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Non-traditional sources of protein in animal nutrition

ABSTRACT

Currently, animal husbandry is one of the fastest growing agricultural subsectors worldwide. This requires an increase in feed production, which in turn will require an increase in the base of feed ingredients, mainly protein. One of the current global problems in animal husbandry is the shortage of feed protein. Therefore, the feed industry should be aware of the trends, problems and opportunities existing in the field of protein feed production.
The aim of the study is to consider alternative protein sources that can partially or completely replace the usual protein in animal feed.The search and analysis of literature was carried out using the following Internet resources RSCI, PubMed, Web of Science, Science Direct, Scopus, e Library, Google Scholar (Google Academy) for the period 2020–2024.

Results. Alternative protein sources not only fill the gap in protein requirements, but also pave the way for sustainable animal husbandry. Non-traditional protein products used in animal feed are expanding rapidly, and the emerging market for alternative protein is attracting investment. Alternative protein sources are essential to meet the growing demand for protein-rich feed ingredients, so the feed production sector needs to find alternative sources based on research results.

Key words: expression, genes, large white, pigs, TNFAIP3, CDS1, MTAP

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Научный обзор

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Нетрадиционные источники белка в кормлении животных

РЕЗЮМЕ

В настоящее время животноводство является одним из наиболее быстрорастущих сельскохозяйственных подсекторов во всём мире — это требует увеличения производства кормов, что в свою очередь потребует увеличения базы кормовых ингредиентов, в основном белковых. Одна из современных глобальных проблем в животноводстве — нехватка кормового белка. Следовательно, кормопроизводство должно быть в курсе тенденций, проблем и возможностей, существующих в сфере производства белковых кормов.
Цель исследования — рассмотрение альтернативных источников белков, которые могут частично или полностью заменить обычный белок в кормах для животных.
Поиск и анализ литературы проводились с использованием интернет-ресурсов РИНЦ, PubMed, Web of Science, Science Direct, Scopus, eLibrary, Google Scholar (Google Academy) for the period 2020–2024.

Выводы. Альтернативные источники белка не только восполняют пробел в потребности в белке, но и прокладывают путь к устойчивому животноводству. Нетрадиционные белковые продукты, используемые в кормах для животных, быстро расширяются, а развивающийся рынок альтернативного белка привлекает инвестиции. Альтернативные источники белка имеют большое значение для удовлетворения растущего спроса на богатые белком кормовые ингредиенты, поэтому сектор производства кормов должен найти альтернативные источники, основываясь на результатах исследований.

Ключевые слова: альтернативный белок, корма, водоросли, листовой белок, отходы пищевой промышленности, побочные продукты, микробиологические белки

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Introduction

Recent years have witnessed a growing interest in non-traditional sources of protein, due to concerns around the sustainability and environmental impact of conventional protein sources, as well as the need to meet the considerable and increasing demand for protein raw materials for the feed industry in a growing global meat production which has increased fivefold since the 1960s all over the world[1]. According to the analytical company Feedlot, in January — August 2024, Russian agricultural organizations produced 6.5 million tons of meat in slaughter weight, which is 4.1% higher than the same period in 2023. Traditionally, poultry meat production occupies the largest share in the total production of meat in the country, it is about 49.7%, pork accounts for 43.6%, beef — 6.6%, lamb and goat meat — 0.1% [1]. The growing meat production was accompanied by an increase in demand for animal feed, especially protein feed. According to the Feedlot company's statistics, the feed market in Russia grew by 11% over the past three years, and in 2024 alone it grew by 6%, as production of feed for farm animal for the first seven months of 2024 amounted to 25.9 million tons. The cost of the primary conventional protein in animal feed like soybean meal and fish meal is increasing continuously[2].

The purpose of this study is to review alternative sources of proteins with potential to partially or fully substitute conventional protein (soybean meal and fish meal) in animal feed.

Materials and methods

Methodology. Selection, search, relevance, analysis.

The process of selecting literature had to meet the following criteria:

1) *Key words.* The works cited in the study were selected using key words that would give the clearest possible idea of the subject of the author's study such as: alternative protein, algae, leaf protein, food industry waste, by-products, microbiological proteins.

2) *Characteristics that were used in the literature search process*:

• publications had to be published in the last five years;

• the language of publication is English and Russian;

• access to the full text of the publication.

The search and analysis of literature was carried out using the following Internet resources: RSCI, PubMed, Web of Science, Science Direct, Scopus, e Library, Google Scholar (Google Academy) for the period 2020–2024. As a result of the research, 50 scientific papers were selected. After determining the relevance to the research topic, duplicate articles, university theses and university books were deleted, so the list of references became 35 references.

Results and discussion

There are various non-traditional protein sources that have great potential for use in preparing animal feed. The most important of these sources are as follows:

1. *Algae proteins.* Algae can be classified into two main groups; first one is the microalgae or microphytes, which are microscopic algae invisible to the naked eye, can be found all over the world in practically all kinds of aquatic environments, they include blue green algae (cyanobacteria), eukaryotic algae (dinoflagellates), unicellular algae (Bacillariophyta or diatoms). Microalgae are good pollution bioindicators, due to their large distribution, and different tolerance ranges [2]. Microalgae, capable of performing photosynthesis, are important for life on earth, that roughly half of the oxygen production on earth comes from microscopic marine algae.

Also, due to their very high protein content, and their richness in nutrients and minerals, they have been utilized in many industries like pharmaceuticals, food and feed, cosmetics, antimicrobials etc. [3] (Fig. 1).

The second group of algae is macroalgae (seaweeds) which includes green, brown and red algae (Fig. 2).

Seaweeds or macroalgae are very rich in useful metabolites (phlorotannins, carotenoids, pigments, agar, polyunsaturated fatty acids, alginate, carrageenan and carbohydrates (polysaccharides)) and minerals (sodium, zinc, iodine, calcium, manganese, selenium, iron), being considered as a natural source of additives that can substitute the antibiotic usage in feed of various animals and they are a valuable protein

Fig. 1. (A) *Chlorella vulgaris* (B), Chlorella pyrenoidosa (C), Spirulina platensis [4]

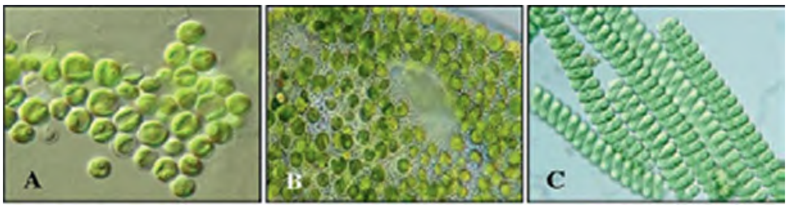

Fig. 2. (A) Green algae (B), Brown algae (C), Red algae

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[2] Савкина Л. Тенденции кормового рынка в России и мире. Импортозамещение в производстве аминокислот и витаминов. Амбиции и реальность. Рынки кормов и животноводства в России и мире: инвестиции и инновации для развития бизнеса. Материалы II Отраслевого бизнес-форума, посвященного индустрии комбикормов. М.: КормВетГрейн Экспо. 2024.

Table 1. **Different species algae in diets of farm animals**

Species algae	Algae groups	Protein content,%	Feeds	Levels of the total diet,%	References
Chlorella vulgaris	Green micro algae	61.6	fish feed	2.5–10	[8, 9]
Ulva lactuca	Green macro algae	15.13	poultry feed	15	[10]
Laminaria japonica	Brown macro algae	13.24	swine feed	5	[11], [12]
Asparagopsis taxiformis *Euglena gracilis*	Red macro algae Single-celled micro alga	13.28 26.1	ruminant feed	1 and 2.5 10 and 25	[13]
Asparagopsis taxiformis	Red macro algae	13.28	beef cattle feed	0.05, 0.10 and 0.20	[6]
Spirulina (cyanobacteria Arthrospira platensis)	Blue-green micro algae	65–77	swine feed	9.5	[14]

source [5]. Brown algae are the poorest among algae species in terms of protein content, which ranges between 5 and 15% of the dry weight [6].

The seaweeds show great variation in the nutrient contents, which are related to several environmental factors. Thus, the protein, peptide, and amino acid concentration, like other bioactive components of algae, is affected by a variety of circumstances, such as nutrient availability, light intensity, temperature, pH, and rainfall [7]. Powdered algae extracts can be included in the formulation of pellets or granules for animal feed.

Below Table 1 indicates the use of some species of algae in different animal feeds.

2. *Insects and worms proteins.* Fish meal is considered a practicable solution for the utilization of the discard from marine capture commercial fisheries. However, the recent global decline in fish production has caused a decrease in the amount of raw material for fishmeal production, which has prompted the scientific and industrial community to search for solutions to this problem using insect proteins. The use of insects as a non-traditional protein source for production-animal feed is one such avenue gaining attention. Insect meal has been produced from organic food waste, which is an effective way to dispose of organic waste in a safe way, in addition to obtaining product contains a high percentage of protein (50–75%), to be used in the feed production, as it has been proven that insects are efficient in converting organic waste into proteins and fats, which makes them an interesting alternative source of feed [15]. The larvae of flies of the order *Diptera* are a promising alternative source of protein in animal nutrition, offering high protein content and a low environmental impression compared to traditional feed sources; they process various wastes that cannot be directly used in animal feed; also, they require less space for cultivation and have a more efficient feed conversion [16]. As examples, black soldier fly (*Hermetia illucens*), yellow mealworm (*Tenebrio molitor*), and common housefly (*Musca domestica*) have been used as an alternative protein source in feed for pigs. Because they have well-balanced nutritional value as a protein source for pigs [17]. Soybean meal has also been partially replaced in fish and livestock feed by grasshopper meal (*Oxya hyla hyla*) which contains about 64% protein [18]. Additionally, Black soldier fly, mealworm, housefly, cricket/Grasshopper/Locust (*Orthoptera*), silkworm, and earthworm are the commonly used insect meals in broiler and laying hen diets, due to its high protein content and essential amino acid profile compared to conventional feedstuffs [19].

The Russia market for insect-based animal feed is rapidly growing. The insect-raising projects existing in the country specialize in the processing of animal waste by the insects [20], and producing the animal feed based on insect biomass for poultry, aquaculture, and pet food Table 2.

3. *Food industry wastes and by-products.* Globally, the food industry sectors are increasing very rapidly, driven by demand growth, producing a lot of waste, whether in the stage of preparing raw materials or what is produced incidentally as secondary materials (by-products) after the producing process. The food industry waste can be used directly in the preparation of feeds such as soybean meal and wheat bran, also it can be converted using extrusion, enzymatic and microbial fermentation processes or using insects to obtain high protein products. These wastes and by-products are important sources of cheap protein and are divided into: Plant-Based Sources and Animal-Based Sources.

3.1. Plant-Based Sources. They include waste and by-product related to the primary and further processing of plant-based raw material in various food sectors. The most important food sectors are summarized in: non-alcoholic and alcoholic industry, oil industry, bakery and confectionery industry, grain industry, fruit and vegetable industry.

Table 2. **Some species of insects and worms used in animal feed**

Insects and worms	Scientific name	Protein content, in % of dry mass	Animal feed	References
Flies	Larvae of *Lucilia spp.*	62.80	broiler feed	[21]
The greater wax moth	The caterpillar of *Galleria mellonella*	43.68	fish feed	[22]
Earthworms	Family *Lumbricidae*	55–70	trout feed	[23]
Black soldier fly	*Hermetia illucens*	62.4	compound feed for young sturgeon fish	[23]

Soybean oil industry waste is the first choice for animal feed production in Russia due to high availability and low price. However, the presence of anti-nutritional factors limits its use in the animal feed industry such as aquaculture feed [24]. The concentrations of anti-nutritional factors in plant raw materials can be reduced in the feedstuff by using various techniques, such as extrusion [25], heat treatment, soaking, adding chemical and organic solvents, bacterial and enzymatic fermentation [24].

The brewing industry produces more than 100 billion liters a year worldwide and consequently more than 20 million ton of solid waste. This waste is mostly destined for animal feed, due to its amino acid content, which is necessary for the proper growth and development of animals [26]. According to Voloshin and Glazkov, adding beer waste to compound feed for fattening calves gives better results on meat quality compared to other feed sources such as beet pulp, wheat germ, and sprouted wheat [27].

3.2. Animal-Based Sources. The management of meat production waste has been and continues to be one of the most important issues related to pollution management all over the world. Meat production waste processing is a step towards sustainable animal by-products management and circular bio-economy [28].

The meat industry wastes include those related to animal slaughter, and producing meat products. These wastes includes animal tissue, bones, blood, skin, and by-products resulting from the production of meat products, in addition to restaurant waste and expired animal products. Meat waste can be converted by microbial/enzymatic fermentation [24], and by insects/worms to obtain high protein feed additives to enrich the feed of farm animals, such as protein hydrolysates in the diet of monogastric animals and pets such as cats and dogs. The advantages of enterprises aimed at using insects as productive insects for processing waste from meat production factories and slaughterhouse include lower costs for animal feed obtained, that the insects receive maximum energy and nutrients even from low quality raw material (meat industry and slaughterhouse wastes). In this regard, it was found that the Argentine cockroach surpasses other productive insects in many respects, which may make it the most promising species for the development of industrial entomology [20].

4. Single cell proteins (SCP) or microbial proteins. Single cell protein (SCP) is a bulk of dried cells which can also termed as microbial protein, bio-protein or biomass, it can be a good substitute for fish meal or soybean meal in feed [29]. Industrially, there are several other ways of getting single cell proteins, they can be produced from yeast, algal biomass, and fungi by growing them rapidly on substrates with minimum dependence on soil, water and climate conditions [30]. Microbial protein has a number of advantages over animal and plant protein: amino acid composition, low fat content, and the possibility of cultivating producers on secondary products of processing plant raw materials: sugar cane, sugar beet, sorghum, rice, orange broth, etc. [31]. Despite these numerous advantages, they have disadvantages and toxic effects too, especially related to mycotoxins and bacterial toxins.

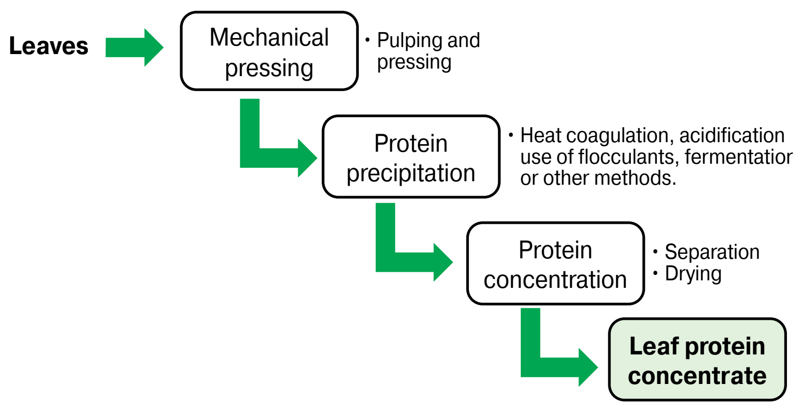
Mycoprotein is a form of single-cell protein derived from fungi. In feed for poultry and fish, mycoprotein from *Paecilomyces variotii* can serve as an alternative protein source, replacing fish meal or soy protein [32].

It was reported that isolated yeast strains (*Hanseniaspora uvarum*, *Hanseniaspora guilliermondii*, *Cyberlindnera fabianii*, and *Issatchenkia orientalis*) are promising single cell proteins producers for possible use as animal feed [33].

5. Leaf protein concentrate. Traditionally, the seeds are used as a protein source in animal feed, but the leaves are also protein factories producing good-quality protein commonly called green proteins because of the association with chlorophyll, about 80% of proteins plant leaves are located in the chloroplasts [34]. Some forage crops, like alfalfa, pea, aquatic plants, faba and soy bean produce several times more of green protein per unit area than grain crops, that in many cases are utilized by grazing livestock. On the other hand, leaves from various non-crop plants like Moringa leaves were investigated as a potential source of proteins for monogastric animal feeding purposes [35]. Because of the high content of fibers indigestible by monogastric animals in the leaves, extraction of leaf protein is an attractive solution to the demand for protein feed for monogastric animal, which is done according to Figure 3.

Typically, there are several sequential operation steps needed to liberate proteins from the interior of cells, including a first mechanical step: to break cells open; second step: the protein is solubilized. After solubilization, in the third step: the protein is precipitated followed by suitable purification steps.

Fig. 3. Leaf protein extraction scheme [34]



Conclusion

Based on our review of the scientific literature, we are able to draw following conclusions:

1) The alternative protein sources not only bridge the gap of protein need but also pave the way for sustainable animal production.

2) Non-traditional protein products used in animal feed are rapidly expanding and the emerging alternative protein market is attracting investments.

3) Alternative sources of protein are important to meet the increasing demand of protein rich feed ingredient, so feed production sector must find an alternative options, based on researches results.

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All authors bear responsibility for the work and presented data.
All authors made an equal contribution to the work.
The authors were equally involved in writing the manuscript and bear the equal responsibility for plagiarism.
The authors declare no conflict of interest.

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