

concentrated in the Republic of South Africa, the USA, Canada, and some European countries. But in terms of sales of this type of feed, the North American continent and Europe are in the lead, where in 2017 it was sold, respectively, 144.5 and 142.1 thousand tons. Moreover, this figure increased seven times over six years. The total revenue from sales of protein from insects in the world has reached 1.1 billion dollars. [11-17]. The world leader in the production of protein feed additives and insect fat is AgriProtein from the Republic of South Africa, established in 2008. In 2017, it sold 325.8 thousand tons of feed protein in the amount of 632 million dollars. The volumes of production and sales of other companies are much more modest [15-17]. Over the past few years, the technology for the production of feed protein from insects around the world has come a long way thanks to investments in this area: Protix (Netherlands) has received more than €40 million in investments, its competitor Agriprotein (South Africa) – in the region of $100 million, Ynsect (France) – more than 100 million euros. The first two companies breed black soldier fly larvae (Hermetia illucens) and Ynsect breeds mealworms [18-19]. The key players in the global market of edible insects for animal feed are EnviroFlight, LLC, Ynsect, AgriProtein Holdings Ltd, Enterra Feed Corporation, Protix, Entomotech SL, Kreca Ento-Feed BV, Deli Bugs, Haocheng Mealworms Inc, Entomo Farm, NextProtein, Beta Hatch, Hexafly Biotech, Entobel, HiProMine, Innova Feed, Nusect, Protenga i Mutatec.

Pig and poultry feeding tests.

Scientists from Brazil's Federal University of Minas Gerais (UFMG) recently proved that insect-based animal feed has advantages over grain feed [20]. Tests have shown that crickets, black soldier and worms have the same protein digestibility as soy and provide more lipids (+10…35 %), vitamins and minerals. The inclusion of insects in compound feed is one of the strategies for finding alternatives to create conditions for animal feeding that would be consistent with the concept of sustainable development.

PROteINSECT platform allows studying the potential of insect protein for feed and food products, published the results of research in various markets on the use of two types of fly larvae in feed for chickens, pigs and fish [2].

In a test with pigs (48 neutered piglets) for 4 weeks at concentrations of 2 % raw insect meal and 1.25 % extracted insects, PROtelNSECT researchers found no significant differences in body weight, daily weight, feed intake and feed conversion ratio, which is observed in comparison with piglets reared on a commercial diet. They noted that the levels of good microorganisms (Lactobacilli) were significantly higher in piglets fed insects. No differences were found in the levels of negative microorganisms (Enterobacteriaceae and E.Coli). Insect meal and derived insect proteins in the piglet feed created a healthy environment in the animal's gastrointestinal tract, the scientists added.

PROteINSECT also tested 300 Ross chicks for 39 days at concentrations of 2 % raw insect meal and 1.25 % extracted insects, with a commercial diet fed bird as control. The results showed that there were no significant differences in animal productivity [21]. In addition, when larvae were added to the diet of broiler chickens, a decrease in the amount of E. coli and Salmonella in faeces was observed (Erickson et al. 2004).

Table 2. The content of crude protein and fat in different sources of protein [2]

Source of protein	Crude protein (%)	Crude fat (%)
Hermetia illucens	35…57	35
Musca domestica	43…68	4…32
Tenebrio molitor	44…69	23…47
Fish meal	61…77	11…17
Soya meal	49…56	3

From a nutritional point of view, the digestibility of proteins is 70…80 %, and thus is close in value to soy flour. An index of essential amino acids has been developed (Smith, 2010). The values given and their interpretation depend on the dietary requirements of different animal species. Thus, as can be seen from the table, in some species of insects, these indicators were higher even compared to soy flour.

Unlike the sources mentioned, the disadvantage of using insects can be a microbiological safety risk (insects can be carriers of pathogenic bacteria and viruses), as well as a toxicological risk (some beetles produce toxic carcinogens as a means of protection, while some other species accumulate in body heavy metals). The addition of insects to cattle feed is unacceptable under any circumstances, as they are sources of animal protein.

Table 3. Index of essential amino acids

Animal species	Tenebrio Molitor	Mealworm Beetles	Zophobas	Musca Domestica		Hermetia illucens		Soya meal
	larva	larva	larva	larva	case-worm	larva	case-worm	
Weaning pigs	1.43	1.34	1.25	1.24	1.17	1.21	1.5	1.35
Broilers	1.39	1.29	1.21	1.19	1.1	1.17	1.43	1.31

There is also data on the use of insects in feeding broiler chickens. During the trial, 450 1-day old male broilers (Ross 308) were assigned to one of 3 diets. Experimental diets were formulated by mixing a diet based on corn and soybean meal with three different oils (corn, coconut and insect oils) to reach 50 g per kg of diet. It was concluded that insect dietary oil improved feed conversion ratio and increased medium chain fatty acid incorporation into fat pad and antioxidant serum in broiler chickens. [22]. Chinese researchers studied the effect of different levels of Hermetia illucens larval meal inclusion on growth productivity, nutrient absorption, blood counts, and intestinal morphology in piglets. The results of the study show that feeding 2 % complete fat with H. illucens larvae to partially replace fishmeal altered the metabolism, immune status, and intestinal morphology of weaned piglets. These data provide information on the food potential of H. illucens larvae as a suitable alternative source of fishmeal [23].

Several studies have been conducted to determine if BSFL (black soldier fly larvae) is suitable as an ingredient in poultry and as an alternative to soy. Dabbou and colleagues (2018) conducted a longitudinal study with the inclusion of BSFL diet on broiler chicken growth rates, blood counts, and intestinal morphology. In the study, 256 broiler chickens were fed four different inclusions of partially defatted BSFL food from days 1 to 35: test diet with food inclusion of 0% BSFL, with 5 %, with 10 %, and with 15 % as a substitute soy (and corn gluten). The diets were isonitrogenic and isoenergetic. The results of this study suggest that the inclusion of a BSFL diet of up to 10 % in male broilers increases body weight and daily feed intake, however only during the initiation period (days 1 to 10). During this period, the growth and development of chickens was much faster than in subsequent periods (the growing period from 10 to 24 days and the finishing period from 24 days to 35 days). An increase in feed intake and an increase in live weight is due to an improvement in the palatability of the diet. It has already been reported that chicken is better at consuming feed that includes BSFL food. During rearing and finishing periods, FCR and body weight were negatively affected by the 15 % BSFL groups compared to the 5 % and 10 % inclusion groups. It has been hypothesized that the chitin content of a 15 % BSFL diet may negatively affect protein digestibility (Dabbouetal, 2018). In contrast to another study, body weight and carcass weight of broiler chickens fed 16 % defatted BSFL inclusion was found to be higher than that of control chicken after 34 days (BSFL replaced by soy). It has been suggested here that more crude protein was likely the cause and the chitin content did not appear to affect protein digestibility (Altmannetal, 2018).

Altmann and colleagues (2018) analyzed the change in meat quality and sensory properties of breast fillets from broiler chickens packaged according to modern industrial packaging practices with modified atmosphere highly packed (HiOx MAP) over time. Breast fillets of broiler chickens fed defatted BSFL meal as a replacement for 50 % soy (total inclusion during the starter period was 19.5 % and during the rearing period 16 %) seemed to have more intense flavor when fresh compared to with breast fillet control group (no BSFL diet meal). There is also data on the study of the effect on egg production. Dietary inclusion of low fat BSFL also has an impact on egg production. In an 8-week study of 108 individual 19 laying hens (Shaver White) fed a standard corn-soy meal diet, defatted BSFL meal was included as a substitute for soy at 5 % and 7.5 %. The results obtained indicated that dietary 7.5 % defatted BSFL resulted in similar egg production, average egg weight and egg quality parameters compared to the control diet (analyzed on day 5, 22, 24 and 26 weeks). In contrast, 5 % inclusion resulted in a significant decrease in daily oocyte production. Egg weight and egg weight were significantly less than for eggs laid by control hens. Similar results between the control and 7.5 % BSFL inclusion group were attributed to a significant increase in feed intake of chickens in the 7.5 % BSFL inclusion group compared to the control and 5 % BSFL inclusion group (Mwanikietal, 2018). Mwaniki et al., 2018 showed that yolk color, shell tear strength, and shell thickness increased significantly with BSFL.

European TSE legislation prohibits the use of dead insects or treated insects in poultry and pig feed. However, live insects, vegetable oil, or hydrolysed protein are allowed. For example, Dutch firm Coppens already combines insect oil in its commercial pig feed. More research is being done to support the health benefits of chitin and lauric acid (found in insects). For example, Wageningen UR in the Netherlands is an active player in this type of research. The IPIFF notes that insect food for pigs and birds will be a major focus once its use is approved.

Fish feeding trials.

Skretting reported that the company is using insect feed in commercial feeds in the Norwegian salmon industry. Commercial salmon feed with insect meal is made at the Skretting Norway factory in Avereux. Nordlaks is the first customer to test 360000 insect meal feeds. Other companies around the world are also bringing topical insect-derived products to market. This year, Protix launched an insect-eating salmon called Friendly Salmon, where 100 % of the fishmeal is replaced with insect meal. Protix also sells other species under the Friendly Fish brand, such as trout and shrimp. When researching the use of insects in aquafeeds, the criteria are: the fish are fed a diet in which at least 50 % of the fishmeal is replaced by insect meal and the weight of the fish after the insects is doubled [24].

The biomass of the larvae of the black soldier fly Hermetia illucens was obtained by breeding the insect in the laboratory on an environmentally friendly fodder grain substrate. The protein concentrate with chitin was isolated by partial defatting of dry larvae by direct extraction. The resulting product contained 53.4 % crude protein, 18.3 % chitin and 5.1 % crude fat. Experimental fish food was prepared by wet pressing at low pressure. At the same time, 100 % of the fish meal was replaced by a protein concentrate with chitin obtained from the larvae. The experimental feed contained 14 % less protein and 8.4 % less fat than the control, and included 8.24 % chitin. The control feed contained 45 % fishmeal. Fish of experimental and control groups of young red tilapia. The protein-chitin concentrate of Hermetia illucens larvae almost completely corresponds to fishmeal in terms of nutritional value [21].

BioMar has been researching insect food since 2015 at its R&D centers and since 2017 has been conducting tests for their customers feeding their fish with insect food diets. This fish has already entered European supermarkets among retailers seeking to implement future-oriented food solutions focused on natural products. [22].

Prospects for the use of insects.

The top three manufacturers by production volume are AgriProtein (South Africa), Enterra Protix (Canada) and Biosystems (Netherlands). They prefer to work with the black soldier fly (Hermetia illctns), the advantages of which are that its larvae contain more amino acids than any other insects, while they are absorbed by almost 100 %, and the fly itself is unpretentious in nutrition and happily reproduces as on a clean vegetable raw materials, as well as on any waste, including biological, which allows agricultural holdings to earn extra money on the disposal of organic waste. At the same time, the black soldier fly is not a carrier of infections due to its high antibiotic properties [11-17]. Brazilian scientists have already studied the effects of insect feeds on pigs, quails, fish and domestic animals. Experiments have shown better feed conversion and meat quality. However, scientists note that although it is technologically possible to produce compound feed from insects, while this is not economically viable, it would be advisable to use them for fattening animals from which elite meats are produced. Also, countries need to adapt their legislation to use such feeds [8]. It should be noted that the volume of production of fishmeal, high-quality soybean meal extract and soybean meal is hundreds of times higher than insect protein products. ABN Amro published a price comparison in a report that compares the trade prices of protein sourced from different sources. The data shows that BSF and small mealworm are the most competitive with existing high quality protein sources such as fishmeal and high quality soybean meal. Once the insect sector grows, it can become more efficient, leading to lower costs.

Conclusions

In the last few years, insect feed protein production technology has advanced globally and continues to gain momentum. Insects are a promising alternative source of animal protein. They have a high nutritional value, consume fewer resources and are environmentally friendly. Insects are a source not only of valuable protein, but also of fatty nutritive acids, biologically active substances, macro- and microelements and antioxidants.

Today, flour worms, dipteran larvae, as well as crickets, grasshoppers, and cockroaches are used for the industrial production of protein. An analysis of the literature has shown that insects do not receive traditional sources of animal protein in terms of nutritional value, and in some cases showed better feed conversion and improved meat quality. However, in order for this direction to become economically viable and competitive, it is necessary to actively increase the production of fodder protein from insects and adapt legislation at the state level.

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СТАН І ПЕРСПЕКТИВИ ВИКОРИСТАННЯ КОМАХ У КОМБІКОРМОВОМУ ВИРОБНИЦТВІ

Анотація

У зв'язку зі стрімким ростом населення та ростом споживання м'ясної продукції, питання пошуку альтернативних джерел білку тваринного походження у комбікормовому виробництві стоїть як ніколи гостро. Перспективним білковим компонентом у кормовиробництві на сьогоднішній день є комахи. У статті досліджено стан та перспективи використання комах, які мають високу поживну цінність, споживають менше ресурсів та є екологічно безпечними. Досліджено обсяги виробництва білка, який отримують з личинок мух, борошняних черв'яків та інших видів комах. Наведено розподіл використання комах для різних видів тваринництва, птахівництва та аквакультури за останні роки. Представлено основні світові лідери, які займаються вирощуванням личинок та розведенням черв'яків. Наведено порівняльний аналіз вмісту чистого білка і жиру в різних видах комах та традиційних джерелах білка, таких як рибне і соєве борошно. Представлено літературний огляд результатів використання провідними світовими вченими комах у годівлі свиней та птиці. Доведено, що корми для тварин на основі комах мають переваги в порівнянні з зерновими кормами. Наведено результати випробувань, які показали, що цвіркуни, чорні мухи-солдати та хробаки мають рівень засвоюваності білка такий же, як і в сої, і забезпечують більше ліпідів, вітамінів і мінералів. Включення комах до складу комбікормів є однією з стратегій пошуку альтернатив для створення таких умов годування тварин, які б відповідали концепції сталого розвитку. Також наведено дані про дослідження впливу комах на виробництво яєць, які показали, що колір жовтка, міцність на розрив оболонки та товщина шкаралупи значно збільшувались при додаванні black soldier fly larvae. Представлено результати досліджень використання комах у годівлі риби. Використання протеїн-хітинового концентрату личинок Hermetia illucens у годівлі тиляпії показало, що він практично повністю відповідає рибній муці по поживній цінності.

Ключові слова: комахи, переробка, білок, комбікорм, тваринництво, птахівництво, аквакультура.

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