The possibilities of alternative protein use in animal nutrition

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Abstract. The Food and Agriculture Organization (FAO) predicts there will not be enough food for human and animal nutrition until 2050. Global demand for animal protein for human consumption is increasing, and this consequently increases the price of these ingredients. This will open several challenges to provide enough animal feed. In the European Union, the use of processed animal proteins in pig and poultry diets is prohibited due to the bovine spongiform encephalopathy (BSE) legislation, while globally, the land availability for soy cultivation is limited. The European food market is dependent on huge import of soybean, which is the main source of valuable proteins and one of the main ingredients in feeds. Feed ingredients must not contain antinutritive factors that would adversely affect animal production and must have an acceptable price. Some of the alternative plant sources of protein are fava beans, peas, lentils, hemp, different grain seeds, etc. To find alternative sources of protein of animal origin scientists are increasingly investigating the use of worm, snail or grasshopper meals and also marine organisms, usually algae, shells or starfish. Single cell proteins are a specific kind of protein from different microbial sources, including microalgae, yeast, fungi, and bacteria.

1. Introduction

The Food and Agriculture Organization (FAO) predicts there will not be enough food for human and animal nutrition in the world until 2050. According to prediction, the production of meat (poultry, swine, and beef) will increase almost two times [1]. However, global demand for animal protein for human consumption is increasing, and this consequently increases the price of these ingredients. This will open several challenges to the global capacity to provide enough animal feed. However, in the European Union, the use of processed animal proteins in pig and poultry diets is prohibited due to the bovine spongiform encephalopathy (BSE) legislation, while globally, the land availability for soy cultivation is limited. The European food market is dependent on the huge import of soybean, which is the main source of valuable proteins and one of the main feed ingredients [2]. Researchers over the world are investigating the possibility of using other sources of protein for animal nutrition.

The most widely used protein sources in livestock production (monogastric animals) are corn, soybean meal, sunflower meal (cake) and rapeseed cake. From this point of view, plant species characteristic of an area can significantly reduce production costs, especially for small producers, and could be a source of alternative protein of plant origin. They must not contain antinutritive factors that would adversely affect animal production and must have an acceptable price. Some of the alternative plant sources of protein are fava beans, peas, lentils, hemp and different grain seeds. To find alternative sources of protein of animal origin for animal nutrition, especially in organic production systems,
scientists are increasingly investigating use of worm, snail, or grasshopper meal and also marine organisms, usually algae, shells, or starfish. Animal protein meals are good sources of essential amino acids, especially lysine and methionine, energy and minerals (calcium and available phosphorus) [3]. Insects can be sustainable alternative sources of protein, particularly if they are grown on biological waste substrates. In that way, they can effectively convert low-quality wastes into high-quality proteins. The main obstacles to animal-based protein use are consumer acceptance, regulatory issues and cost-effectiveness (competitiveness) [4].

2. Plant-based proteins

Plant-based protein consumption is increasing very fast globally. It has reached an annual consumption rate of about 7% [5]. Frequently used protein-rich plants are soybean, different legumes and oilseeds. Comparing their raw states, plant-based proteins have similar protein content to meat. On the other hand, they are rich in fibre and contain less saturated fat than meat [6].

At this moment, food producers and consumer society promote the reduction of animal-based protein consumption. It seems that plant-based proteins are a more sustainable and healthier option [7]. There is an extensive diversity of sources, and one of them is legumes [8]. Legumes (Family Leguminosae) can be divided into pulses (fava beans and peas) and oilseeds (soybean). They differ in carbohydrate and lipid contents [9] (Table 1). Pulses are low in fat and are valuable sources of vitamins (i.e. B12), minerals (i.e. iron, zinc, magnesium, calcium), and phytochemicals, positive for both human and animal health [10].

2.1. Legumes and oilseeds

A valuable but not enough exploited sustainable protein source is fava bean (Vicia faba L.). It has a low fat level (1-2%), and is rich in fibre (7-9%) and polyphenols. Fava bean is also a good source of lysine. [9]. From the agricultural point of view, fava bean has many environmental advantages, because it can fix atmospheric nitrogen and grow and develop at extreme climatic conditions [9,11].

Another possible source of protein is lentil (Lens culinaris). Lentil grain contains 40% starch, 25% crude protein and 15% neutral detergent fibre (calculated on dry matter basis), making lentil a nutritious ingredient for pig feed [12]. Lentil not used for human consumption can be an alternative feedstuff. It can substitute soybean meal in swine diets to reduce feed cost [12, 13]. The main obstacle to using lentil in pig nutrition is the presence of anti-nutritional factors in raw lentils. Adverse effects of feeding lentils to swine include reduced protein utilization and impaired meat quality and taste [14].

**Table 1** Nutritional value of some legumes and oil cultures [15, 16]

|                | Soybean | Fava bean | Lentil | Pumpkin | Pea |
|----------------|---------|-----------|--------|---------|-----|
| Protein (g)*   | 41.00   | 27.99     | 28.60  | 57.76   | 25.70 |
| Fat (g)        | 19.60   | 1.57      | 1.6    | 15.06   | 1.4  |
| Carbohydrates (g) | 7.60   | 54.70     | 57.60  | 6.84    | 53.70 |

* Calculated on 100g of dry matter

Pumpkin seed cake, which remains from the oil extraction process, could be a valuable protein-based ingredient in animal nutrition, especially to meet the protein requirements of ruminants [17]. It contains almost 60% protein, more than many commonly used oilseed-based feed ingredients [18], such as soybean meal [19]. Pumpkin cake is rich in amino acids lysine (3.2%) and methionine (1.8%), and improves the palatability of ruminant feed [20]. Substitution of soybean meal with pumpkin seed cake in the diet of dairy goats does not decrease milk production or change the fatty acid profile of milk [17].
2.2. Microalgae
To mitigate environmental issues due to the expansion of agriculture, use of land, and carbon emissions, microalgae could be a sustainable food source both for humans and animals. Compared to other alternative sources of proteins, microalgae contain valuable nutrients, such as omega-3 and omega-6 polyunsaturated fatty acids, and could compare to marine fish. The nutritional benefits of fish, such as essential omega-3 fatty acids and protein, often come directly from their consumption of marine algae [21]. Microalgae are also low in chemical contamination and have great purity.

Pigments are valuable components of microalgae that can act as antioxidants. They can improve animal health and be a natural colorant. The addition of algae into animal feed provides many benefits, such as improvement of growth and body weight, lowering feed intake, improve immune response, act as antibacterial and antiviral components (replacement of antibiotics), and microalgae enrich animal origin products with bioactive compounds, i.e., peptides and antioxidants. Recently, algae became a “cell factory” in the food industry and showed the rapid growth of the bio-economy in the feed industry. Microalgae are one of the few vegetable sources of vitamin B12 and iodine [6]. Microalgae’s bioactive compounds could improve biological defences in the body against inflammatory diseases [22, 23]. However, the nutritional value of microalgae varies depending on the species, growth conditions, harvest location and season [6] (Table 2).

| Microalgae species       | Composition (%) | Lipids | Protein | Carbohydrates |
|--------------------------|----------------|--------|---------|---------------|
| *Botryococcus braunii*   |                | 33     | 39.61   | 2.38          |
| *Chlorella vulgaris*     |                | 14-22  | 51-58   | 12-17         |
| *Spirulina maxima*       |                | 6-7    | 60-71   | 13-16         |

3. Animal-based proteins
Contemporary aquaculture uses ingredients that are not suitable for human consumption to produce valuable proteins, which contributes to food security and upgrades the nutritional value of proteins as well. Due to the increase in global population, and the increase of the proportion of animal proteins in human diets, demands for valuable proteins are also increasing. Consequently, global aquaculture is facing continuing growth, followed by growth in global aqua feed production, which is expected to grow up to 73.15 million tons by 2025 [27]. In the past, fishmeal was the main protein source in aqua feed diets due to its nutritional profile that corresponds to the requirements of most aquatic species. Intensive use of this valuable ingredient together with limited sources has led to a drastic increase in its price. This was the driving force for scientists and feed producers to seek alternative protein sources and contribute to sustainable aquaculture.

The goal of sustainable aquaculture was to find alternatives by utilizing agro-industrial by-products, food leftovers, former foodstuffs, new by-products (e.g. from green biotechnologies), new protein-rich feeds produced by recycling unused biomasses (earthworms, insects) and aquatic resources (algae). Insect and worm meals had already consumed in many countries of South Asia, Africa, and Latin America. Several years ago, they started to be present on the global market. They are considered as a sustainable protein source and a possible solution for the replacement of animal-based protein [28]. Regarding nutritional quality, insects are good sources of protein and fat (Table 3). They also contain all essential amino acids necessary for human and animal health. They are rich in polyunsaturated fatty acids, vitamins and minerals. However, insects contain the antinutritional factor, chitin, which can reduce protein digestibility and can cause allergy. The nutritional value of insect meal differs depending on the species, phase of development, and type of feed.

The most frequently used insects in animal nutrition are yellow mealworm (*Tenebrio molitor*), black soldier fly (*Hermetia illucens*) and house cricket (*Acheta domestica*). The amino acid profile of *T.*
molitor meal generally meets fish requirements, and, in some cases even surpasses these requirements. In comparison to fishmeal, insects are generally low in omega-3 fatty acids that are required for optimal fish quality. However, it is possible to influence insect meal composition by rearing insects on substrates rich in omega-3 fatty acids. For example, if T. molitor is fed on bio wastes containing linseed as a source of omega-3 fatty acids, the fatty acid composition of the insect meal will be changed. Apart from the nutritive value of insect meal, safety should be also taken into consideration when using bio waste as a rearing substrate. Microbiological safety, heavy metal content and screening of pesticides residues in insect meal are very important in evaluation. Insects are also recognized as a valuable source of antimicrobial peptides, which do not contribute to the development of natural bacterial resistance. When used in animal nutrition, insect antimicrobial peptides can inhibit the growth of potentially pathogenic intestinal bacteria. Larvae of T. molitor are recognized as a source of protein with antimicrobial activity, which is active against Gram-positive bacteria and fungi [29, 30].

Table 3. Nutritional value of animal-based protein raw materials [31, 32]

|                | Fish meal (III quality) | Meat meal (III quality) | Worm meal |
|----------------|-------------------------|-------------------------|-----------|
| Protein, g     | 60                      | 50                      | 49-69     |
| Fat, g         | 10                      | 15                      | 10-27     |
| Ash, g         | 20                      | 30                      | 5-8       |

4. Single-cell proteins

Single-cell protein is the biomass or protein extract from pure or mixed cultures of algae, yeasts, fungi or bacteria. It can be used as an ingredient or a substitute for protein-rich foods and is suitable for human consumption or as animal feeds [33].

Single-cell protein was first mentioned in the 1960s to describe protein-rich foods produced from yeasts as dietary supplements for livestock and humans. Single-cell protein was considered as an alternative protein source that might fill a gap in food and feed production [34]. The growth of microorganisms, more rapid than that of the higher plants, makes them very attractive as high-protein crops; whereas only one or two grain crops can be grown per year, a crop of yeasts or moulds can be harvested weekly, and bacteria can be harvested daily [35]. Single-cell protein-based meal has the potential to provide the animal feed industry with a sustainable, renewable feed ingredient to make up for the deficiencies of plant-based meal and reduce the need for fishmeal in diets [36]. Single-cell protein is currently produced from a limited number of microbial species, particularly when considering human consumption. The range of sources for Single-cell protein used in animal feed is broader than that approved for human consumption and is expanding. Bacterial single-cell protein generally contains 50-80% protein on a dry weight basis and the essential amino acids [38].

5. Conclusions

Alternative proteins, plant or animal origin, could be used as substitutes for traditional feed ingredients. It requires research attention and interest in the media and wider forums as a way to fulfil the nutritional needs and food demands of the growing population. Some results show that numerous protein alternatives can have important environmental and health benefits. Most protein alternatives have resulted from the fourth industrial revolution and promise other advantages such as greenhouse gas reduction. Alternative proteins also promote food security by decreasing land usage to grow animal feed for the production of human food.

Acknowledgments

This work was financially supported by the Ministry of Education, Science and Technological Development, Republic of Serbia (Project No. 451-03-9/2021-14/200222)
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