We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

Chapter 25

Use of Corn Dried Distillers Grains (DDGS) in Feeding of Ruminants

Ewa Pecka-Kiełb, Andrzej Zachwieja, Dorota Miśta,
Wojciech Zawadzki and Anna Zielak-Steciwko

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/66357

Abstract

Bioethanol is the product of fermentation of starch contained in renewable resources, such as corn, wheat, rye and rice. Depending on the technology used for its production, dried distillers decoction may exist in different forms: dried distillers grain (DDG); dried distillers grain with solubles (DDGS) and high-protein dried distillers grains (HPDDG), as well as wet distillers grain (WDG), wet distillers grain with solubles (WDGS), and high-protein wet distillers grains HPWDG). Research conducted in recent years has demonstrated the possibilities of corn DDG as feed for livestock due to its high content of valuable protein, high calorific value and bioelements. Distillers grain has been used as feed for beef and dairy cattle, sheep, swine and poultry. In case of ruminants, it is important that distillers grain is foodstuff high in ruminal undegradable protein, with beneficial fibre content that does not cause rumen acidosis. DDGS has positive influence on milk yield and its fat and protein content. Research on rumen fermentation has proven that DDGS positively affecs processes in forestomachs: methanogenesis, ammonia emission and volatile fatty acids profile. Reprocessing of agri-food industry by-products may well be an alternative for traditional methods of feeding animals and utilizing valuable nutrients that they contain.

Keywords: dried distillers grains with solubles (DDGS), corn, ruminants, animal production

1. Introduction

The prospective exhaustion of non-renewable energy sources and the negative influence their burning has on the environment enforces the search for alternative fuels coming from the plant biomass. Nowadays, in an attempt of replacing conventional fuels, bioethanol coming from the plant-based biofuels is used [1]. Bioethanol is obtained from the fermentation of starch contained in renewable material, such as, corn, wheat, rye, rice, and similar things. Its production involves fermentation of raw material and its distillation followed by dehydration. The byproduct of ethanol production is a decoction.

2. Bioethanol production process and types of distillation decoctions

The chemical formula for ethyl ethanol is C_2H_5OH and its calorific value equals 19.6 MJ/L. There exist two technological processes for obtaining ethanol from corn: the wet and the dry ones [2, 3] (**Figure 1**). The processes are alike, but they result in different byproducts. Dry grinding allows for greater volume of bioethanol, but the only other product is the animal feed (WDGS, DDGS). When the wet technology is used, apart from ethanol and animal feed corn oil, corn syrup and gluten are obtained. The production of ethanol requires a two-stage fermentation of starch: the first stage is the decomposition of starch into glucose and maltose, the second stage is yeast fermentation during which disaccharides and monosaccharides are converted into ethanol. The polymeric structure of starch is destroyed by enzymes and temperature. Two enzymes are used in the industrial process. The first one is α-amylase, whose function is to hydrolyze polymers to produce shorter chains (dextrins), which remain in the solution: this is the condensation stage. Then, due to the activity of glucoamylase in the saccharification stage, dextrins convert to simple sugars, glucose and maltose (dimer of α-1–4 glucose) [2]. The obtained solution undergoes yeast fermentation (*Saccharomyces cerevisiae*): one molecule of glucose is converted to two molecules of carbon dioxide. Post fermentation liquid is then distilled and the decoction is separated into the solid and liquid phases with the use of decanters. The liquid phase is then evaporated and condensed into syrup, which is mixed with the solid phase from the decanters. The resulting decoction is centrifuged, dried and finally granulated.

Depending on the technology used for ethanol production, different types of decoctions may be obtained [4]: dried distillers grains (DDG) obtained from distilling ethanol from yeast production; dried distillers grains with soluble (DDGS)—the most widely used—obtained from wet corn residues (DG) mixed with condensed liquid phase in the form of syrup (CDS) and dried; and high-protein dried distillers grains (HPDDG)—bran and germ (rich in fiber and fat) are removed before distillation allowing for the production of dried decoction with high-protein content [5]. Foodstuffs in hydrated form containing dry mass between 5% and 8% (WDG, WDGS, and HPWDG) are cheaper but difficult to transport and to store. That is the reason why dried distillers grain is the most widely used product of this kind [1].

The output of bioethanol depends on the plant used (**Table 1**). Yield per hectare, soil and weather conditions make corn the main resource for ethanol production. According to Food and Agricultural Policy Research Institute [6], in 2021, the production of ethanol will reach 141,28 metric tons in the USA and 7174 in the UE (**Figure 2**).

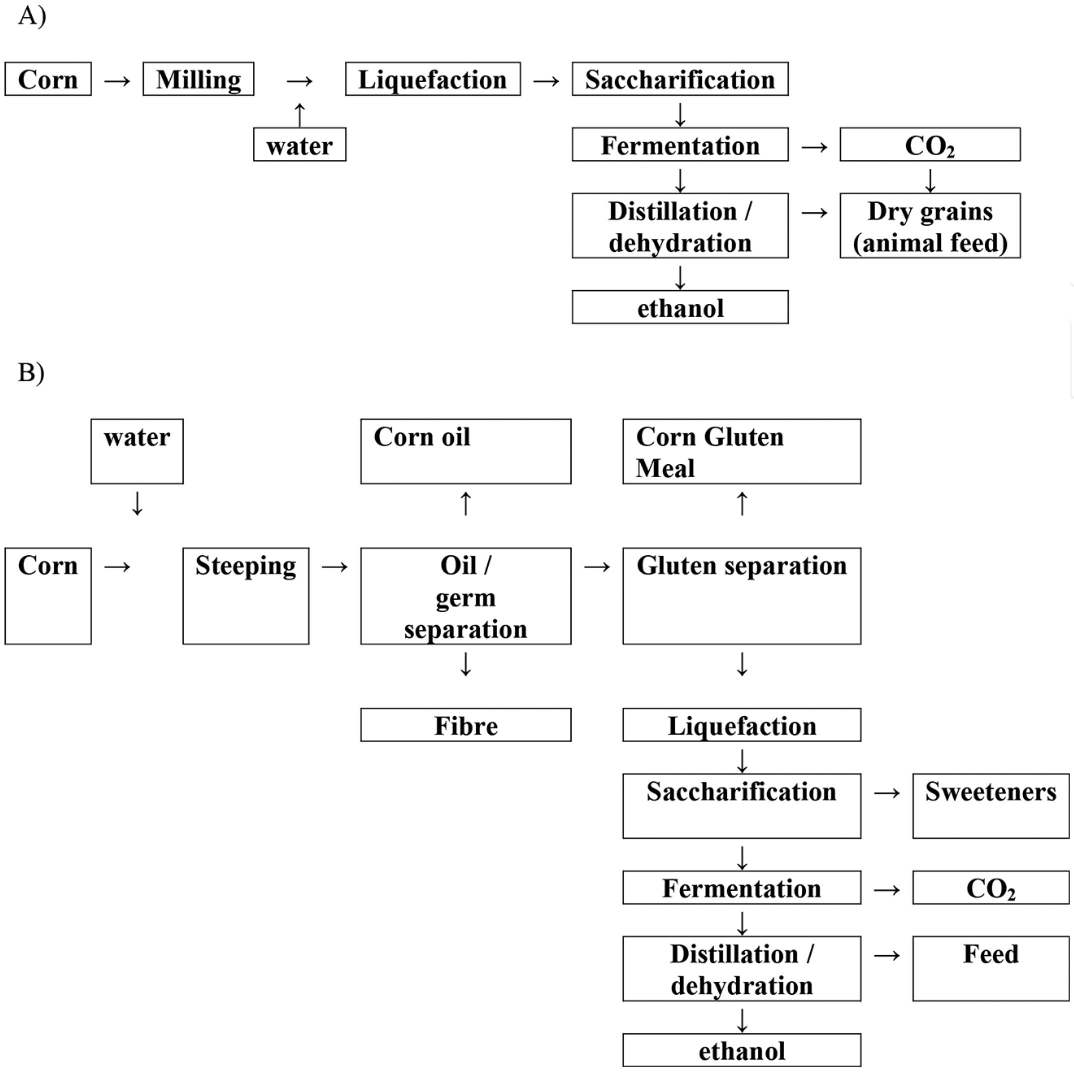

Figure 1. Ethanol production from corn: (A) Dry mill process and (B) wet mill process [3].

Raw material	Production (t/ha)	Yield (l/t)	Yield (l/ha)
Corn	3.0	380	3420
Sugercane	80.0	75	6000
Cassava	20.0	180	1379
Potato	20.0	130	2600

Table 1. Alcohol production rates from different raw materials [7].

According to Lee and Bressan [7], it is possible to produce 308 l of ethanol and 329 kg of DDGS from 1 ton of corn [8]. The numbers suggest that in 2021, the production of DDGS will be 146,784 metric tons in the United States and 7453 metric tons in the EU.

More and more restrictive laws concerning the disposal of biofuel byproducts make it necessary to utilize the decoctions in an alternative way: using them as feed for livestock is a good solution. Additionally, corn dried distillers grain may reduce prices of nutritive fodder used for feeding animals [9]. In July 2006, according to IndexMundi [10], the price of a ton of corn in the USA was $ 119.69, soybean—$ 349.33, oats—$ 161.6, barley—$ 140.19, and DDGS—$ 120.00. Price analysis suggests that replacing 20% of soy would reduce the cost of feed by 13%.

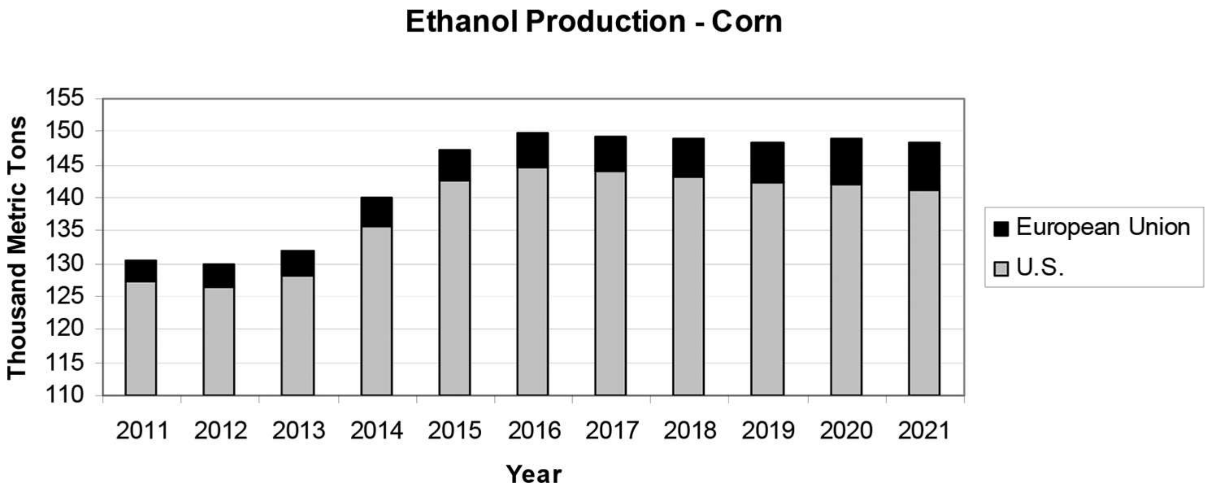

Figure 2. Production of ethanol from corn in the United States and the European Union. Food and Agricultural Policy Research Institute (FAPRI) [6].

3. Nutritional characteristics of DDGS

Corn is one of the most frequently grown agricultural crops in the world and increasingly important not only in food but also in chemical and energy industries. The earliest research into dried distillers grain as possible sources of protein in feeding livestock took place in 1945 [11]. In recent years, the possibility of using dried distillers grains as a feed for farm animals, especially cattle (both beef cattle and dairy cattle), pigs, and poultry, has been demonstrated [12, 13].

Corn dried distillers grain is high-protein feed: on average it contains 28–36% total protein (BO) in dry matter [14] which is characterized by the low rate of decomposition in the rumen, resulting in high content of ungradable fraction (RUP)—from 47% to 63% BO (55% on average) [4]. The presence of dead yeast cells gives the protein better amino acids composition and very good nutritive value.

Because of the high content of insoluble fibre, DDGS has positive influence on digestion and lowers the pH in the digestive system. This results in the reduction of pathogen population and diminishes the occurrence of diarrhoea in young animals. DDGS is also a good source of protein and energy for lactating cows [15].

DDGS has lower level of energy than the soybean meal (by 4%), barley (by 17%), and wheat (by 25%), but higher than the rapeseed meal (20–40%). Energy values for different feeds in swine, poultry, and ruminants are shown in **Table 2** [16]. The tabular content of energy for corn DDGS, except for gross energy (heat of combustion), is lower than in grains. Technological improvements in the ethanol production have made it possible for the net energy of lactation in the decoction to equal the concentration of energy in the grains.

		Wheat	Barley	Maize gluten feed	Wheat DDGS	Extract of soya bean meal
Net energy—pig	MJ/kg	10.61	9.66	6.89	8.00	8.44
Metabolisable energy—poultry	MJ/kg	13.00	11.80	8.2	9.94	10.30
Metabolisable energy—ruminant	MJ/kg	11.90	11.35	11.5	11.2	12.30

Table 2. Wheat DDGS in comparison to other major types of feed [16].

The main source of energy in corn grain is starch, which is almost completely fermented in the process of biofuel production. In DDGS, the main carrier of energy is fat and neutral detergent fibre (NDF). Ether extract constitutes 8.2–11.7% of dry matter, with nonsaturated acids accounting for 80% of fatty acids [14]. Therefore, appropriate introduction of DDGS to feed rations assumes not only the concentration of energy coming from fat but also the improvement of fat composition in milk (enrichment in nonsaturated acids). On the other hand, 5% is the upper limit of fat concentration in the dry mass of feed ratio and it should not be exceeded because of DDGS. Neutral detergent fibre (NDF), which constitutes 40–45% of dry matter, has low content of lignin and easily ferments in the rumen to produce volatile fatty acids. So, DDGS is a foodstuff that does not threaten the rumen acidosis. However, because of large fragmentation of the decoction, it cannot be treated as a source of physically efficient NDF.

The content of amino acids in DDGS is higher than in corn (**Table 3**). It is worth stressing that corn DDGS has the lowest content of lysine, since it is produced from the grain which is poor in this amino acid. Yeast present in the decoction not only improves the composition of amino acids in its protein but also the taste. The ingestion of TMR with DDGS content is usually higher in cows [17]. Nevertheless, it is necessary to balance lysine and methionine, in poultry mainly. The content of protein and fat in DDGS is relatively high, but its composition is slightly different depending on the source (**Table 4**).

Amino acid	Corn	DDGS
Arginine	0.54	1.05
Histidine	0.25	0.70
Isoleucine	0.39	1.52
Leucine	1.12	2.43
Lysine	0.24	0.77
Methionine	0.21	0.54
Phenylalanine	0.49	1.64
Threonine	0.39	1.01
Thryptophan	0.09	0.19
Tyrosine	0.43	0.76
Valine	0.51	1.63

Table 3. Comparison of essential amino acid content (g/100 g of dry matter) in DDGS and corn [17].

Dry matter content (%)	Ash (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	NDF (%)	ADF (%)	Author
91.82	5.01	24.87	8.72	11.2	36.71	11.86	Pecka-Kiełb et al. [18]
88.9	5.8	30.2	8.8	10.9	42.1	16.2	Spiehs et al. [19]
93.3	5.3	24.3	7.5	10.5	Na	Na	Szulc et al. [20]
86.0	3.90	29.1	Na	9.80	Na	Na	Lumpkins et al. [13]
88.5	Na	29.3	Na	9.55	37.3	18.5	Janicek et al. [21]

Na—no data available in the sources.

Table 4. Composition of DDGS.

Corn dried distillers grain is rich in phosphorus (0.43–0.83% of dry matter) and its level depends mostly on the content of condensed syrup (CDS)—the carrier of phosphorus compounds. In our research [22], it has been determined that high producing dairy cows may show symptoms of subclinical hypophosphatemia, which is often accompanied by postpartum paralysis [23]. Very low level of phosphorus in cows' blood serum is probably underrated in diagnosing postpartum paresis (milk fever). For cows, DDGS may be a valuable source of phosphorus in postpartum period preventing hypophosphatemia.

Another element whose concentration in DDGS is visibly higher than in other foodstuffs is sulphur. According to Shurson [24], corn decoction may contain from 0.31% to 1.93% S in dry matter. Its high concentration is partly due to sulphates from sulphuric acid used for cleaning brewery installations. High content of sulphur in DDGS is yet another argument for utilizing it in the postpartum period. The decoction may provide sulphur anion reducing cation-anion balance of feed ration (DCAB), which is recommended for preventing postpartum paralysis. It is essential that feed ratio does not contain more than 0.4% of dry matter (NCR, 2001). Feeding diets with higher concentration of this element may result in disorders of the nervous system, and disturb absorption and metabolism of copper and selenium (the so-called antagonism of elements syndrome)

4. Influence of corn dried distillers grains on health and productivity of animals

Literature abides in research results concerning the addition of wet (WDGS) [25] and dried (DDGS) [26] distillers grains to TMR. Distillers grains is used as a substitute for the postextraction of soy meal, or as an additive to TMR mixture in the ratio of 10% to 20% [25]. According to Janicek et al. [21], this ratio of DDGS in compound feeds for cattle influences the growth of milk yield and the content of fat and protein in it. Powers et al. [26] showed that the use of DDGS and WDGS in feeding high producing dairy cows gives positive result irrespective of the type of decoction, i.e., dried and wet.

The percentage of fat in milk increases slightly in livestock fed TMR with the addition of DDGS and WDGS. However, feeding the wet decoction causes substantial growth of FAT percentage in milk, probably due to access to fibre in WDGS.

Other authors [25, 26] demonstrated that the use of mixtures with dried distillers grains decreases the ratio of n6/n3 fatty acids in milk, which improves its dietary properties.

One of the possible reasons may be the reactions of lipolysis, hydrogenation, and synthesis of fatty acids in the rumen, so their volume depends on the ratio and changes in the profile during fermentation. Analyzing conversions of fatty acids in cow and sheep rumen and their flow to duodenum, Beam et al. [27] and Jenkins [28], assert the amount of fat obtained from the feed. The compositions of DDGS show high levels of nonsaturated fatty acids (**Table 5**), which has a beneficial influence on their profile in the rumen digesta. The level of C18:1n9c and C18:2n6c acids in the rumen digesta in the *in vitro* examination increases with the addition of DDGS. However, the levels of C15:0, C16:0, and C20:0 saturated fatty acids and nonsaturated C14:1 in the rumen digesta during *in vitro* fermentation does not change [29].

Fatty acids	DDGS
C14:0[1]	0.03
C16:0[1]	10.58
C18:0[1]	1.92
C20:0[1]	0.40
C14:1[1]	0.04
C18:1n9c[1]	28.54
C18:2n6c[1]	54.31
C18:3n3[1]	1.16

[1]g/100 g fat

Table 5. Percentage of fatty acids in DDGS [29].

According to Al-Suwaiegh et al. [25] and Anderson et al. [30], the percentage of protein and lactose in milk in cows fed DDGS is similar to those fed WDGS. The growth in milk production and the percentage of casein fraction after the inclusion of DDGS in the feed ration of milking cows in the early stages of lactation have been shown (**Figure 3**) [20].

The use of 10–15% of DDGS dry feed in cows in the postpartum period increases the general protein and immunoglobulin level in colostrum. DDGS has no impact on the content of amino acids in colostrum per 1 g of protein. However, with increased DDGS content in cow diet, some physico-chemical properties of colostrum deterirate (decrease in thermal stability and shortening of coagulation time under the influence of rennet). Yet, despite the deterioration of the values of technological properties, DDGS demonstrates the beneficial use of colostrum components, and in consequence the level of total protein and immunoglobulin in the serum of calves [29].

In sheep, 10–20% of DDGS in the feed does not have negative effect on the production of milk. It slightly lowers the protein, dry matter, and the fat content [31]. In sheep and goats, the use of DDGS may increase the level of PUFA acids in kefir produced from their milk [32]. Available literature does not present research on the influence of DDGS on the composition and quality of goat's milk. It might be the consequence of a small number of these animals as compared to the dairy cows. Studies by other authors show that the DDGS and WDGS have limited usage in optimizing feeding of livestock. Heavy doses are harmful because of the high level of fat, which reduces the digestibility of feed ratios. About 20–25% of DDGS in compound feeds is considered to be safe and optimal for dairy cows, whereas for beef cows it is safe up to 50%.

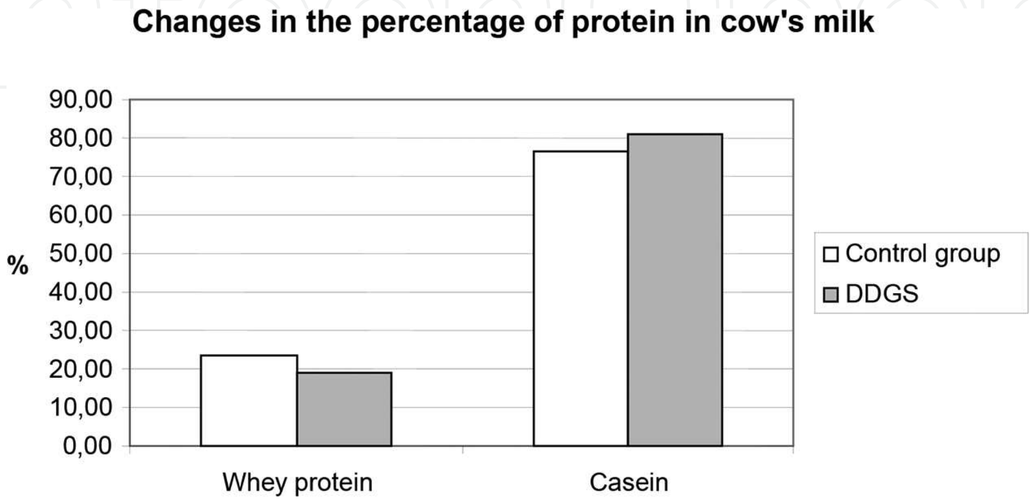

Figure 3. Changes in the percentage of whey protein and casein in cow's milk [20].

In feeding sheep, DDGS has no impact on the condition of animals or milk productivity [33]. About 21.20% of DDGS in dry matter of feed for ewes decreases glucose level in blood and increases the level of insulin. The authors have also confirmed that DDGS is a good source of nutrient for sheep, which has a positive influence on the mass growth of newborn lambs, and has no impact on their mortality [34].

Şahin et al. [35] demonstrated that the inclusion of DDGS in the diet of 3-month-old lambs did not have negative impact on their growth, forage consumption or rumen parameters. According to the authors, only when DDGS constitute 20% of forage, it can be considered as a good source of protein in lambs' diet, as digestibility is considerably lower when DDGS constitutes 10% of the feed. Schauer et al. [36] asserted that 60% inclusion of DDGS in the diet does not show considerable impact on the productivity in growing slaughter lambs (**Table 6**). In goats, however, DDGS may completely replace the soybean meal and up to 31% of corn in addition to the dry matter of the diet. Also, other authors did not observe negative influence of DDGS on productivity in slaughter animals, carcass components, or fatty acids profile in sheep meat [37]. Literature of the subject does not contain research on the influence of DDGS on the quality of goat meat. As in the case of goat's milk, it may be linked with small number of animals and insignificant influence of goat meat on the world economy.

In beef cows, 35% content of DDGS in feed ration results in the growth of PUFA and CLA acids in meat [38]. Other authors asserted that 25% content of dried distillers grain does not harm the quality of meat (**Table 7**) [39].

Recent research has demonstrated the impact of DDGS on fermentation in the rumen. It increases the pH amplitude of ruminal fluid and extends the time in which the pH falls below 5.8 [15], and the concentration of acetate and its proportions to propionate decrease [40]. Corn dried distillers grain results in linear decrease of methane production in the rumen of cows in proportion to the growth in DDGS contents in the diet *in vivo* [41] as well as *in vitro* [42].

	Treatment[1]		
Item	**Control**	**20%**	**60%**
Initial weight (lbs)	68.00	70.00	70.00
Final weight (lbs)	132.00	137.00	137.00
ADG (lbs/day)	0.58	0.62	0.62
Intake (lbs/hd/d)	3.69	3.91	4.20
Mortality	0.75	0.25	0.00
Leg score	10.30	10.50	10.50
Conformation score	10.30	10.30	10.50
Fat depth (in)	0.29	0.32	0.32
Quality grade	10.30	10.80	11.00
Yield grade	3.26	3.57	3.55

[1]Control = 0% replacement of barley with dried distillers grains; 20% = 20% dried distillers grains in ration replacing barley; 60% = 60% dried distillers grains in ration replacing barley.

Table 6. The influence of dried distillers grains on feedlot lamb [36].

Item	**Control**	**25% DDGS**
Initial BW- Body Weight (kg)	379	377
Final BW- Body Weight (kg)	494	485
ADG (kg/day)	9.01	8.52
Yield grade	2.62	2.74

Table 7. The influence of corn dried distillers grains on feedlot beef cattle [39].

In sheep, a 3% decrease in the production of methane in the group fed 30% of DDGS is observed. This decrease in the rumen fermentation is considered good for animals. The emission of methane is a waste of energy, which may result in drop in milk productivity of ruminants [18, 43]. In cows, the growing proportion of DDGS in the substrate in the *in vitro* study causes a significantly reduced ammonia production in the rumen digesta; after 24 hours of fermentation, the amount of ammonia is more than five times lower with DDGS (22.4 mmol/l) in comparison to control, where TMR was the substrate (124.6 mmol/l). The i*n vitro* studies showed that the use of DDGS reduced the acetate and propionate levels in lambs [44]. In sheep and cows, the contents of DDGS in forage reduce the production of acetate in the rumen and increases the ratio of propionate [18, 42].

In the *in vivo* conditions, DDGS does not change SCFA concentration in the ruminal fluid of cows, but it lowers the content of acetate in SCFA in groups of animals fed DDGS (57.4 mol% in the group of 10% DDGS in dry matter ration, 53.1 in 15% DDGS in dry matter ration, and 63.5 in 30% DDGS in dry matter ration) as compared to control group where traditional TMR (65.7 mol%) was used. DDGS increases the levels of propionate. The SCFA utilization factor expressed as the ratio of nonglycogenic to glycogenic SCFA acids (that is NGR) decreases in animals fed DDGS [45].

The obtained results show beneficial impact of DDGS on the content of the most important volatile acids in the rumen digesta. The use of DDGS as a substrate in the *in vitro* fermentation of the rumen digesta in cows as well as sheep changed the levels of butyric and isovaleric acids: their levels were decreasing with the augmented ration of DDGS

The consequence of the drop in production of isoacids reduced the decomposition of protein in the rumen, which is desirable in this group of animals [18, 42].

Research results suggest the possibility of using corn dried distillers grain as an addition or a substitute for other compound feeds in feeding lactating dairy cows. In recent years, studies of corn DDGS in feed rations for cows in the dry period showed that it may be included in TMR in this phase of the production cycle. The dry period is connected with the significant physiological, metabolic, and nutritional changes. Feeding cows determine possible problems in the postpartum period, define their metabolic status, and in consequence their health condition, fertility, value of functional traits, which affect the efficiency of milk production. Proper inclusion of DDGS in the feed ration allows for the assumption that not only the concentration of energy from fat, but also the improvement of milk composition (it will be richer in non-saturated fats). DDGS does not threaten the incidence of rumen acidosis. It may be an important source of phosphorus for cows in postpartum period and its use may prevent hypophosphatemia. High content of sulphur in DDGS is yet another argument for its use around the calving period. The decoction is an important source of sulphur anion which diminishes the cation-anion balance of the feed ration (DCAD). When DDGS was used in the last three weeks before calving as 10%, 15%, and 20% of the dry matter of feed ration, respectively, the experiment results showed a drop of DCAD of the feed ration from 189 (TMR without the addition of DDGS) to 10 mEq/kg when 20% of DDGS was used [29].

When 10% DDGS is used, in cows immediately after calving, the level of liver enzyme aspartate aminotransferase type (AST) grows and the level of triglycerides drops, which suggests the development of subclinical ketosis. However, the 15–20% DDGS content does not increase ketogenesis or alkalosis. Large doses of 20% DDGS cause excessive increase of AST activity after calving. Feeding 20% DDGS to cows in the postpartum period favourably influences the content of Ca and P in the serum after calving, and physiological hypocalcaemia is not observed in this period. The decrease of the total protein and G type immunoglobulins in the blood of cows receiving larger amounts of DDGS in their feed rations simultaneously causes

http://dx.doi.org/10.5772/66357

a slight decrease in the level of albumins. It may indicate the possibility of more intense transmission of immunoglobulins to mammary gland before calving [29].

The results of the study in their overwhelming majority confirm the possibility of safe and efficient inclusion of DDGS in nutritional programme of ruminants, but—as in the case of all types of feed—standard precautions are necessary. Changeable/varying content of particular nutritional components, physical and chemical properties connected with the method of fermentation in the production of bioethanol or storing of the decoction may pose problems.

The process of drying DDGS is of significant importance for the production of DDGS—too fast and in too high temperature causes negative changes in protein: denaturation of protein takes place and products of Maillard's reaction are created, which results in the growth of nitrogen insoluble in acidic detergent (ADIN), indigestible fraction of the total protein [24]. In the studies by Cromwell et al. (1993) [46], the percentage of ADIN in total nitrogen of DDGS is between 8.8% and 36.9%. It shows that with inappropriate drying of the decoction, almost 40% of the total protein may have no nutritional value. Colour is a good marker of a correct/accurate drying process of DDGS—good quality decoction should be light orange in colour.

Another problem encountered when using DDGS is a big variability in the molecular size. American studies determined that the average size of decoction molecules is 1282 μm and the range was from 612 to 2125 μm. Such large differences in the molecular size cause spontaneous stratification of DDGS components during the transport and storage of the feedstuff. The smallest precipitated fraction has strong caking properties and may result in dangerous suspension of hard mass in storing silos. Additional factors enlarging the problem is high temperature (summer period), increased water content (secondary moisture), and fat concentration [24].

Distillers grains may also be a source of mycotoxin. If bioethanol is produced from low-quality mould-infected grain, it may pose great threat to animal health and determine the quality of animal products. The concentration of mycotoxins in DDGS is on average three times higher than in the mould-infected grain from which it comes. In Austrian research [19], where 89 samples of DDGS (70% from the USA, 30% from Asia) were tested, it was shown that the biggest/most serious problem was the presence of zearalenone (ZON), B1 and B2fumonisins (FUM), and deoxynivalenol (DON). Mycotoxins were discovered in 91, 85, and 57% of samples. Aflatoxin B1 (AFB1) and T-2 toxins were smaller threats. Their highest mean and maximum levels of concentration were observed for DON (1405 and 12000 g/kg) and FUM (935 and over g/kg). It was also demonstrated that only 1% of samples were free from any mycotoxins. Because of the confirmed threat of toxic compounds, it is recommended that every batch of DDGS reaching farmsteads is examined in reference laboratories (with the use of chromatographic techniques) for the presence of mycotoxins.

One of the great advantages of DDGS is the possibility of storing it even for a year; WDGS may be stored for 3–7 days. However, there may be difficulties in balancing the diet combining different components of the feed rations with distillers grains [37]. DDGS contains relatively large amounts of elements such as sulphur, phosphorus, and nitrogen, which enter the environment as a consequence of excretion process. High content of phosphorus in the organisms of ruminants may lead to disturbances in phosphate-calcium balance between phosphate and calcium [33, 45, 47]. Because of the need to balance DDGS as a feed additive containing different proportions of nutrients, every batch of DDGS requires standard chemical analyses performed on all compound feeds by the manufacturers [37, 45]. **Figure 4** shows the recommended chemical analyses of distillers grains [2].

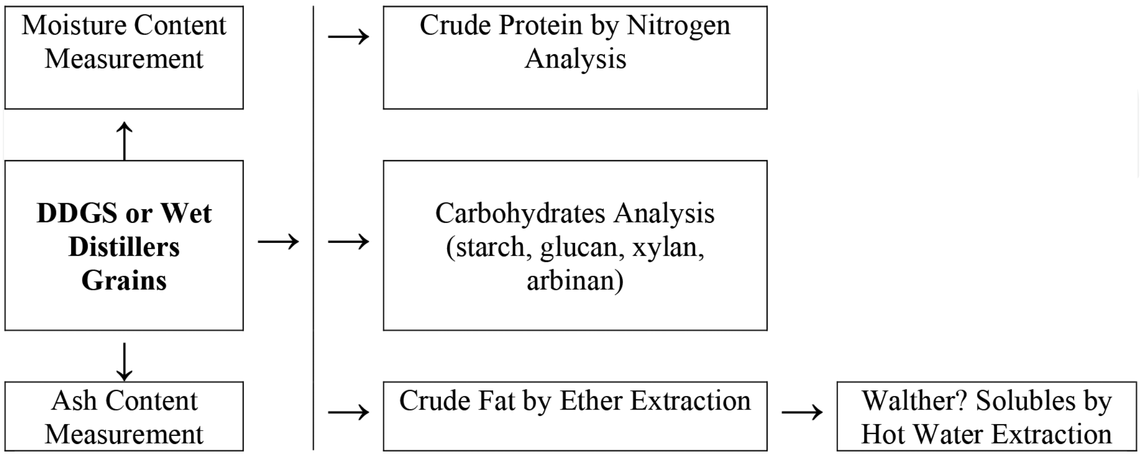

Figure 4. Diagram of biomass analysis [2].

5. Conclusions

Existing research results suggest the effective use of dry and wet distillers grains in livestock nutrition and especially the inclusion of corn dried distillers grains (DDGS) in feed rations for cows, sheep, swine, poultry, and even rabbits. Reprocessing the byproducts of agriculture and food industry is likely an alternative for traditional nutrition of animals. It is also a good way of utilizing the valuable nutrients that these byproducts contain. Compared to other feeds, DDGS is cheaper but its use poses problems, as it is a changeable composition, which requires technological procedures to standardize it.

The growing demand for renewable sources of energy will parallel the supply of biofuels, whose byproducts are the alternative feed materials, rich in energy and protein. The production of corn dried distillers grains (DDGS) acquired in the process of bioethanol making is relatively large and it may lead to problems utilizing it without negative impact on the environment. One of the eco-friendly alternatives for using dried distillers grains is feeding the livestock. Corn DDGS is particularly a valuable feed for dairy cows in the postpartum period, when its use prevents the postpartum paralysis (it is a good source of phosphorus and sulphur), diminishes the negative balance of energy (large fat content) and the threat of rumen acidosis (favourable composition fibre fraction NDF), as well as improves the feed intake (yeast content). The decoction may partly substitute the soybean meal in feed rations for high producing lactating cows. Optimum addition of DDGS for dairy cows is 10–15% of dry matter in the feed ration. One of the beneficial effects of DDGS as a component in feed rations is the decrease in methane production. Another one may be lowering the costs of feed for animals as it is relatively cheap. Propagation of DDGS reprocessing as animal feed will significantly reduce potential threats for the environment.

Author details

Ewa Pecka-Kiełb[1*], Andrzej Zachwieja[2], Dorota Miśta[1], Wojciech Zawadzki[1] and Anna Zielak-Steciwko[1]

*Address all correspondence to: ewa.pecka@up.wroc.pl

1 Department of Biostructure and Animal Physiology, Wroclaw University of Environmental Life Sciences, Wroclaw, Poland

2 Department of Cattle Breeding and Milk Production, Wroclaw University of Environmental Life Sciences, Wrocław, Poland

References

[1] Zachwieja A, Kupczyński R, Bodarski R, Paczyńska K, Miśta D, Pecka E, Zawadzki W, Tumanowicz J, Adamski M. An influence of dried distillers grains with soluble (DDGS) application on dietary cation-anion balance, changes in rumen fermentation profile, metabolic profile of cows and physico-chemical features of colostrums. Przemysł Chemiczny. 2013;**92**:1050–1055.

[2] Kim Y, Mosier NS, Hendrickson R, Ezeji T, Blaschek H, Dien B, Cotta M, Dale B, Ladisch MR. Composition of corn dry-grind ethanol by-products: DDGS, wet cake, and thin stillage. Bioresource Technology. 2008;**99**:5165–5176. Doi: 10.1016/j.biortech.2007.09.028.

[3] Piscina PR, Homs N. Use of biofuels to produce hydrogen (reformation processes). Chemical Society Reviews. 2008;**37**:2459–2467 DOI: 10.1039/B712181B.

[4] Schingoethe DJ. Utilization of DDGS by cattle. In: Proceedings of 27th Western Nutrition Conference; 19–20 September 2006; Winnipeg, Manitoba, Canada. 2006; pp. 61–74.

[5] Hubbard KJ, Kononoff PJ, Geham AM, Kelzer JM, Karges K, Gibson ML. The effect of feeding high-protein distillers dried grains on milk production of Holstein cows. Journal of Diary Sciences. 2009;**92**:2911–2914. DOI: 10.3168/jds.2008-1955

[6] Food and Agricultural Policy Research Institute (FAPRI) [Internet]. 20v12. Available from: http://www.fapri.iastate.edu/outlook/2012/[Accessed: 2016-08-10].

[7] Lee TSG, Bressan EA. The potential of ethanol production from sugarcane in Brazil. Sugar Tech. 2006;**8**:195–198. DOI: 10.1007/bf02943556

[8] Świątkiewicz M, Hanczakowska E, Olszewska A. Distiller's dried grains with solubles (DDGS) in swine nutrition. Zootechnic news. 2014;4:141–153.

[9] Gurung NK, Solaiman SG, Rankins DL, McElhenney WH. Effects of distillers dried grains with solubles on feed intake, growth performance, gain efficiency and carcass quality of growing Kiko x Spanish male goats. Journal of Animal and Veterinary Advances. 2009;**8**:2087–2093. DOI: javaa.2009.2087.2093

[10] IndexMundi, Commodity Prices [Internet]. 2006. Available from: http://www.indexmundi.com/[Accessed: 2016-08-14].

[11] Hughes CW, Hauge SM. Nutritive value of distillers' dried solubles as a source of protein. Journal of Nutrition. 1945;**30**:245–258.

[12] Liu K. Particle size distribution of distillers dried grains with solubles (DDGS) and relationships to compositional and color properties. Bioresource Technology. 2008;**99**:8421–8428. DOI: 10.1016/j.biortech.2008.02.060.

[13] Lumpkins BS, Batal AB, Dale NM. Evaluation of distillers dried grains with solubles as a feed ingredient for broilers. Poultry Science. 2004;**83**:1891–1896.

[14] Schingoethe DJ, Kalscheur KF, Garcia AD. Distillers grains for dairy cattle. South Dakota State University Cooperative Extension Service [Internet]. 2002. Available from: http://pubstorage.sdstate.edu/AgBio_Publications/articles/ExEx4022.pdf[Accessed: 2016-08-03]

[15] Zhang SZ, Penner GB, Yang WZ, Oba M. Effects of partially replacing barley silage or barley grain with dried distillers grains with solubles on rumen fermentation and milk production of lactating dairy cows. Journal of Diary Sciences. 2010;**93**:3231–3242. DOI: 10.3168/jds.2009-3005.

[16] Hazzledine M, Pine A, Mackinson I, Ratcliffe J, Salmon L. Estimating displacement ratios of wheat DDGS in animal feed rations in Great Britain. A report commissioned by the International Council on Clean Transportation. Working Paper 2011–8. [Internet]. 2011. Available from: http://www.fapri.iastate.edu/outlook/2012/[Accessed: 2016-08-10]

[17] Belyea RL, Rausch KD, Tumbleson ME. Composition of corn and distillers dried grains with solubles from dry grind ethanol processing. Bioresource Technology. 2004;**94**:293–298. DOI: doi.org/10.1016/j.biortech.2004.01.001.

[18] Pecka-Kiełb E, Zawadzki W, Zachwieja A, Michel O, Mazur M, Miśta D. In vitro study of the effect of corn dried distillers grains with solubles on rumen fermentation in sheep. Polish Journal of Veterinary Sciences. 2015;**18**:751–758. DOI: 10.1515/pjvs-2015-0097.

[19] Spiehs MJ, Whitney MH, Shurson GC. Nutrient database for distillers' dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. Journal of Animal Science. 2002;**80**:2639–2645.

[20] Szulc T, Zachwieja A, Demkowicz M, Newlacil I, Pecka E. The efficiency of the replacement of protein meal by DDGS—dried distiller grains with solubles in the ration for dairy cows during early lactation. Electronic Journal of Polish Agricultural Universities. Series Animal Husbandry. 2011;**14**(2):03. http://www.ejpau.media.pl/volume14/issue2/art-03.html

[21] Janicek BN, Kononoff PJ, German AM, Doane PH. The effect of feeding dried distillers grains plus solubles on milk production and excretion of urinary purine derivatives. Journal of Diary Sciences. 2008;**91**:3544–3553. DOI: 10.3168/jds.2007-0777.

[22] Bodarski R., Kinal S., Preś J., Krzywiecki S., Słupczyńska M., Twardoń J., Mordak R. Potassium, calcium and magnesium salts indispensable In kation-anion balance regulation of Leeds and mixed rations.[Sole potasu, wapnia i magnezu niezbędne w regulacji bilansów kationowo-anionowych pasz i dawek TMR]. Przemysł Chemiczny. 2010; 89: 939–944..

[23] Preś J, Mordak R, editors. Wybrane elementy żywienia a problemy zdrowotne krów mlecznych, 1st ed., MedPharm, Wrocław; 2010:222p.

[24] Shurson J. Quality characteristics and nutritional profiles of DDGS [Internet]. 2006. Available from: http://www.biofuelscoproducts.umn.edu/sites/biodieselfeeds.cfans.umn.edu/files/cfans_asset_414236.pdf[Accessed: 2016-08-03]

[25] Anderson JL, Schingoethe DJ, Kalscheur KF, Hippen AR. Evaluation of dried and wet destillers grains included at two concentrations in the diets of lactating dairy cows. Journal of Diary Sciences. 2006;**89**:3133–3142. DOI: 10.3168/jds.S0022-0302(06)72587-5

[26] Powers WJ, Vanv Horn HH, Harris B Jr, Wilcox CJ. Effects of variable sources of distiller dried grains plus solubles on milk yield and composition. Journal of Diary Sciences. 1995;**8**:388–396. DOI: 10.3168/jds.S0022-0302(95)76647-4.

[27] Beam TM, Jenkins TC, Moate PJ, Kohn RA, Palmquist RA. Effects of amount and source of fats on the rates of lipolysis and biohydrogenation of fatty acids in ruminal contents. Journal of Diary Sciences. 2000;**83**:2564–2573. DOI: 10.3168/jds.S0022-0302(00)75149-6.

[28] Jenkins TC. Lipid metabolism in the rumen. Journal of Diary Sciences. 1993;**76**:3851–3863. DOI: 10.3168/jds.S0022-0302(93)77727-9.

[29] Zachwieja A, Bodarski R, Kupczyński R, Zawadzki W, Miśta D, Adamski M, Pecka E, Paczyńska K, Tumanowicz J. The impact of dried corn decoction on the balance of cationic-anionic feed ration in the dry period of dairy cows, thier health status, colostrum quality and calves passive immunity. Research report 2014. NN311537540, 1–105.

[30] Al-Suwaiegh S, Fanning KC, Grant RJ, Milton CT, Klopfenstein TJ. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. Journal of Diary Sciences. 2002;**80**:1105–1111.

[31] Wertz-Lutz A, Zelinsky R, Held J. Effects of increasing the energy density of a lactating ewe diet by replacing grass hay with soybean hulls and dried distillers grains with solubles. Animal Science Field Day Proceedings and Research Reports. 2007. Available from: http://openprairie.sdstate.edu/cgi/viewcontent.cgi?article=1004&context=sd_sheepreport_2006[Accessed: 2016-08-10]

[32] Cais-Sokolińska D, Wójtowski J, Pikul J, Danków R, Majcher M, Teichert J, Bagnicka E. 2015. Formation of volatile compounds in kefir made of goat and sheep milk with high polyunsaturated fatty acid content. Journal of Diary Sciences. 2015;**98**:6692–6705. DOI: 10.3168/jds.2015-9441.

[33] Dimova N, Ivanova I, Mihailova M, Todorov N, Naydenova N. Wheat distiller's grains as a source of protein in dairy sheep. Bulgarian Journal of Agricultural Science. 2009;**15**:574–582.

[34] Radunz AE, Fluharty FL, Zerby HN, Loerch SC. Winter-feeding systems for gestating sheep I. Effects on pre- and postpartum ewe performance and lamb progeny preweaning performance. Journal of Animal Science. 2011;**89**:467–477. DOI: 10.2527/jas.2010-3035.

[35] Şahin T, Kaya Ö, Aksu Elmali D, Kaya İ. Effects of dietary supplementation with distiller dried grain with solubles in growing lambs on growth, nutrient digestibility and rumen parameters. Revue de Médecine Vétérinaire. 2013;**164**:173–178.

[36] Schauer CS, Stamm MM, Maddock TD, Berg PB. Feeding of DDGS in lamb rations. Feeding dried distillers grains with solubles as 60 percent of lamb finishing rations results in acceptable performance and carcass quality. Sheep and Goat Research Journal. 2008;**23**:15–19.

[37] Pezzanite L, Gunn P, Neary M, Lemenager R, Lake S. Value of distiller's grains as a feed for sheep. Purdue University Cooperative Extension Service [Internet]. 2010. Available from: https://www.extension.purdue.edu/extmedia/AS/AS-603-W.pdf/[Accessed: 2016-08-14]

[38] Łozicki A, Dymnicka M, Arkuszewska E. Evaluation of selected parameters of quality and nutritive value of meat of fattened bulls fed diet with distillers dried grains with solubles (DDGS) from wheat or maize as a source of protein. Polish Journal of Food and Nutrition Sciences. 2013;**63**:179–186. DOI: 10.2478/v10222-012-0075-3.

[39] May ML, Quinn MJ, Depenbusch BE, Reinhardt CD, Gibson ML, Karges KK, Cole NA, Drouillard JS. Dried distillers grains with solubles with reduced corn silage levels in beef finishing diets. Journal of Animal Science. 2010;**88**:2456–2463. DOI: 10.2527/jas.2009-2637

[40] Kelzer JM, Kononoff PJ, Gehman AM, Tedeschi LO, Karges K, Gibson ML. Effects of feeding three types of corn-milling coproducts on milk production and ruminal fermentation of lactating Holstein cattle. Journal of Diary Sciences. 2009;**92**:5120–5132. DOI: 10.3168/jds.2009-2208

[41] Benchaar C, Hassanat F, Gervais R, Chouinard PY, Julien C, Petit HV, Massé DI. Effects of increasing amounts of corn dried distillers grains with solubles in dairy cow diets on methane production, ruminal fermentation, digestion, N balance, and milk production. Journal of Diary Sciences. 2013;**96**:2413–2427. DOI: 10.3168/jds.2012-6037.

[42] Miśta D, Pecka E, Zachwieja A, Zawadzki W, Bodarski R, Paczyńska K, Tumanowicz J, Kupczyński R, Adamski M. Effect of corn dried distillers' grains with solubles used as replacement of concentrate components on *in vitro* ruminal fluid fermentation. Folia Biologica (Krakow). 2014;**62**:345–351. Doi: 10.3409/fb62_4.345.

[43] Patra AK. The effect of dietary fats on methane emissions, and its other effects on digestibility, rumen fermentation and lactation performance in cattle: a meta-analysis. Livestock Science. 2013;**155**:244–254. DOI: 10.1016/j.livsci.2013.05.023.

[44] Behlke EJ. Attenuation of ruminal methanogenesis [thesis]. University of Nebraska-Lincoln, USA; 2007.

[45] Wysocka O, Pecka E, Zawadzki W. The potential of using corn dried distillers grains with solubles (DDGS) in order to improve the fermentation profile in sheep. Folia Pomeranae Universitatis Technoligiae Stetinensis. 2015;**35**:109–120.

[46] Cromwell GL, Herkelman KL, Stahly TS. Physical, chemical and nutritional characteristics of distillers dried grains with solubles for chicken and pigs. Journal of Animal Science. 1993;**71**:679–686.

[47] Strzetelski J. New energy-protein by-products of agri-food industry in cattle feeding. Bulletin of Polish Association of Feed Manufacturers, Warsaw, 2007

IntechOpen