Chapter 14

Use of Wheat Distiller Grains in Ruminant Diets

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Additional information is available at the end of the chapter

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Abstract

Wheat grain is commonly used to produce ethanol in Canada and Europe. During ethanol production processing, starch in the grain is fermented almost completely, and the remaining protein, fibre, fat, minerals and vitamins increase approximately 3-fold in concentration compared to the original grain. By-product derived from the ethanol production is named distiller grain and primarily used in feeding livestock animals. Wheat-based distiller grain is high in energy, protein and fibre. These properties give wheat distiller grain unique feeding opportunities for various classes of livestock as both energy and protein supplements as well as fibre source. This chapter summarizes some recent research findings published in peer reviewed and extension chapter on the use of wheat distiller grain in ruminant diets. Substantial variation in chemical composition exists among the distiller grain samples, which are mainly influenced by inherent original grain and technology used in ethanol plant. Wheat distiller grain can be used to partly replace grain or forage portion at moderate levels to meet energy and fibre requirements of cattle. A manure management plan needs to be developed that considers the fact that inclusion of wheat distiller grain in the diet will dramatically increase the nitrogen and phosphorus content in manure.

Keywords: wheat grain, distiller grain, nutrient content, ruminants, dairy and beef cattle, digestibility, feed efficiency, growth performance, milk production, manure management

1. Introduction

Traditionally, wheat grain is primarily used for human food consumption; the milling of wheat produces flour for human use and appreciable quantities of by-products for animal feeds. On average, wheat grain contains 65% starch, 15% protein, 14% fibre, 2.2% oil and 10% moisture [1]. With expansion of fuel ethanol production in North America and other places in the world during the last decade wheat grain has been used as second feedstock after corn for ethanol production due to its high starch content. Many different classes and types of wheat can be used for ethanol production. In general, soft wheats such as soft white and soft red classes are preferred to hard wheats because they contain higher starch content. Varieties with higher protein are less desirable, but may still be used when blended with one or more high starch varieties.

Increase of fuel ethanol production has resulted in a significant increase in the use of distiller grains in the diets of livestock animals, especially in ruminant feeding. Distiller grains have historically been used as a protein source for dairy cattle. Whereas, increased supply and reduced cost make it also a source of energy to replace grain. The distiller grain has comparable energy value to its original grain, high quality protein and high fibre content but highly digestible which is suitable for ruminant feed but not suitable for monogastric animals or poultry because of high fibre content. Wheat distiller grain is the major by-product of ethanol production when wheat grain is used as a substrate for ethanol production. In the last decade, research has documented the variation in chemical composition of wheat distiller grain, and its feed value as protein, energy or fibre source for dairy and beef cattle as well as small ruminant animals. Studies have frequently focused on comparing the feed value of wheat distiller grain to corn distiller grain and characterizing the impact of inclusion of these by-products on nitrogen and phosphorus excretion in manure. To our knowledge, there is no review article that has addressed these research findings, even though several review articles on the use of corn distiller grain in animal production and one book chapter on use of wheat distiller grain in pigs and poultry have been published [2, 3]. The objective of this chapter is to describe some recently developed knowledge and application of wheat distiller grain in ruminant animal diets.

2. Production of distiller grain in ethanol plant

There are two main distillery processes, dry-milling and wet-milling distillery. The dry-milling process is the main process for producing ethanol [4]. The dry-milling process includes primarily the follow steps: grinding or milling, liquefaction, saccharification, fermentation and distillation [5]. The grain is ground to produce bran-free flour, and then mixed with water and enzymes (amylases) to produce a mash (liquefaction). The saccharification is conducted by adding enzymes to the mash to transform starch into dextrose. After saccharification, yeast is added to start the fermentation process to produce a 'beer' and CO_2. The beer is separated through a continuous distillation column to yield alcohol [5]. The remaining material is called whole stillage and consists of all the components of the original grain (except the starch), yeast and added water. The whole stillage is centrifuged to produce wet distiller grain (solid fraction) and thin stillage (liquid fraction). The wet distiller grain contains 30–35% dry matter, while thin stillage has only 5–7% solids. The thin stillage is concentrated through evaporation into condensed distiller solubles, which are mixed with wet distiller grain and dried to become dried distiller grains with solubles, which are the most produced co-products from bioethanol plants. In general, from each tonne of wheat grain, ethanol production results in approximately 365 l of ethanol, 290 kg of CO_2 and 290 kg of distiller grain. With continuing changes of technologies in ethanol plants, it should be noted that wheat distiller grain are still evolving, thus the composition and feed value of distiller grain are changing.

3. Chemical composition of distiller grain

During ethanol production process, starch is mostly converted into ethanol and it leaves all other components of grain to be condensed. Therefore, compared to the original wheat grain, starch contents of distiller grain is very low (4.3%), whereas the contents of non-fermentable components including crude protein, neutral detergent fibre, acid detergent fibre, ether extract and phosphorus are considerably higher (**Table 1**). The primary nutrient contents of wheat distiller grain are crude protein and neutral detergent fibre ranging from 30 to 45% or from 25 to 55%, respectively. The chemical composition of wheat distiller grain can vary considerably depending on numerous factors mainly including wheat source and technology used in ethanol plant (**Table 2**). Physical and chemical characteristics of grain vary with

Item	Wheat	Wheat distiller grain
Organic matter	97.9	94.4
Starch	60.2	4.3
Neutral detergent fibre	14.3	31.6
Acid detergent fibre	4.2	11.4
Crude protein	15.1	38.8
Ether extract	2.3	3.8
Calcium	0.05	0.12
Phosphorus	0.39	1.0

Table 1. Chemical composition of original wheat and wheat distiller grain (% of dry matter).

Item	Mean	STD	Min	Max
Organic matter	94.6	0.3	93.9	95.9
Neutral detergent fibre	30.4	6.5	22.7	36.5
Acid detergent fibre	12.3	1.6	9.7	13.7
Crude protein	37.9	3.3	30.6	44.7
Starch	4.2	1.2	2.1	6.4
Crude fat	4.0	0.3	3.7	4.4

Table 2. Mean values, standard error and range of nutrient content of DDGS.

grain source (variety, growing conditions, etc.), which thus directly affect the composition of distiller grain. Furthermore, the variations in nutrient content of wheat distiller grain have not only been reported from plant to plant, but also from batch to batch [6]. The differences among ethanol plants could be substantial according to the method of grain preparation with or without previous de-hulling, the fermentation conditions, drying method, duration and temperature of drying, amount of solubles added back to wet distiller grain and grinding procedure used. All these can potentially contribute to the product variability. The quantity of solubles added to wet distiller grain pre-drying is easily controlled process but it also can potentially create the variability in wheat distiller grain [6]. Solubles are high in fat (up to 34% of dry matter) and low in neutral detergent fibre, therefore, the more solubles are added to wet distiller grain, the higher the fat and the lower the neutral detergent fibre content. The heat damage is another source of variability and it occurs during the drying process. Wheat distiller grains that have undergone high processing temperature will have a reduced protein degradability in ruminants. The heat damage can be easily checked with the colour of distiller grain which varies from light yellow to dark brown. Cozannet et al. [7] measured the luminance values of 10 European wheat distiller grains and it ranged from 43 (black products) to 63 (yellow products) using a Minolta colorimeter. These authors indicated that wheat distiller grain with luminance values <50 was overheated, which will have a high incidence of Maillard reactions.

The amino acid profile of protein is an important nutrition attribute to ruminant animals. We observed that protein of wheat distiller grain had amino acid profiles partly in agreement with that of the initial grain [8]. Li et al. [8] reported that the changes in amino acid profiles from the original grain to its distiller grain did not follow the same trend as changes in the crud protein; proportion of amino acid increased for some, and decreased, or remained unchanged for others. Han and Liu [9] suggested that the amino acid from yeast source during ethanol fermentation would have important influences on amino acid profiles of distiller grain. Yeasts used for starch fermentation represent an additional protein source equivalent to about 5% of the total distiller grain protein content [10]. Theoretically, yeast cannot hydrolyse protein from grain to free amino nitrogen due to the lack of extracellular proteolytic activity [9]. Li et al. [8] discussed that the differences in amino acid composition between the original grain and its distiller grain also depends on the amino acid composition of the yeast used in ethanol fermentation. In fact, it was reported that yeast protein could contribute up to 20% of the protein in distiller grain, and that amino acid profiles of yeast protein were different from those of grain protein [9]. In addition, the level of soluble fractions added into distiller grain is another source influencing the protein content and the amino acid profile. Cozannet et al. [7] reported that although amino acid profile is quite comparable in wheat and wheat distiller grain, lysine and arginine are lower for wheat distiller grain, and the lysine and arginine levels in the crude protein of wheat distiller grain are highly variable, even in light-coloured products: 1.7–3.0% and 3.7–4.6%, respectively.

The considerable variability in chemical composition of wheat distiller grain is one of the main issues challenging in feed formulation for precisely feed livestock animals. Hence, in practice, a determination of nutrient contents of wheat distiller grain from each delivery is recommended if the nutrient profiles are not provided.

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4. Nutrition value of distiller grain

The values of energy and protein are two key nutrient components for a feed ingredient fed to ruminant animal, which ultimately determine whether the nutrient requirement by animal is met. Wheat distiller grain is a good source of energy and protein for ruminants.

4.1. Energy value

Wheat DDGS is commonly used as energy source owing to its highly digestible fibre and moderate level of fat. The energy value of a feed depends primarily on its digestibility in the digestive tract of animal. The digestibility of wheat distiller grain in the rumen of beef cattle was 66.5 and 54.8% for dry matter and neutral detergent fibre, which was lower that of dry matter (82.4%) and fibre (67.9%) of original wheat [11]. The lower ruminal digestibility of distiller grain versus its original grain is due to lack starch in the distiller grain and grain starch is highly fermentable in the rumen. It appears that the digestibility of wheat distiller grain varies between studies [11, 12] which could be due to the variation in chemical composition of distiller grain, animal production level or physiology status, etc.; therefore, the energy value of distiller grain varies from study to study. Beliveau and McKinnon [13] did not find the difference in finishing performance of beef cattle fed diets containing increasing replacement of barley grain with wheat distiller grain up to 23% of the dietary dry matter. These authors concluded that wheat distiller grain had similar value of net energy for maintenance (NEm) and net energy for gain (NEg) to barley grain (i.e. 2.00–2.06 Mcal/kg NEm and 1.34–1.40 Mcal/kg NEg, respectively). However, in the study by Gibb et al. [14], increasing substitution of wheat distiller grain for barley grain from 0, 20, 40 to 60% in diets fed beef cattle linearly increased feed consumption but linearly reduced digestibility of dry matter from 76.4 to 68.9%, as a result, dietary energy content (NEg, MCal/kg) declined linearly from 1.15, 1.14, 1.09 to 1.07, and the NEg of wheat distiller grain decreased from 1.36, 1.27 to 1.21%. Although fibre from wheat distiller grain is considered to be highly digestible [6], the lowered digestibility of diets with increasing levels of distiller grain may have resulted from increased passage rate of feed from the rumen and leave the feeds stay shorter in the rumen, and thus not favourable for fibre digestion [15].

4.2. Protein value

The protein of wheat distiller grain has lower ruminal degradability (49%) than that of wheat grain (79%), and similar to that of corn distiller grain (47%), but it has more desirable amino acid profile as it contains more arginine, lysine, threonine and valine [8]. Li et al. [8] found that the decrease in ruminal degradability of distiller grain protein versus its original grain resulted from the reduced degradation rate. The distiller grain usually has higher rumen undegradable protein compared to the protein from the original grain [12], and consequently, distiller grain has been historically fed to cattle as a rumen undegradable protein source. Highly degradable feed protein is often not favourably received by the ruminant nutritionist since the highly degradable protein is rapidly broken down by the microbial population in the rumen and the released ammonia nitrogen is absorbed through the rumen wall, converted to urea in the liver and excreted in the urine. This metabolic pathway has not only an energy cost but also it presents an environmental issue. The urinary urea nitrogen is rapidly hydrolysed to ammonia upon excretion and can contribute to nitrous oxide emissions. In contrast, ruminal undegradable protein resists fermentation in the rumen and a proportion of the amino acids arising from this protein can be directly absorbed in the small intestine. The rumen undegradable protein of wheat distiller grain could vary substantially and range from 38.3 to 71.7% [6, 8]. The variation in rumen undegradable protein content is primarily caused by differences in heat treatment during the drying of distiller grain. Additionally, the inherent characteristics of the protein fractions within the original grain source [6], and the milling process such as conventional versus fractionation [8] also cause this variation. The effective protein degradability of wheat distiller grain (54%) was found to be similar to that of triticale distiller grain (51%) and higher than that of barley distiller grain (49%) but normally higher than corn distiller grain (47.1%) [8, 16]. Therefore, wheat distiller grain can be used as a good source of degradable and undegradable protein in the rumen [17].

The lower rumen degradability of distiller grain protein versus its original grain appears due to protein molecular changes. Yu et al. [18] reported that the grain had higher ratio of protein amide I to II in the protein structure than its distiller grain produced from bioethanol processing (grain vs. distiller grain; 4.58 vs. 2.84). Protein vibration of amide I and II depends on the protein secondary structure of the backbone and is therefore most commonly used for secondary-structure analysis [19]. It was also reported a positive correlation of protein amide I to amide II ratio with the soluble fraction (r = 0.94) or potentially degradable fraction (r = 0.99), but a negative correlation with the undegradable fraction (r = –0.99) [19]. It suggests that lower protein amide I to amide II ratio was associated with a higher undegradable protein in distiller grain. The ethanol production process during fermentation and drying change grain protein molecular structure, and may affect the protein degradation in the rumen.

Ruminal undegradable protein of wheat distiller grain has a good intestinal digestibility and is one of the best sources of metabolizable protein. However, differences may exist between distiller grain from wheat and corn. Li et al. [8] reported that protein quality (i.e. amino acid profile) of the rumen undegradable protein in wheat distiller grain and corn distiller grain was slightly lower compared with that in the original grains. Nuez-Ortin et al. [12] reported that a wheat and corn blend distiller grain was a better source of truly digested and absorbed protein in the small intestine than wheat distiller grain and corn distiller grain alone. The rumen undegradable protein fraction in corn distiller grain may provide similar amounts of intestinally absorbable total amino acid, but greater absorbable essential amino acid, than the undegradable protein in wheat distiller grain.

5. Feeding distiller grain for beef cattle

Distiller grain from corn grain fermentation is historically fed to dairy cattle mainly as rumen by-pass protein, and rarely used as feed ingredient in beef production because of limited amount of production and higher price compared to other available feed sources. The inclusion of distiller grain in beef cattle diets, especially feeding wheat-based distiller grain in

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Canada has become a common practice only last decade because of increased availability of distiller grain and reduced price along with increased grain cost. Typical beef production in North America includes three different operations: cows and calf production, growing cattle and finishing cattle.

5.1. Distiller grain for beef cows

Cow-calf operations are widespread throughout beef-producing countries, and the goal of a cow-calf operation is to produce young beef cattle, which are usually sold. Typically lower-quality forages high in fibre and low in protein are the basis for the beef cows and replacement heifers operations. Cow-calf operations generally raise their stock primarily on pasture and other forms of roughage rather than grain feeds. The cattle require protein, energy and phosphorus supplementation at this feeding system. Because most forage protein is degraded in the rumen, the wheat distiller grain can be an acceptable supplement in an extending grazing system for beef cows. The nutritive profile of wheat distiller grain makes it attractive in forage-based production setting distiller grain as an excellent source of total digestible nutrient containing digestible fibre and relatively high fat. Distiller grain is also high in crude protein with high rumen by-pass protein. Distiller grain is also a good source of phosphorus (0.6%), a nutrient commonly deficient in forage-based diets. The study using distiller grain in cows and calf operation is lacking. Van De Kerckhove et al. [20] reported that wheat distiller grain was an alternative to barley grain as an energy and protein supplement in a chaff and hay grazing system supplemented with rolled barley, wheat distiller grain fed at levels to meet the requirements of total digestible nutrients by cows. Beef cows require maintenance levels of energy and protein, which increase as the animals get close to calving time. The energy from wheat distiller grain is largely in the form of digestible fibre and fat. Therefore, distiller grain fits well as energy supplement in forage-based diet.

5.2. Distiller grain for growing cattle

The growing step operation is the process of growing cattle at moderate rates of gain with the goal to develop frame and muscle, and to minimize fat deposition. The daily gains target from 0.9 to 1.2 kg, depending on the type of cattle being fed. Cattle are typically fed either in a feedlot or on-farm by providing a forage-based diet supplemented with protein and energy source. It is evident that growing cattle fed under dry lots or on pasture have the potential to use wheat distiller grain as a supplemental source of energy and protein. Beliveau and Mckinnon [13] conducted a growing study using beef steers fed diets with increasing rates of replacement of barley grain with wheat distiller grain from 0, 8, 16, 24 to 32% (dietary dry matter) and observed a linear improvement of feed consumption and growth performance. Similarly, in another study from the same team, McKinnon and Walker [21] observed a linear improvement of average daily gain and feed efficiency with increasing replacement of wheat distiller grain for barley grain. However, other studies [14, 22] did not find evident beneficial effects of including wheat distiller grain in place of barley grain in growing cattle diets. The discrepancy between studies could be due to dietary factors such as levels and quality of forage used in diets, proportion of distiller grain included and its quality.

Growing beef cattle require protein in the form of amino acids to maximize growth rate. One of the most effective and practical methods of improving feed efficiency, growth performance and reducing nitrogen excretion in beef cattle operations is to optimize protein formulation in the diet of growing cattle. Previous works show the necessity of protein supplements to maintain optimum growth rate in growing cattle diets, when these diets are based on barley or corn grain. Wheat distiller grain has not only the similar content of energy for cattle growth because of highly digestible fibre and relative high fat, but also has high protein content either in total or in the form of rumen by-pass. We previously conducted a growing study using beef steers to compare protein source with canola meal, wheat distiller grain, corn distiller grain or fractionated corn distiller grain, and found an improvement of averaged daily gain and feed efficiency over the control group (no protein supplement) [23]. However, steers fed corn distiller grain performed slightly better than that of steers fed wheat distiller grain, likely because of higher fat in corn than wheat distiller grain. McKinnon and Walker [21] reported that growing steers fed wheat distiller grain at 25 or 50% of dietary dry matter gained faster and were more efficient than steers fed a barley grain diet. In contrast, no benefit was reported when wheat distiller grain was fed at level of 17% [24] or at levels up to 40% [14] in growing diets. It appeared that when the level of wheat distiller grain is too high, dietary protein level can be exceeded to the protein requirement by animal. For example, in the study by Gibb et al. [14], including 40% of wheat distiller grain resulted in a dietary crude protein concentration up to 26%, which considerably exceeded the protein requirement of 12–14% for growing cattle. Although protein can be utilised for energy, the transamination, deamination and excretion of excess nitrogen is physiologically costly to the animals and results in an overall loss of net energy.

5.3. Distiller grain for finishing cattle

Following growing period, beef cattle then go into the finishing phase. Rations for finishing beef cattle are high energy rations designed to put gain on as rapidly and efficiently as possible, to lay down adequate marbling, and to maximize carcass yield within a limited time frame. Thus, the finishing diets usually consist of high grain such as barley, corn or wheat at ranging 85–95%, and 5–15% of roughage. The role of roughage in finishing diets primarily serves as fibre source to stimulate chewing activity and to maintain rumen health. Number of studies were attempted to determine the optimum inclusion rate of wheat distiller grain as energy source in finishing diets. In barley grain-based finishing diets, no protein supplement is necessary since the protein requirement is met (12%). Feed consumption was either linearly increased [14, 25], linearly decreased [26] or did not differ [13] with increasing the inclusion rate of wheat distiller grain from 10, 20, 40 to 60%; however, growth performance and feed efficiency were overall not affected with increasing the replacement of grain with wheat distiller grain. These results indicated that wheat distiller grain can be successfully incorporated to substitute a portion of grain within finishing diets with minimal or no adverse impact on cattle growth performance.

The low starch content, but high fibre content of wheat distiller grain is suggested that feeding wheat distiller grain may help reduce the ruminal acidosis and maintain rumen health. It is speculated that a possible reduction in ruminal acidosis by feeding wheat distiller grain may reduce the requirement for roughage in finishing cattle diets [27]. By entirely replacing roughage with wheat distiller grain, we observed that steers maintained a similar ruminal pH status, but reduced feed intake and improved digestibility compared to a diet containing minimum roughage (i.e. 5%) [11]. Apparently, cattle were able to prevent a further decline in ruminal pH status by adjusting feed intake; thus, cattle fed a roughage-free diet consumed less feed to keep a similar ruminal pH status as cattle fed a standard finishing diet. Our results suggested that wheat distiller grain is less effective than barley silage for maintaining ruminal pH even though the rapidly fermented starch content of diets containing wheat distiller grain is less compared with conventional finishing diets. Based on the previous metabolism study, a growth study was conducted using finishing steers fed diets that were replaced partly for barley grain and entirely for roughage with wheat distiller grain so that up to 35% of distiller grain was incorporated in total. The results showed that final live weight, daily gain and feed efficiency were not affected by increasing levels of wheat distiller grain. Therefore, although substitution of wheat distiller grain for roughage in finishing diets may increase the incidence of ruminal acidosis, this outcome does not appear to adversely impact the performance of the cattle. Such a practice could provide an alternative to roughage source to feedlot producers when the roughage is in shortage or provide a potential saving from reducing acres to roughage production.

Carcass traits and beef quality can be significantly impacted by changing diet formulation and quality of feed ingredients. However, several studies showed that the beef quality from cattle fed wheat distiller grain is comparable with that produced using the diets without wheat distiller grain incorporation. Yang et al. [23] reported that feeding wheat distiller grain to replace a portion of barley grain and barley silage in finishing beef cattle rations had overall no impacts on carcass traits. Actually, substituting wheat distiller grain for barley silage in diets fed to growing beef cattle improved meat fatty acid profiles by increasing content of total polyunsaturated fatty acids, linoleic fatty acids and alpha-linolenic acid in beef [28]. These results suggest that replacement of barley silage with wheat distiller grain cause favourable changes in the fatty acid profile of meat such as omega-3 fatty acids in beef. Similarly, Walter et al. [25] included 40% wheat distiller grain in finishing diets and observed no adverse impact on carcass quality or sub-primal boneless boxed beef yields. Animals fed wheat distiller grain included at 20 or 40% produced backfat, yield, ribeye area and marbling scores consistent with barley-finished cattle with no change in meat quality (chemical composition, cooking time, cooking loss, tenderness, drip loss, colour) or differences in sensory tests (taste, smell, sight) [29]. The addition of 20 or 40% of wheat distiller grain to the diet improves the meat fatty acid profiles by decreasing the fatty acid isomers 10*t*-18:1 (unhealthy trans-fat isomer) and increasing the fatty acid isomer 11*t*:18:1 (health promoting isomer) [29, 30].

6. Feeding distiller grain for dairy cows

The co-products from brewing or wet milling corn processing that are similar to the distiller grain from ethanol plant, has been historically fed to dairy cattle as protein supplement, especially as ruminal undegradable protein source. However, with expansion of ethanol production and consequently increasing distiller grain availability, feeding wheat distiller grain to dairy cattle has been spread recently not only as protein source but also as energy or fibre sources [31]. In fact, high-producing dairy cows are often at risk of subacute rumen acidosis, a common digestive disorder usually caused by feeding a diet containing highly fermentable carbohydrates with insufficient effective fibre to maintain rumen health [32]. Because the distiller grain contain low starch which is highly fermentable in the rumen, and high digestible fibre as well as relative high fat, it was suggested that feeding distiller grain in dairy cow diets could be potentially reduce the incidence of rumen acidosis while maintain milk production. Numbers of studies have been conducted to assess wheat distiller grain as a fibre and energy source to partly replace grain, or roughage or both. Penner et al. [33] evaluated wheat distiller grain to include 10% of wheat distiller grain in the ration showed that feeding wheat distiller grain as a forage substitute increased milk yield by 7% and milk protein content by 9%, whereas milk fat content decreased from 3.36 to 3.04% even though milk fat yield was not affected. Zhang et al. [34] reported that feeding wheat distiller grain in partial replacement of barley grain had no negative effect on dairy cow production. Feeding wheat distiller grain as a partial replacement of barley silage can improve dairy cow production, but, it may decrease chewing time, ruminal pH and milk fat concentration [35]. Overall, substitution of wheat distiller grain for part of concentrate or roughage in dairy cow diets improves milk production as a result of increase of feed consumption without negatively impacting milk fat. In contrast, feeding wheat distiller grain to partly replace roughage may reduce milk fat content due to reduction of chewing activity and rumen pH. Thus, dairy producers and nutritionists formulate dairy rations to ensure cow chewing time is sufficient to maintain rumen pH which is linked to maintaining milk fat concentrations [34].

7. Feeding distiller grain for small ruminants

Abundant distiller grain from ethanol production can be used as alternatives to feed grains and other premium ingredients in sheep feeding to reduce feeding costs for sheep farmers. However, most of the studies with feeding wheat distiller grain are with cattle or pigs. With our best knowledge, only one study was conducted using growing lambs fed diets containing wheat distiller grain. O'Hara et al. [36] reported that wheat distiller grain could replace a mixture of barley grain and rapeseed meal at 20% dietary dry matter without negatively affecting feed intake, daily gain and carcass traits of growing lambs. Replacing part of barley grain with 20% of wheat distiller grain in finishing lambs also maintained a healthy rumen function, growth performance and carcass characteristics [36]. McKeown et al. [37] also found that triticale-based distiller grain could replace up to 60% barley grain without adversely affecting on growth performance or carcass traits of lambs. Inclusion of wheat distiller grain in growing or finishing lamb diets is likely a viable feeding management since wheat distiller grain can entirely replace protein supplement to meet protein requirement of growing lambs, and simultaneously used as energy and fibre source because of its high contents of protein, energy and fibre.

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8. Manure management consideration

Ammonia emitted from animal feeding operations is a major air and water pollutant contributing to eutrophication, soil acidity, aerosol formation, and impaired visibility. Although ammonia is not a greenhouse gas, it may indirectly contribute to agricultural emissions of nitrous oxide, a potent greenhouse gas with a global warming potential of approximately 300 times that of CO_2. During last decade, dramatic increase of high-protein by-products feeding in livestock animals as a result of increased production of corn and wheat distiller grain. Consequently, inclusion of the distiller grain in cattle diets as protein and energy source has been becoming a common practice in cattle production because of high nutritional value. With the increased use of high protein distiller grain in cattle diets, the potential for increased manure nitrogen is a concern. For instance, finishing diets that contain 30% wheat distiller grain have more than 20% (dry matter basis) crude protein, compared to the animal's requirement of about 12%. As a result, the excess nitrogen is excreted in manure (feces, urine and bedding) leading to greater NH_3 and N_2O emissions. In feedlot cattle, only a small percentage of the protein consumed by feedlot cattle is retained in animal tissue and as a result 80–90% is excreted in urine and feces, mostly in urine since digestibility of feed protein is relatively high for most types of feeds. Li et al. [38] reported that increased nitrogen intake due to increased distiller grain feeding quantitatively increased nitrogen retention, excretion in feces and urine, whereas, proportionally, nitrogen excretion in urine increased (primarily in the form of urea) and nitrogen excretion in feces decreased. The study clearly identified that urinary nitrogen is the principal source of NH_3-N volatilized from cattle manure during the initial 10 days of storage, accounting for an average of 90% of the emitted NH_3-N. Thus, from an environmental point, it is important to match dietary protein supplies as closely as possible to rumen microbial and animal needs. However, when the distiller grain is included at high proportion as energy source in cattle diets, high nitrogen excretion is not avoidable, a factor that needs to be considered for manure management.

Wheat distiller grain also contains high concentrations of phosphorus and sulphur [11]. The resulting manure from cattle fed wheat distiller grain, with high phosphorus content, can be beneficial for crop production, but it may also have a negative environmental impact due to increased phosphorus accumulation in crop lands surrounding feedlots [39]. Environmental concerns regarding phosphorus excretion are primarily associated with pollution of surface water. Dietary phosphorus intake was positively associated with the amount of phosphorus excreted in livestock manure [40]. Concentration of sulphur in wheat distiller grain was reported to range from 3.9 to 11.4 g/kg in dry matter [6, 11]. The high sulphur in distiller grain is mostly from chemicals added during the ethanol fermentation to control pH and for cleanup. Excreted sulphur can contribute to H_2S emissions from livestock manure [41]. Li et al. [38] reported that increasing substitution of wheat distiller grain for barley grain and barley silage in diets fed to finishing cattle increased urinary phosphorus excretion. Thus, potential environmental implications of liquid runoff from the feedlot surface and potential phosphorus contamination of surface water need to be considered. In addition, the increased intake and urinary excretion of sulphur as a result of increased inclusion of distiller grain in feedlot diets [38] may increase ammonia and H_2S emissions from the feedlot, in particular when combined with increased nitrogen excretion. Therefore, cattle producers that replace grains or forages with distiller grain need to take appropriate steps to develop nutrient management programs in order to minimize nutrient loss to the environment and to maximize use of both nitrogen and phosphorus.

9. Conclusion

Increase of biofuel ethanol production has resulted in an increase of the production of wheat-based distiller grain, and thus increases in the use of distiller grains in the diets of livestock animals. The chemical composition of wheat distiller grain can vary considerably from plant to plant or between batches within plant depending on the type of wheat fermented and technology of fermentation used in ethanol plants. Direct nutrient analysis of each lot of wheat distiller grain is recommended if such information is not provided to ensure accurate ration formulation for precisely feeding ruminant animals. Wheat distiller grain contains higher protein, fibre, fat and minerals but very lower starch than the original grain. Protein quality in wheat distiller grain is high with moderate rumen degradability, and its fibre is highly digestible in the rumen. Therefore, wheat distiller grain can be used as good protein and energy source in ruminant diets. Wheat distiller grain is commonly fed in beef and dairy cattle feeding as either a protein or energy source or both. It is recommended that wheat distiller grain not be included in dairy rations at levels above 20%, whereas they can be fed to 40% of the diet of growing and finishing cattle. Wheat distiller grain can also be used as fibre source to partly replace roughage in cattle diets, whereas its effectiveness of stimulating chewing activity and maintaining rumen pH status is limited. Thus, feeding wheat distiller grain in place of roughage may increase the risk of rumen acidosis especially if it is used to replace all of the forage in beef cattle diets. With the mandatory inclusion of renewable fuels in gasoline, distiller grain is certain to continue to be an important feed source for ruminants. Development of rapid analysis procedures such as near-infrared spectroscopy may allow this ingredient to be formulated into diets with greater accuracy. The wheat distiller grain is high in nitrogen and phosphorus, and high inclusion in cattle diets, especially when it is used as energy source in cattle diets may exceed the protein requirement, thus increase the manure nitrogen excretion, a factor that needs to be considered for manure management.

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