Flaxseed Meal

Subjects: Agriculture, Dairy & Animal Science

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Flaxseed meal (FSM) is rich in protein, α-linolenic acid, dietary fiber, flaxseed gum, and other bioactive substances. The crude protein content of FSM is up to 40%. Thus, FSM can be used as a potential high-quality protein feed resource. However, due to the presence of anti-nutritional factors, such as cyanogenic glycosides (CGs), phytic acid, anti-vitamin B6 factor, and other anti-nutritional factors, the application of FSM is restricted in animal husbandry.

flaxseed meal plant protein microbial fermentation cyanogenic glycosides feed resource animal husbandry

1. Introduction

In recent years, conventional protein feed resources such as soybean meal have been in a long-term supply-demand imbalance, which has led to increased feed costs and reduced sustainability for animal husbandry. Therefore, it is urgent to increase the development and utilization of non-conventional feed resources to alleviate the current situation of conventional feed resource shortage and reduce feed costs. In this case, alternative protein feed resources might be useful for animal nutrition.

Flaxseed is one of the world's oldest oilseed crops. In the years 2016–2020, the average cultivated area of flaxseed in the world was about 3.39 million hectares [1]. The global production of flaxseed has remained stable at about 3000 kilotons for years, and the top five countries of flaxseed production are Kazakhstan, the Russian Federation, Canada, China, and the United States of America. Flaxseed oil, which is mostly obtained via squeezing and extracting from flaxseed, is an important source of supplemental n-3 polyunsaturated fatty acids (PUFAs) [2]. Despite the extraction of the beneficial component (i.e., flaxseed oil), the by-product, flaxseed meal (FSM) still has good nutritional value. However, the research on FSM is relatively limited. Like many other feed ingredients, FSM has many excellent functions and can be used as a high-quality non-conventional protein feed for livestock and poultry. However, FSM has been used in the feed industry for a short time, and one of the most notable anti-nutritional factors in flaxseed, cyanogenic glycosides (CGs), severely limits the exploitation of application in the feed industry [3].

2. Nutrition Composition and Characteristics of Flaxseed Meal

FSM is rich in n-3 PUFA, dietary fiber (DF), protein, and other nutrients. The crude protein (CP) content of FSM can be as high as 35–40% [4], which shows a comparable nutritional value with soybean protein (**Table 1**). Therefore, FSM has the potential to replace soybean meal as a protein raw material. In addition to being rich in protein, FSM is an essential source of α-linolenic acid (ALA) and DF [5]. However, FSM is susceptible to flax variety, origin climate, oil extraction methods, and production processes, resulting in discrepancies in nutrient composition and nutritional level [6].

Table 1. The main nutritional composition of flaxseed meal and soybean meal (air dry basis, %).

Items	Flaxseed Meal	Soybean Meal
Crude protein	33.90	43.82
Ether extract	7.02	1.05
Crude ash	5.45	5.86
Neutral detergent fiber	35.96	12.44
Acid detergent fiber	16.18	5.89
Crude fiber	9.88	5.20
Calcium	0.37	0.39
Phosphorus	1.50	0.66
Arginine	3.00	3.34
Histidine	0.67	1.28
Isoleucine	1.33	1.97
Leucine	1.91	3.43
Lysine	1.19	2.95
Methionine	0.77	0.63
Phenylalanine	1.49	2.21
Threonine	1.13	1.82
Tryptophan	0.51	0.55
Valine	1.55	2.17

Note: data are obtained from the national standard GB/T 39235-2020 swine nutritional requirements of the People's Republic of China. http://c.gb688.cn/bzgk/gb/showGb?

2.1. Flaxseed Protein

The main components of protein in FSM are globulin and albumin [7]. The concentration and composition of essential amino acids (AAs) in FSM are similar to those in soybeans meals (**Table 1**) [2]. In addition, flaxseed proteins can be hydrolyzed by proteases to produce biologically active peptides. Active peptides play important

type=online&id=3356B6508971EE7EB81904C9C83892E5, accessed on 14 October 2022.

physiological roles in the body with anti-inflammatory and antioxidant properties [8]. Flaxseed protein is considered a good source of plant protein. Adding an appropriate amount of FSM to livestock and poultry diets can improve animal immunity, thereby improving animal production performance and related livestock product flavor [9].

2.2. Dietary Fiber

DF in flaxseed averages about 28%, which is divided into soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). The ratio of SDF to IDF varies from 20:80 to 40:60 [10]. DF ranked seventh among essential nutrients in a balanced diet. Flaxseed DF has been reported to have several beneficial effects, including increasing perceived satiety [11], enhancing fat excretion [12], improving constipation [13], and has a specific effect on intestinal microbiota to produce short-chain fatty acids (SCFAs) that affect host metabolism [14]. Thus, flaxseed DF is an excellent source of supplemental DF, which has a variety of benefits for animals.

2.3. Polyunsaturated Fatty Acids (PUFAs)

FSM is considered a superior source of n-3 PUFAs when compared to fish oil, soybean, corn, or marine algae, because of the extremely high content of ALA (about 55%) [15]. ALA is essential to the body but cannot be synthesized *in vivo*, hence the diet is the only way to provide this essential fatty acid (FA). Numerous studies have shown that ALA has important physiological functions in antibacterial, anti-inflammatory, and antioxidant activities [16][17]. ALA as one of the n-3 PUFAs is vital for livestock and poultry production. Studies have shown chickens can hepatically synthesize eicosapntemacnioc acid (EPA) and docosahexaenoic acid (DHA) from ALA. Moreover, when increasing concentrations of flaxseed oil in a laying hen diet, n-3 PUFAs from the diet can be efficiently absorbed, transferred, and deposited into the yolk [18]. Dietary supplementation of coated n-3 PUFAs in sows' diets using flaxseed oil can improve milk IgG levels and the growth performance of suckling pigs [19]. In addition, dietary supplementation with flaxseed oil could enhance milk production and the concentration of functional FAs (ALA) in milk fat [20]. Collectively, the supplement of n-3 PUFA in the diet benefits the growth and FA metabolism of animals, thus improving the nutritional value of animal products, while it provides potential choices of FSM for the development of functional livestock products.

2.4. Flaxseed Gum

Flaxseed gum (FSG) occurs mainly in the outermost layer of flaxseed hulls, which constitutes approximately 8% of seed dry mass [21]. FSG is mainly a heteropolysaccharide composed of neutral arabinoxylan and acidic rhamnogalacturonan [22]. Flaxseed polysaccharides have been found to have special physiological functions [23]. The antioxidant capacity of soluble FSG in reducing 1,1-diphenyl-1-picrylhydrazyl (DPPH) and 2,2-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS) free radicals and converting them to more stable products was demonstrated *in vitro* [24]. Furthermore, soluble FSG has been shown to exhibit strong bile acid binding ability *in vitro*, and decrease the enterohepatic circulation of bile acids, thereby lowering cholesterol levels and producing SCFAs profiles that are relevant in maintaining a healthy gastrointestinal tract [25]. SCFAs are known as important microbial metabolites of the organism, which participate in host metabolism and thus lower colonic pH while they may also reduce the proliferation of harmful pathogens. In addition, FSG may be used as a potential prebiotic to modulate gut microbiota. It can contribute to the regulation of lipid metabolism in the liver, and alleviate adipose tissue deposition, hence, to some extent, protecting animals from the negative effects of dyslipidemia from a high-fat diet [26]. It has also been reported that adding an appropriate amount of FSG to the diet of obese rats can inhibit obesity caused by a high-fat diet, which could be attributed to the regulation of FSG on gut microbiota by decreasing the Firmicutes/Bacteroidetes ratio [27]. Therefore, proper supplements of FSG can effectively prevent and treat the diseases caused by oxidative damage, such as reducing the incidence of obesity and preventing colon cancer.

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