Camelina Meal as a Livestock Feed Ingredient

Subjects: Agriculture, Dairy & Animal Science

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Camelina sativa is an annual oilseed crop that requires low inputs. Recently, interest in camelina oil for both human use and biofuel production has increased. Camelina meal can result in decreased dry matter (DM) intake; it has greater neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents, as well as greater antinutritional factors than protein meal produced from some of the more commonly cultivated oilseeds. It is, however, still a viable feed ingredient in animal diets as a protein source.

biofuel crops novel oilseed

1. Introduction

Camelina (*Camelina sativa*) is a member of the Brassicaceae family and is an annual oilseed crop. Camelina is also known as false flax or gold of pleasure. Grown as either a summer or winter crop, camelina shows potential as a low-input cover crop in the semiarid climate of the great plains [1]. Camelina has a short lifecycle, making it useful in double cropping systems with soybeans and corn, and its cold and drought tolerance make it useful in a wheat-fallow system [2]. Camelina has both winter and summer varieties, making it suitable for winter annual production in the Northern Great Plains of the US [3]. The winter camelina yielded 743 kg/ha in the US [3]. The production of camelina has decreased in the US from 2009 to 2017 [1], with 937 acres planted in 2017 [4]. The decrease in camelina production is due to decreasing camelina seed prices, partially from lower crude oil prices [1]. Despite the decrease in US camelina acreage, interest in camelina has been increasing, especially as biofuel production increases [5]. The seed contains 38 to 43% fat and is primarily used for its oil in human use and biofuel [2]. Camelina oil contains high levels of the essential fatty acids linoleic and alpha-linolenic acid, making it useful as an edible oil [6]. Recently, camelina oil has been investigated for use in biofuel production, especially its use in jet biofuel [1]. Once the oil has been removed from the seed, camelina meal becomes the leftover as a byproduct. The oil is primarily extracted from the seed in one of two ways: mechanical expulsion or solvent extraction. Mechanical expulsion involves physically pressing the oil from the seed, while solvent extraction then uses a solvent, often hexane, to further remove oil from the seed. This results in two different camelina meals of differing chemical compositions being produced.

An increase in camelina and biofuel production will result in an increase in byproducts, which may provide an additional opportunity for camelina meal as a feed ingredient in animal production. Animal agriculture already utilizes a wide variety of byproducts, including byproducts from the ethanol industry (distillers' grains) and byproducts of oilseeds (soybean and canola meals). Camelina meal has a high concentration of crude protein (CP) and the essential fatty acid, alpha-linolenic acid (omega-3), making it attractive as a feed ingredient; however, anti-nutritional factors in camelina may limit the inclusion in diets.

2. Production of Camelina Meal

2.1. Mechanical Extraction of Camelina Oil

The mechanical extraction of oilseeds uses pressure to extract the oil from the seed. The mechanical extraction of oil is one of the oldest methods of oil extraction and is commonly used because of its relative ease and low costs [7]. The two main methods of mechanical extraction are a screw press and a hydraulic press. Although mechanical extraction is less expensive than other methods, oil yields are lower than solvent extraction (29.9% vs. 35.9% oil recovered from seeds, respectively; [8]). A screw press has slightly improved yields compared to hydraulic pressing and can also be adapted to continuous extraction which is beneficial when processing large quantities of oilseeds [7]. The lower oil yield from mechanical extraction means that the resulting meal is lower in CP content because it is diluted by the greater fat content. This greater fat content can be beneficial, as it can supply extra energy to the diet; however, in ruminant diets, care must be taken not to over supplement fat, as it can negatively impact the rumen microbes.

2.2. Solvent Extraction of Camelina Oil

Solvent extraction has higher capital costs but results in a greater recovery of oil [2]. Solvent extraction generally begins with pressing the seeds to remove most of the oil or pretreating the seeds via grinding and heating to reduce the viscosity of the oil, and then running a solvent, most commonly hexane, through the press cake to remove the residual oil. Solvent extraction results in oil yields of 95–97% [2]. Once the oil has been extracted, the solvent must be removed from both the oil and the meal. This solvent can be reused to help reduce costs. The greater oil yield from solvent extraction results in a meal that has less fat, and CP is more concentrated because of the lower fat content. The meal is toasted after the solvent is removed at 105 °C for 30–40 min; then, it is ground or pelleted once the meal has been cooled [2]. Toasting the meal after oil extraction using steam helps remove residual solvent and reduce glucosinolates [9].

3. Nutrient Composition of Camelina Meal

3.1. Feeding Value of Crude Protein of Camelina Meal

The primary role of camelina meal is most likely as a protein supplement due to its high levels of CP, which are similar to canola meal but less than soybean meal, both of which are commonly fed as a protein source. Comparing the ruminal protein degradation rate and rumen unavailable protein (RUP) among 10 camelina varieties resulted in a range from 0.123 to 0.191 h^{-1} and 255 to 332 g/kg of CP, respectively [10]. Colombini et al. [10] also evaluated a canola meal that had a ruminal protein degradation rate of 0.156 h^{-1} and RUP content of 275 g/kg of CP. Three varieties of camelina meal had greater RUP contents than the canola meal with an average of 356 g/kg of CP between the three of them, which is similar to the recommendations of 350 g/kg of CP in [11]. It is important to note that although the camelina and canola meals were solvent-extracted, the extraction was performed using a Soxhlet apparatus, and no heat treatment was performed, which may increase the RUP. When Camelina meal is fed to pigs, the ileal standardized digestibility of crude protein was greater in the solvent-extracted meal than the expelled meal (0.67 vs. 0.58; p = 0.007) despite the solvent-extracted camelina meal being heat-treated, which generally decreases CP and amino acid digestibility [12]. The increase in CP and amino acid digestibility in pigs fed solvent compared to expelled camelina meal was likely due to the solvent-extracted camelina having lower levels of glucosinolates and soluble fiber [12].

3.2. Neutral Detergent Fiber and Energy Value of Camelina Meal

Most of the energy that is supplied by camelina meal, and oilseed meals in general, comes from residual fat, NDF, and protein. The energy value of a feed can be expressed in a variety of ways. Gross energy is the total energy released when a feedstuff is completely oxidized through combustion, which is associated more with the chemical composition of the feed than the nutritional quality [11]. Although GE does not consider the energy available to the animal, because of the limited reports on more appropriate energy measures in the literature, GE can provide a general idea of the energy content of the feeds. Expelled camelina meal has a greater GE content than the solvent-extracted meal, as expected due to the greater fat content in the expelled meal. Both canola meal and soybean meal have lower GE concentrations than the solvent-extracted camelina meal, likely due to the greater NDF concentration in the camelina meal.

Another major component of camelina meal is the NDF and ADF contents. Solvent-extracted camelina meal generally has greater NDF and ADF concentrations, likely due to less dilution from fat when compared to the expelled meal. Canola meal and solvent-extracted camelina meal have similar NDF concentrations, with camelina meal having a wider range and greater mean than canola. Soybean meal has significantly less NDF than camelina meal. The significant amounts of NDF in camelina meal may limit its use in animal feeds as NDF has limited digestion in non-ruminants; however, ruminants are still able to utilize the NDF, and glucosinolates are still the main limiting factor for camelina meal inclusion.

4. Anti-Nutritional Factors Present in Camelina Meal

The greatest factors limiting the use of camelina meal as a feed ingredient for animals are the anti-nutritional factors that are present [13]. The anti-nutritional factors in camelina meal are glucosinolates, sinapines, erucic acid, trypsin inhibitors, and tannins, with glucosinolates being the main concern. Glucosinolates are hydrolyzed into isothiocyanates, thiocyanates, nitriles, and epithionitriles that are highly toxic to animals [13]. Sinapines are present in plants for the biosynthesis of lignin and flavonoids but have a bitter flavor, which can decrease DMI and cause a fishy taste in eggs [13]. Camelina meal contains lower concentrations of sinapine (0.1–0.5%) than canola, and, thus, sinapine does not induce any unpleasant effects [13]. Erucic acid is a fatty acid that reduces the palatability of feed and in monogastrics may induce myocardial lipidosis [12]. Canola was developed from rapeseed primarily to reduce its erucic acid content and must now contain <2% erucic acid in its fatty acid profile [9]. Erucic acid content in camelina meal is slightly higher than canola meal at 3.1% in solvent-extracted camelina meal [12]. Concentrations of trypsin inhibitors and tannins are both low in camelina meal. Trypsin inhibitors reduce amino acid digestion and intake at a concentration of 3 trypsin inhibitor units (THI)/mg in the feed, and solvent-extracted camelina meal contains 0.00663 TIU/mg [12]. Overall, glucosinolates present the biggest concerns for anti-nutritional factors in camelina meal and are the main component limiting its use as an animal feed ingredient.

Glucosinolates are present in all members of the brassica plant species. The metabolites of glucosinolates cause reductions in feed intake and decreased growth and production [14]. Pigs are more sensitive to glucosinolates with tolerance levels for pigs, ruminants, and poultry of 0.78, 1.5 to 4.22, and 5.4 mmol/kg, respectively [14]. The glucosinolate content of expelled and solvent-extracted camelina meals ranges from 39.12 to 44.90 and 23.10 to 37.63 mmol/kg, respectively. It is important to note that only two papers were available on the glucosinolate levels in solvent-extracted camelina meal. In [15], the authors performed solvent extraction with hexane but did not state the temperature used and whether the meal was toasted or not. Cerisuelo et al. [12] also performed solvent extraction, but they used a Soxhlet apparatus and did not state whether the resulting meal was toasted or not.

5. Beneficial Nutritional Factors in Camelina Meal

Camelina meal contains high levels of omega-3 (α-linolenic acid) and omega-6 (linoleic acid) fatty acids. Omega-3 fatty acids have been of special importance due to their health-promoting effects in humans [16]. The inclusion of omega-3 fatty acids in poultry diets helps increase the omega-3 content in both the meat and eggs because of their high capacity for lipid biosynthesis. This makes camelina meal a potential source of omega-3 for enriched poultry products.

Feeding broiler chickens a diet containing 10% camelina meal led to a 2- to 2.5-fold increase in omega-3 fatty acids in the white and dark meats compared to a control diet based on corn and soybeans [16]. When laying hens were fed a diet containing 10% camelina meal, even greater increases in omega-3 fatty acids in eggs were observed. Compared to those on a corn–soybean control diet, the camelina-fed hens had an eight-fold increase in omega-3 fatty acids in their eggs [16]. Consuming two large eggs from the camelina-fed hens could provide over 300 mg of omega-3 fatty acids to a human diet. In a soybean-meal-based diet fed to brown egg layers that had a 10% inclusion of either camelina meal or flax meal, the camelina-fed group had a greater yolk content of omega-3 and total n-3 poly-unsaturated fatty acids as well [17]. Thus, feeding camelina meal to chickens has the potential to increase the nutritional quality of the final product, especially in laying hens. However, in solvent-extracted camelina meal, the effect of omega-3 fatty acids may not be as pronounced because of the lower fat content in these meals.

Camelina meal can also improve the fatty acid composition of milk when fed to dairy cattle [18]. When sunflower meal was replaced with camelina meal, milk yield, fat content, and protein content were not affected, but milk fat content was numerically decreased in the camelina-fed groups [19]. The saturated fatty acid content of the camelina-fed groups was decreased, and the poly unsaturated fatty acid content was increased. This is consistent with other studies that have found that feeding camelina meal decreases milk fat content and modifies the fatty acid composition with greater poly unsaturated and less saturated fatty acids [18][20].

6. Conclusions

Camelina meal can result in decreased DM intake; it has greater NDF and ADF contents, as well as greater antinutritional factors than protein meal produced from some of the more commonly cultivated oilseeds. It is, however, still a viable feed ingredient in animal diets as a protein source. The nutrient composition of camelina is similar to canola meal, with high levels of protein and fiber, but is not as good of a source as soybean meal because soybean meal has more protein and less fiber. The oil extraction method produces similar meals, but expelled camelina meal has much greater fat and lower protein, while the solvent-extracted meal has lower fat and greater protein. In addition, the solvent-extracted camelina meal may be produced under greater temperatures, especially if the meal is toasted to remove residual solvent, which can reduce the glucosinolate content of the meal. This is especially important as the primary barrier to the utilization of camelina meal in animal feeds, especially pigs, is the high levels of glucosinolates. Decreasing the glucosinolates either through heat treatment, fungal fermentation, or selective breeding to produce low-glucosinolate varieties could improve the feeding value of camelina meal. Currently, camelina meal is safe to feed at 10% inclusion in poultry and cattle diets, and the utilization of camelina meal in animal feeds will be dependent on the cost competitiveness with other oilseed meals. Camelina meal is currently an acceptable protein source for animal feeds but could be improved similarly to canola, where future research should be focused on reducing anti-nutritional factors through breeding and production methods.

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