OILSEED BY-PRODUCTS AS ALTERNATIVE PROTEIN SOURCES IN ANIMAL AND POULTRY NUTRITION

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Abstract

This review aims to comparatively evaluate soybean, sunflower, rapeseed and hempseed meals as protein sources for animal and poultry nutrition. A comparative analysis of published data was conducted focusing on proximate composition, protein and amino acid profiles, fibre content, energy value, digestibility and major antinutritional factors. The reviewed evidence indicates that soybean meal has the most favorable overall protein quality, whereas sunflower and rapeseed meals provide valuable alternatives but are constrained by higher fibre levels and specific nutritional limitations. Hempseed meal shows potential as an alternative protein ingredient, although its nutritional value and practical application require further evaluation. Differences among oilseed meals are associated with crop characteristics and processing conditions.

The review highlights the comparative nutritional advantages and limitations of these four meals and provides a basis for their more appropriate use in animal and poultry diets according to species requirements and dietary formulation.

Key words: *soybean meal; sunflower meal; rapeseed meal; hempseed meal; animal nutrition*

INTRODUCTION

Adequate dietary protein is essential for animal growth, productivity, health and feed efficiency, providing amino acids necessary for tissue development and physiological functions. The increasing demand for animal-derived products has intensified interest in sustainable, nutritionally efficient and locally available protein sources.

Oilseed meals are valuable by-products of vegetable oil production, providing protein, amino acids and other nutrients. Their nutritional value depends on plant species, cultivation conditions, oil extraction methods and processing technologies. Soybean meal is widely used in livestock and poultry diets due to its high protein content, favourable amino acid profile and digestibility. Sunflower, rapeseed and hempseed meals are promising alternative or complementary protein sources, particularly in regions where these crops are widely cultivated.

However, differences in protein quality, amino acid balance, fibre content, energy value, digestibility and antinutritional factors influence the suitability of these ingredients for animal nutrition. Their comparative assessment is therefore essential for efficient feed formulation [1, 2].

This review aims to compare soybean, sunflower, rapeseed and hempseed meals in terms of nutritional value, amino acid composition, fibre and energy characteristics, antinutritional factors and potential applications in livestock and poultry nutrition.

MATERIAL AND METHOD

This review was conducted as a narrative literature review of scientific publications addressing the use of oilseed by-products as protein sources in animal and poultry nutrition.

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Relevant scientific literature was identified through searches of major electronic scientific databases, including Web of Science, Scopus, PubMed, and Google Scholar. The review included peer-reviewed original research articles, review papers, and relevant scientific publications reporting data on the chemical composition, nutritional value, processing characteristics, and feeding effects of oilseed by-products in livestock and poultry. Particular attention was given to studies published in recent years. The literature data were synthesized qualitatively, taking into account differences in experimental design, animal species, dietary composition, processing technology, and inclusion levels among the reviewed studies.

Statistical analyses and software versions were reported only when they were specified in the original publications. No new statistical software was used for statistical processing in the present review.

RESULTS AND DISCUSSIONS

Soybean meal (SBM) **Soybean meal (SBM)** is a major co-product of soybean oil extraction and one of the most widely used plant-protein ingredients in livestock and poultry diets due to its high protein content, favourable amino acid profile and broad availability [3, 4, 5].

Commercial solvent-extracted soybean meal typically contains 44–48% crude protein, although its composition varies according to soybean origin, growing conditions, hull removal and processing technology [6, 7, 3]. It provides essential amino acids, including lysine, arginine, leucine, isoleucine, threonine and tryptophan, with generally high digestibility in monogastric animals. Siegert et al. (2023) [8] reported high standardized digestibility of several amino acids, although differences between sources were observed. Methionine and cysteine are relatively limiting in poultry diets, making supplementation with sulfur-containing amino acids necessary in some formulations.

The energy value of SBM depends on its protein, residual oil and fibre contents, as well as processing conditions. Variations in metabolizable energy can affect broiler diet efficiency and production costs [8, 9]. Its non-starch polysaccharides and other fibre fractions may also influence energy availability and nutrient utilization.

The main nutritional limitations of SBM include trypsin inhibitors, lectins, raffinose, stachyose and non-starch polysaccharides, which may impair digestion and nutrient absorption [4, 10, 11]. Appropriate heat treatment reduces heat-sensitive antinutritional factors, whereas excessive heating may damage proteins and reduce amino acid availability, particularly lysine. Therefore, adequate processing is essential to preserve its nutritional quality.

Sunflower meal (SFM) is a by-product of sunflower oil extraction and a potentially valuable alternative or complementary protein source for livestock and poultry. Its crude protein concentration is variable, generally ranging from approximately 23 to 44%, depending on seed characteristics, extraction technology and especially the extent of hull removal [12, 13]. Dehulled products usually contain more protein and less fibre than meals containing a large proportion of hulls. This variability means that the feeding value of SFM should be assessed for each source rather than assumed to be uniform.

The amino acid profile of sunflower meal is characterized by relatively favourable concentrations of sulfur-containing amino acids. In contrast, lysine is generally the first limiting amino acid, and threonine may also be present at lower levels than in soybean meal. As a result, SFM can complement other protein ingredients, but diets with substantial inclusion may require lysine supplementation and careful balancing of digestible amino acids. Total amino acid

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concentration alone does not fully describe protein value; digestibility and availability must also be considered. Evidence suggests that sunflower meal can be used more flexibly than traditionally assumed when its composition and inclusion rate are appropriately managed. [12] reported that sunflower meal included at up to 30% in diets for pullets and laying hens did not impair ileal digestibility of most amino acids. Some amino acid digestibility measures improved at particular inclusion levels. These findings provide useful evidence of the ingredient's potential, although the results should not be directly generalized to broilers without considering differences in age, growth rate and nutrient requirements. The main limitation of SFM is its relatively high structural fibre concentration, which originates largely from the seed hulls. High fibre can reduce dietary energy density and may limit the digestibility of protein and other nutrients, especially in young poultry. Nevertheless, fibre is not exclusively undesirable: moderate structural fibre can influence gizzard development and gastrointestinal function. The effect therefore depends on fibre level, particle characteristics, bird age and the overall diet formulation.

Sunflower meal also contains phenolic compounds, including chlorogenic acid, which may affect protein utilization and the functional properties of sunflower proteins. Dehulling is one of the most effective approaches to improve its nutritional value because it reduces fibre and increases the relative concentration of protein and digestible nutrients. Fractionation, suitable enzyme supplementation and precise formulation can provide further benefits. In practice, SFM is most useful when its protein and energy values, fibre content and lysine concentration are measured and used to formulate a balanced diet [12, 13, 14, 15].

Rapeseed meal (RSM) is generated during vegetable-oil extraction and is an important alternative protein source for livestock and poultry. Conventional products commonly contain approximately 35–40% crude protein, although composition varies with cultivar, environmental conditions, processing technology and hull content [16, 17, 18, 19]. The ingredient can contribute to protein-source diversification and support more efficient use of oil-industry co-products. Its nutritional value should be assessed in relation to the specific processing method and the requirements of the target animal.

Rapeseed protein has a useful amino acid profile and is relatively rich in the sulfur-containing amino acids methionine and cysteine. However, lysine concentration is generally lower than in soybean meal. In addition, the digestibility of rapeseed protein may be affected by its fibre fraction and antinutritional compounds. For poultry, it is therefore important to formulate diets according to standardized digestible amino acids and to combine RSM with complementary ingredients where necessary [18, 20, 21].

Compared with soybean meal, RSM typically contains more fibre and has a lower energy density. Its fibre fraction includes non-starch polysaccharides that are poorly digested by poultry. These components may increase digesta bulk, influence intestinal viscosity and contribute to endogenous nutrient losses, thereby limiting nutrient utilization, particularly in rapidly growing broilers [22]. The effect of fibre depends on its concentration and characteristics, the bird's age and the composition of the complete diet.

Glucosinolates are among the most important antinutritional factors in rapeseed meal. When hydrolysed, they can produce compounds such as isothiocyanates, thiocyanates and oxazolidine-thiones. At sufficiently high levels, these products may reduce palatability and feed intake and can interfere with thyroid function. Modern low-glucosinolate, low-erucic-acid cultivars have reduced this concern compared with

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traditional rapeseed varieties [23]. Other compounds, including phytate, tannins and sinapine, may also influence the ingredient's nutritional quality.

Processing can improve the usefulness of RSM. Dehulling reduces the hull-derived fibre fraction and increases the relative concentration of protein and other nutrients. Fermentation and enzyme-based treatments have also been studied as methods for improving digestibility and reducing antinutritional compounds. Hong et al. (2025), [24] for example, reported improved nutritional characteristics following solid-state fermentation with a microbial consortium. Although the effectiveness of these approaches depends on the process conditions, they may expand the opportunities for using RSM in poultry diets.

Hempseed meal (HSM), also referred to as hempseed cake, is obtained after mechanical or solvent extraction of oil from hemp seeds (*Cannabis sativa L.*). It has attracted attention as a potential alternative protein ingredient because it combines protein with a residual lipid fraction. Hempseed cakes often contain approximately 30–34% crude protein and 10–12% residual lipids, although the values vary with cultivar and extraction method [25]. Certain processed hemp protein products may contain higher protein concentrations [26].

Hempseed protein contains all essential amino acids and is particularly notable for its arginine content. Nevertheless, the nutritional value of HSM should be evaluated using amino acid digestibility and availability as well as total protein concentration. Differences in cultivar, hull content, oil extraction and processing may affect the protein, fibre and lipid fractions. Such variation is important when determining suitable inclusion levels in poultry diets, where rapidly growing birds have high requirements for digestible essential amino acids. Fibre concentration depends strongly on the proportion of hull material remaining after processing. Hull-rich fractions contain more structural carbohydrates, while cotyledon-rich fractions are relatively richer in protein and lipids [27]. High fibre can reduce energy density and limit nutrient utilization in monogastric animals, particularly poultry. Dehulling may therefore improve the suitability of HSM by reducing fibre and increasing the relative concentration of protein. For ruminants, fibre is generally less restrictive because it can be fermented in the rumen, although protein degradability and intestinal amino acid supply remain relevant [28].

Potential antinutritional factors in hemp-derived ingredients include phytate and protease inhibitors. Phytate can reduce phosphorus availability and may affect the utilization of other minerals, while protease inhibitors may interfere with protein digestion. Appropriate thermal or enzymatic processing and the use of feed enzymes may help mitigate some of these effects. However, the extent of improvement depends on the composition of the raw material and the processing conditions [25, 28].

Feed safety is another consideration, particularly the botanical part from which the ingredient is obtained. Cannabinoid concentrations can differ between seeds and products derived from flowers or leaves, so hempseed meal should not be treated as equivalent to hemp inflorescence meal. Abdalla et al. (2024) [29] highlighted that the safety and regulatory status of hemp-derived feed products differ across jurisdictions. Saengsuwan et al. (2025), [30] in research on hemp inflorescence meal for laying hens, also emphasized the need for safety assessment; that study should not be used as direct evidence for the composition of conventional hempseed meal. HSM is a promising alternative protein ingredient, but its application requires consistent quality assessment and further research.

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Application of oilseed meals in animal and poultry nutrition. Oilseed meals are protein-rich co-products that can help diversify feed ingredients, make use of agricultural processing by-products and reduce dependence on soybean meal. Their feeding value is determined not only by crude protein concentration but also by amino acid composition and digestibility, fibre fractions, energy value, processing conditions and antinutritional compounds. Sunflower, rapeseed and hempseed meals therefore represent complementary resources rather than direct, interchangeable substitutes for soybean meal [13, 14, 26].

In poultry diets, the inclusion of each meal should be matched to the bird's age, production stage and nutrient requirements. Sunflower meal may provide protein and sulfur-containing amino acids but often requires attention to fibre and lysine. Rapeseed meal can contribute methionine and cysteine, while fibre and glucosinolates must be controlled. Hempseed meal offers protein and residual lipids, but its variable composition, fibre and antinutritional factors require careful evaluation. Combining different protein sources and supplementing limiting amino acids can help achieve a balanced diet without relying exclusively on one ingredient. Oilseed meals can also contribute to more resource-efficient and sustainable feed production because they use co-products of vegetable-oil extraction. Nevertheless, sustainability benefits must be accompanied by nutritional and safety control. Variation among batches can be substantial, especially where processing methods and dehulling intensity differ. As emphasized by [14], differences in nutritional value make ingredient characterization particularly important when locally produced meals are used.

CONCLUSIONS

Oilseed meals are valuable alternative protein sources in animal and poultry nutrition. Soybean meal remains the main reference ingredient, while sunflower, rapeseed and hempseed meals offer opportunities to diversify feed formulations. Their effective use depends on protein quality, amino acid digestibility, fibre content and antinutritional factors.

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