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Corn distillers grain

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Common names

Corn distillers grain

- Spent grains, wet distillers grains, wet distillers grain, distillers wet grains, WDG
- Dried distillers grains, distillers dried grains, distillers dried grain, dried distillers grain, DDG
- Wet distillers grains with solubles, wet distillers grain with solubles, distillers wet grains with solubles, WDGS, DWGS
- Dried distillers grains with solubles, distillers dried grains with solubles, distillers dried grain with solubles, dried distillers grain with solubles, DDGS
- Condensed distillers solubles (CDS), dried distillers solubles (DDS)

Distillers can also be written *Distillers'* and *Distiller's*.

Species

Zea mays L. [Poaceae]

Feed categories

- Cereal grains and by-products
- Plant products and by-products

Related feed(s)

- Corn gluten meal
- Corn gluten feed
- Barley distillery by-products
- Wheat distillers grain
- Maize grain

Description

Corn distillers grain is the main by-product of the distillation of alcohol from maize grain. Distilleries produce alcoholic beverages, industrial ethanol and ethanol biofuel with the following by-products (definitions are given in **Processes**):

- **Spent grains, wet grains, wet distillers grain** (WDG), **wet distillers grain with solubles** (WDGS)
- **Dried distillers grain** (DDG), **dried distillers grain with solubles** (DDGS)
- **Condensed distillers solubles** (CDS), **dried distillers solubles** (DDS)

There are two main distillery processes: dry-milling distillery and wet-milling distillery. The dry-milling (or dry-grind) process is the main process for producing ethanol. This process starts with removing the bran by grinding before steeping the grain in water and results in ethanol and various "distillers" by-products. The wet-milling process starts with steeping the grains and then separates the kernel into various fractions, which allows for the production of multiple food and industrial products, including starch, fructose, oil and ethanol. This process yields numerous by-products including maize gluten meal, maize gluten feed and maize germ meal (USGC, 2012).

While official and trade definitions exist for the different maize distillery by-products, the boundaries between these products may be somewhat fuzzy. Particularly, the amount of solubles blended back to the distillers grain to create DDGS can be variable. In fact, many research studies do not designate whether the product used was with or without solubles, and virtually all corn distillers grain available are DDGS, so the practical distinction between corn distillers grain with or without solubles is rarely useful (Schingoethe, 2006).

This datasheet will deal primarily with the DDGS of maize-based, dry-milling ethanol production, which are now the dominant distillery by-product. The changes in this industry have been tremendous. In the USA, distilleries produced in 1992 two million tons of corn distillers grain, with 40% from the production of alcoholic beverages and 60% from biofuel production. In 2010, the USA were the main world producer of maize-based ethanol biofuel and American maize distilleries yielded more than 34 million tons of corn distillers grain. Biofuel production accounted for 97% of the corn distillers grain produced in the USA. Projections for US corn distillers grain are about 38.6 million tons by 2020 (Hoffman et al., 2010). The situation is different in Europe and Canada, where wheat is the main cereal grain used for biofuel production, followed by maize, rye, sorghum and grain mixtures (Piron et al., 2009).

Distillery by-products have a long and rich history in animal feeding. They used to be considered offals and were dumped in sewers and rivers. Spent grains were sold a low price to local farmers as animal feed (Lyons, 2003). Corn distillers grain only became an important by-product in the middle of the 19th century in the UK, when the Coffey-patent still (continuous distillation column) replaced pot stills, allowing the use of maize in grain whisky production, partly replacing barley (Weir, 1984). In New York in the 1850s, the large-scale feeding of dairy cows with distillery mash in unsanitary conditions resulted in the "swill milk" scandal, a major food scare that led to better regulations of the dairy industry (Wilson, 2008). The first study about feeding distillers grains to cattle was published in 1907 (Weiss et al., 2007).

Corn distillers grains are valuable feed ingredients, rich in protein, moderately rich in fat and relatively poor in fibre, and can be fed to all classes of livestock (Hayes, 2008). It should be noted that, as of 2012, maize ethanol by-products are not only relatively recent but are still evolving due to changing technologies and demand in biofuel.

Distribution

Wet corn distillers grain is mainly found in the vicinity of ethanol plants. In the USA, it was estimated that 86% of the corn distillers grains are transported by road within 80 km from the ethanol plant (US EPA, 2010).

Distillers dried grain is a commodity. In 2008, the USA exported 4.5 million tons (81%) of the brewery and distillery by-products traded worldwide. The other main exporters were China, Canada, Germany and Poland. The main importers of brewery and distillery by-products were Mexico, Canada, Turkey, South Korea and Japan (FAO, 2011).

Processes

Ethanol manufacturing process (dry milling)

The ethanol manufacturing process starts by the cleaning and then the dry-milling of maize grains. The ground grains are mixed with water and enzymes (amylases) to produce a mash where starch hydrolysis occurs (liquefaction step). This mash is cooked to kill the bacteria that produce undesirable lactic acid. Enzymes are added to the mash to transform starch into dextrose (saccharification step). After saccharification, yeast is added to start the fermentation process, which produces a "beer" and CO_2. The beer passes through a continuous distillation column to yield alcohol at the top of the column.

The product that remains at the bottom (**whole stillage**) is centrifuged and yields **wet grains** (also called **spent grains**) and **thin stillage**. Wet grains may be fed to livestock directly or they can be dried to produce **dried distillers grain** (**DDG**). Thin stillage can be sold as high-moisture feed or it can be dehydrated to produce **condensed distillers solubles** (CDS, also called **syrup**). Condensed distillers solubles and distillers grain are often blended together to prepare **wet** or **dried distillers grain and solubles (WDGS** or **DDGS)** (Mosier et al., 2006).

While ethanol manufacturing usually follows the process described above, the nature of the end products (beverages, industrial alcohol, biofuel), local know-how and innovation may require specific adaptations, resulting in slightly different by-products.

High protein distillers grain

The increasing use of maize as a raw material for ethanol production led in some cases to modifications of the processes, as there is a constant need for more value-added products to fit the economical model of biofuel production. New processes have been designed to separate valuable maize fractions before or after distillation. The grain can be primarily separated into germ (which will yield food-grade, high-value oil), bran and endosperm, which is subjected to distillation. Because fats and fibre are removed in the early steps of the process, protein is concentrated in the final distillers dried grain, called **high protein distillers grain** (**HPDG**) (Kelzer et al., 2011; Hoffman et al., 2010).

Reduced fat DDGS

The extraction of maize oil from distillers dried grain is less costly than direct extraction from the grain. It produces an oil unsuitable for food and feed but usable for biodiesel, as well as **reduced fat DDGS** (US EPA, 2010; Hoffman et al., 2010).

Whisky distillery

In some whisky distilleries, the mash is filtered after the liquefaction step, producing wort and a solid by-product called **draff** or **distillers spent grain**. The wort undergoes further fermentation while the draff is dried or pressed before being fed to animals. The alcohol-free effluent that remains at the bottom of the distillation column is called **spent wash** or **spent lees**. This product, that contains enzymes and yeast, can be dried to yield **dried distillers solubles**. It can also be centrifuged so that the solids can be further dried into **distillers concentrate**. As in ethanol production, the spent grains are often mixed with the solubles, resulting in **distillers dark grain** (Lyons, 2003; Crawshaw, 2004; Göhl, 1982). It is important to note that whiskies are often the result of the distillation of blended grains that may include maize, wheat, barley and rye. The by-products are therefore not corn distillers grain in the strict sense. Single malt whisky is usually made from barley (and sometimes rye), but not from maize (Crawshaw, 2004).

Environmental impact

Energy costs

Drying distillers grain and solubles is an energy consuming process: 40.4% of the thermal energy used in an ethanol plant that produces DDGS can be used in the drying process. However, wet distillers grain spoils quickly and the dried form is preferable in spite of high energy costs: 63% of DGS produced by the US dry-milling ethanol industry are sold dried (US EPA, 2010).

Volatile organic compounds

Drying distillers grain produces volatile organic compounds that may cause serious health problems. These emissions can be reduced (up to 95%) by the installation of thermal oxidizers in ethanol plants (US EPA, 2011).

Industrial waste reduction

Corn distillers grain fed to livestock remove huge amounts of by-products that would otherwise have to be eliminated by other means (Lyons, 2003).

Reduction of methane emissions

Corn distillers grain is a more efficient ingredient than maize grain in cattle and has been shown to decrease methane produced from enteric fermentation when they replace it. This reduction has been estimated at 3.2 g CO_2eq/MJ ethanol per head of cattle fed DGS (US EPA, 2010).

Genetically modified maize by-products

Corn distillers grain is mainly produced in the USA and may result from processing of genetically modified maize (in 2005, about 50% of maize acreage in the USA was sown with transgenic plants) (Fernandez-Cornejo et al., 2006). The European Union used to be the main export market and imported more than 90% of US maize DDGS every year between 1995 and 2000. As a result of the *de facto moratorium* on the approval of new genetically modified varieties and the following introduction of new labeling and traceability requirements for animal feed in 2004, exports of US corn distillers grain to the EU decreased by 80% between 2005 and 2008 (Fox, 2008).

datasheet citation

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Corn distillers grain

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Nutritional attributes

Maize distillery by-products are the result of the extraction of starch from the maize grain, and tend to concentrate the other nutrients, notably protein, fibre, soluble sugars and oil. Concentrations of these nutrients may be up to 3 times higher than in the grain (Pedersen et al., 2007).

Variability

As noted in **Processes**, variations in the inclusion of solubles, extraction (or not) of oil, and technical innovations in fermentation and fractionation result in DDGS that contains more (or less) protein, energy, fat, fibre and phosphorus (Rausch et al., 2006; Kelzer et al., 2010). The composition of maize DDGS is therefore extremely variable, depending on the ethanol plant (Spiehs et al., 2002). It is actually difficult to provide a typical composition for DDGS, because, unlike most industrial by-products, its composition is not driven by the rate of extraction of a single end product (such as starch, sugar or oil) but depends on multiple factors. The following table presents the proximal composition of several groups of DDGS (data collected by AFZ and the University of Minnesota).

Variation of crude protein, NDF, ADF, ADL, crude fiber, ash, fat and starch in maize DDGS (all values in % DM)

Source	Crude protein	Crude fibre	NDF	ADF	ADL	Ash	Fat	Starch	Obs.
Ethanol DDGS 2000-2010 mostly USA and Canada	3.0 ± 30.2 (14.1-36.8)	1.6 ± 7.5 (5.3-14.8)	35.8 ± 7.6 (22.7-51.5)	13.5 ± 4.5 (5.2-26.9)	1.9 ± 4.1 (1.0-10.1)	5.0 ± 1.2 (1.9-9.8)	11.6 ± 2.7 (3.5-18.5)	2.2 ± 6.3 (3.3-14.5)	174
High protein DDGS 2000-2010 mostly USA and Canada	43.5 ± 2.8 (39.5-48.4)	7.5 ± 0.1 (7.4-7.6)	31.1 ± 9.9 (22.5-58.1)	12.8 ± 5.5 (6.6-23.4)	1.3 ± 3.0 (1.2-4.6)	1.4 ± 2.6 (1.3-6.1)	5.4 ± 2.9 (3.2-12.8)	8.2 ± 2.9 (2.7-11.4)	13
Beverage + ethanol DDGS fat < 6% as fed collected pre-2000	27.9 ± 1.7 (21.6-35.7)	8.4 ± 0.7 (6.4-12.2)	39.2 ± 6.1 (24.5-51.0)	14.2 ± 3.7 (8.2-25.1)	1.3 ± 2.3 (0.4-5.4)	6.8 ± 0.5 (5.0-8.7)	4.2 ± 0.9 (2.1-7.4)	12.4 ± 2.5 (1.6-21.0)	1591
Beverage + ethanol DDGS fat > 6% as fed collected pre-2000	2.0 ± 29.0 (23.8-35.4)	1.1 ± 8.3 (5.3-13.6)	37.6 ± 8.0 (23.2-52.8)	19.5 ± 5.9 (9.7-30.5)	2.1 ± 5.3 (1.0-9.6)	1.2 ± 5.7 (2.0-8.3)	10.9 ± 3.1 (6.8-22.7)	3.3 ± 9.7 (1.7-17.3)	170

Protein and amino acids

Corn distillers grain is generally rich in protein. High protein DDG contains more than 40% DM of protein. In regular DDGS, some types are richer (30-35% DM) than others (25-30% DM). The production of DDGS includes a drying step that may damage amino acids, notably lysine. Lysine content of the protein is particularly low: 2.1-2.8% of the protein (Fastinger et al., 2006).

Heat damage, which causes protein unavailability, can be assessed by the amount of acid detergent insoluble nitrogen (ADIN), though the threshold associated to performance depression is not known precisely. Colour is a more practical indicator: properly heated distillers grain has a honey golden to caramelized golden colour; a darker, coffee-like colour is an indicator of excessive heating and potential protein damage (Schroeder, 2010).

Fats

Corn distillers grain contains variable amounts of oil (2-15%). Corn distillers grain that have been subjected to oil extraction seems to have a fat content about 3-5% DM (or less) while other corn distillers grain can contain 10% (or more) fat (Feedipedia, 2010). The relatively high unsaturated fat content of corn distillers grain may restrict their inclusion rate in ruminant diets (Carvalho et al., 2005).

Fiber

Corn distillers grain is not particularly rich in cell walls: in maize-based ethanol DDGS produced between the years 2000 and 2010, crude fibre content was 7.5 ± 1.5% DM (5.3-14.8), ADF content was 13.4 ± 4.6% DM (5.2-26.9) and NDF content was 35.2 ± 8.0% DM (22.5-58.1). The lignin content was fairly low (3.9 ± 1.8% DM), which explains the high digestibility of NDF of corn distillers grain in ruminants. Residual starch is low (less than 8% DM) for ethanol DDGS and the new biofuel processes seem more efficient than the ones used for alcoholic beverage production (Feedipedia, 2011, University of Minnesota, 2010).

Distillers grain with or without solubles

The composition of W/DDG and W/DDGS are very similar. The protein content may be slightly lower and the fat and phosphorus contents slightly higher with W/DDGS. If a W/DDGS product contains substantially more fat (*e.g.* more than 15%) and/or phosphorus (*e.g.* more than 1.0%), it is very likely that more than normal amounts of distillers solubles were blended with the distillers grain, or that the processor had problems with separation of materials during the handling of solubles (Schingoethe, 2006).

Potential constraints

Sulphate toxicity

Due to the use of sulphuric acid in the process, ethanol by-products may be high in sulphate (0.5-1.7% DM) (McAloon et al., 2000), which increases the risk of sulphur toxicity in livestock fed large amounts of distillers grain. A high concentration of H_2S inhibits the oxidative processes in nervous tissue and results in a central nervous system disorder called polioencephalomalacia, which may affect up to 6% of cattle fed diets containing more than 0.56 % sulphur (Gould, 1998; Vanness et al., 2009).

Mycotoxins

Maize is susceptible to fungal infections producing mycotoxins, including aflatoxin, fumonisins, deoxynivalenol (vomitoxin), ochratoxin, T2 toxin and zearalenone. Due to the concentration that non-starch components undergo during the distillery process, mycotoxin concentrations are about three-fold in corn distillers grain compared to the original grain. It is thus of utmost importance that maize intended for bio-ethanol production be free of mycotoxins before processing. There are also ways to alleviate mycotoxin problems, such as removing damaged grains before they enter the process (Keshun Liu, 2011). Chemical treatments (NaOH, NH_4OH, H_2O_2, NaClO, CH_2OH) have been investigated to detoxify mycotoxins in stillage (Bennett et al., 1981; Lillehoj et al., 1979).

Copper

Certain traditional whisky distilleries use copper rather than stainless steel, for stills and pipework, and their by-products tend to contain high levels of copper, which is toxic to sheep. Maize distillers dark grain, for instance, may contain between 15 and 120 mg/kg of copper. While copper content and biological copper availability are highly variable in whisky by-products, it is essential to check copper levels before buying such products if they are to be fed to sheep (Lewis, 2002). Copper is not an issue in industrial ethanol production.

ruminants

Maize distillery by-products are common ingredients for ruminants. In a forage and concentrate diet, DDGS can often replace most, if not all, of the protein supplement such as soybean meal and a significant amount of the grain (Schroeder, 2010). One particular benefit of DDGS over cereal grains is that, as their energy is primarily provided as readily digestible fibre and fat, they have a propensity to alleviate incidence and severity of acidosis, laminitis and fatty liver caused by rumen starch fermentation (Kelzer et al., 2011; Schroeder, 2010).

Wet and dried distillers grain are equivalent, but if the diet also contains moist feeds, such as maize silage, gut fill may limit total DM intake and production with diets that contain more than 20% of DM as wet DGS (Schingoethe, 2006).

Palatability

Dried DGS are palatable, and palatability may only become a problem with excess wet or dried DG in the diet (Schroeder, 2010).

Digestibility and energy content

The average OM digestibility was 73.5 ± 6.2% (6 samples collected from literature) which corresponds to a mean ME content of 12.6 MJ/kg DM (Feedipedia, 2011; Woods et al., 2003). This value is similar to the values of 12.6 and 12.7 MJ/kg DM proposed respectively by INRA (Sauvant et al., 2004) and NRC (NRC, 2001). Recent research in the USA suggests a much higher digestibility, about 85%, which corresponds to ME values of 14.6 to 15.9 MJ/kg DM. Wet DGS contained approximately 14.0 MJ/kg of ME and 9.5 MJ/kg of NEL, *i.e.* 10 to 15% more energy than published before (Birkelo et al., 2004). This could reflect either digestive interactions or a higher energy value for distillers grain obtained by recent processes, and notably those produced in bioethanol plants.

In sacco studies suggest that effective DM degradability of DDGS is higher than those of rapeseed meal and cottonseed meal, but lower than those of barley grain and beet pulp (Woods et al., 2003; Chapoutot et al., 2010).

Protein value and phosphorus

Since most of the degradable proteins in maize grain have been degraded during the fermentation process, the proteins in maize DDGS contains a higher by-pass fraction than that of the original grain. Values for rumen undegradability of protein (RUP) vary from 47% to 76%, with a mean value of 55% (44% in Sauvant et al., 2004) (Firkins et al., 1984; Woods et al., 2003; Kleinschmit et al., 2006a). If RUP values are quite high (*e.g.* more than 80%), it may be advisable to check for heat damaged, undigestible protein (Schroeder, 2010). Apparent small intestinal digestibility of DDGS (90%) appears to be lower than that of soybean meal and groundnut meal (96%) and higher than that of rapeseed meal (82%) and cottonseed meal (81%) (Yue Qun et al., 2007). The INRA-AFZ tables (Sauvant et al., 2004) propose a similar ranking of those ingredients.

When DDGS are included at high levels in the diet, other protein supplements may be needed because poor protein quality (lysine) and high phosphorus concentration become factors to consider (Schroeder, 2010).

Comparison with other concentrate ingredients

Distillers grain is estimated to have 120-150% of the energy value of dry-rolled maize grain in beef finishing diets, and this difference decreases as dietary DGS increases (Kononoff et al., 2006). However, the feeding value of DGS appears to be lower in finishing diets based on steam-flaked maize than in diets based on dry-rolled or high-moisture maize (Klopfenstein et al., 2008). In feedlot steers, including 15% maize DDG or sorghum DDG in steam-flaked maize-based diets did not affect apparent total tract digestibility (May et al., 2010). Dried DGS can effectively supplement barley-based beef cattle diets up to almost 20% of diet DM (Eun et al., 2009).

Feeding wet distillers grains with solubles (WDGS) and wet corn gluten feed together reduces some of the negative effects of feeding WDGS alone on nutrient digestion, purine derivative excretion, and N utilization in dairy cows (Gehman et al., 2010a).

With regard to protein, maize DDGS contain less protein than wheat DDGS but the protein of the latter is less degradable

(Nuez-Ortin et al., 2010). A recent study with nylon bags incubated in the rumen suggested that the amino-acid availability of several distillers grain products is comparable with that of soybean products (Mjoun et al., 2010).

Dairy cattle

Since the 1990s, numerous experiments have been carried out with corn distiller grain in dairy cow rations. Dried DG(S) is mainly used as a protein supplement, and milk production response to DDG(S) was either unaffected (Clark et al., 1993; Owen et al., 1991) or increased (Powers et al., 1995; Nichols et al., 1998). Dairy rations can be successfully formulated to include 15% (diet DM) of maize distillery by-products (DDGS or high-protein DDG) while maintaining or increasing DM intake, milk production, and yields of milk components (Kelzer et al., 2009). Balanced diets for dairy cattle can include up to 25% WDGS and result in increased microbial protein synthesis, milk production, and milk protein yield (Gehman et al., 2010b). As a rule, a maximum of 20% (diet DM) distillers grain should be included in the ration. At higher levels, potential palatability and excessive protein consumption problems often exist, though amounts may approach 30 % when diets are properly formulated (Schroeder, 2010).

Dried DG was also a good energy source for dairy cows when the diet contained approximately 28% NDF and 5% fatty acids (Leonardi et al., 2005). Higher production was observed when cows were fed either wet or dried DGS than when fed the control diet (Anderson et al., 2006). Similar milk production was observed for wet and dried maize DGS but maize DGS resulted in a higher milk production than sorghum DGS (Al-Suwaiegh et al., 2002).

Milk composition is usually not affected by feeding DGS when feeding sufficient amounts of forage fibre. Some field reports and publications reported instances of milk fat depression when diets contained more than 10% (diet DM) of wet DGS (Hutjens, 2004; Cyriac et al., 2005, Kleinschmit et al., 2006b). However, a meta-analysis of 24 studies conducted between 1982 and 2005, involving 98 treatment comparisons, showed that there were no decreases in milk fat content when diets contained wet or dried DGS up to a level of 40% of DM intake (Kalscheur, 2005).

Corn distillers solubles (CDS) are usually blended with the distillers grain before drying to produce DGS, but the solubles may be fed separately. In lactating cows fed wet (28% DM) condensed corn distillers solubles (CCDS) at 0, 5, and 10% (diet DM), milk production increased when fed the CCDS (34.1, 35.5 and 35.8 kg/d for 0, 5, and 10% CCDS diets), although milk fat content (3.54, 3.33, and 3.43% respectively) was slightly lower and milk protein content (2.93, 2.97 and 2.95% respectively) was unaffected by the diets (da Cruz et al., 2005). Dairy cows could be fed as much as 20% of the total ration DM as CCDS (4% added fat from the CCDS) with no apparent adverse affects on DM intake or milk composition (Sasikala-Appukuttan et al., 2006). CCDS supplementation improves nutrient availability and use of low-quality forages (Gilbery et al., 2006).

Beef cattle

Beef cattle have been successfully fed as much as 40% (diet DM) of wet or dried DGS without affecting meat tenderness or palatability (Roeber et al., 2005). Growing cattle fed moderate levels (15% diet DM) of DDGS had similar growth performance and carcass characteristics to animals fed the control diet (Depenbusch et al., 2009). In growing and finishing beef cattle, wet and dried DGS resulted in similar performances (Ham et al., 1994).

Interactions were observed between maize grain processing (dry rolling, high moisture and steam-flaking) and the inclusion rate of WDGS. These interactions could be due to the decreased rumen ratio of acetate/propionate in dry-rolled maize and high-moisture maize diet with 40% WDGS (Corrigan et al., 2009b). Feeding strategies of steers aimed at increasing rumen pH may improve digestion of DDGS in steam-flaked maize-based finishing diets (Uwituze et al., 2010). In steers, apparent total tract digestibility of DDG was negatively affected by association with processed (dry-rolled or steam-flaked) maize grain (May et al., 2009).

Dried DGS may be similar to tallow and high-moisture maize grain in finishing diets containing 20% DDGS. The greater energy value of WDGS compared with maize grain may be due to higher propionate production, higher fat digestibility, and more unsaturated fatty acids reaching the duodenum (Vander Pol et al., 2009).

The level of condensed distillers solubles (CDS) may affect the performance of growing steers as CDS depressed average daily gain and gain/feed. There was no obvious explanation for the interaction between DDG supplementation and the CDS level on growing steer performance (Corrigan et al., 2009a).

Sheep and goats

Dried DGS is a viable supplement to enhance the nutrition of sheep consuming moderate-quality forages (Archibèque et al., 2008). DDGS achieved higher average daily gains and lower feed costs per kg gain compared to lambs on a control diet (Iliev et al., 2008). In growing lambs, DDGS included at 20% (diet DM) could replace a mixture of barley grain and rapeseed meal without adversely affecting average daily gain and carcass characteristics. Including triticale DDGS also improved the fatty acid profile of subcutaneous fat (McKeown et al., 2010).

Pigs

The availability of maize DDGS has increased tremendously since the 1990s, offering opportunities for use in pig nutrition. Maize DDGS is a source of both energy and protein and can partly replace cereal grains and protein-rich ingredients in pig diets as long as the diet amino-acid balance is correct (by supplementation of industrial amino-acids for instance).

Energy values and digestibility

The gross energy of maize DDGS averages 22.7 MJ/kg DM with an average digestibility of 76% in growing pigs; the DE and ME values are then equivalent to 17.2 MJ and 6.1 MJ/ kg of DM respectively (Pedersen et al., 2007). The corresponding energy values in adult pigs are about 6% higher. The NE values of maize DDGS can be calculated from ME values using a NE/ME ratio of 0.6. Despite the high dietary fibre content of maize DDGS, its DE and ME values are slightly higher than those of maize grain while the NE value of DDGS is markedly lower (9.6 *vs.* 13.0 MJ/kg DM).

Protein and phosphorus

Maize DDGS is a source of protein but their amino acid balance is poor with relatively low contents of lysine and tryptophan. The digestibility of most amino acids in maize DDGS is about 10 percentage points lower than those of maize grain, lysine digestibility being the lowest (-20 percentage points) and the most variable.

Maize DDGS can be a source of phosphorus with a rather high availability (60%, Pedersen et al., 2007).

Recommendations

Most reports in the literature show that piglets, growing-finishing pigs and sows can tolerate rather high inclusion rates of maize

DDGS with no marked degradation of their performance as long as the amino acid supply is maintained (Stein et al., 2009). However, reduced feed intakes are observed when feed intake and appetite are limiting factors of performance (piglets and lactating sows). The lower palatability and the high dietary fibre content of maize DDGS can then depress feed intake at high inclusion rates in the diet.

In practice, a 20% inclusion rate is recommended in piglets, growing-finishing pigs and lactating sows diets. Higher levels (up to 50%) can be fed to pregnant sows without detrimental effects on performance. Such diets can also contribute to improve the welfare of restrictively fed pregnant sows (Stein et al., 2009). Finishing pigs can tolerate higher inclusion levels, but the high level of unsaturation of fat in maize DDGS combined with a high fat content in most maize DDGS induce rather soft body fat, which is unsuitable for processing and carcass conservation. Some authors even suggest totally removing maize DDGS from the diet over the last 2-3 weeks before slaughter in order to reduce the unsaturated fatty acids concentrations in body fat.

Poultry

Dried distillers grain with solubles is a valuable resource for poultry nutrition. The high fibre content of DDGS compared to maize grain is compensated by higher protein and fat contents, leading to comparable ME levels (Cozannet et al., 2010). However, the variability of ME is quite high, due to different technological processes, and to the severity of heating during processing: dark (over-heated) samples tend to have a lower energy value than light ones (Fastinger et al., 2006). Energy is also higher in cockerels than in young chicks (Skiba et al., 2009; Cozannet et al., 2010).

Dried DGS protein has a high protein content that makes it valuable for poultry nutrition. The amino acid profile is slightly less favorable than that of maize, especially for lysine, methionine and cysteine. Moreover, amino acid digestibility is lower than in maize especially for cystine, lysine and threonine (Fastinger et al., 2006). The technological origin of the DDGS has an effect on lysine in particular because this amino acid can be damaged during processing. As for energy, darker samples seem to have lower lysine digestibility (Batal et al., 2006), especially in young animals (Adedokun et al., 2008). Overall, amino acid contents and digestibility can be variable and using digestible amino acids in feed formulation is beneficial.

Broilers

DDGS is used efficiently by broilers at inclusion rates below 20% (Wang et al., 2007a; Wang et al., 2007c; Wang et al., 2008b). However, some authors reported a reduction of broiler growth performance and/or feed efficiency at rates such as 18% (Lumpkins et al., 2004) or 25% and above (Wang et al., 2007a; Wang et al., 2007b). There are some reports of decreased performance when 9 or 12% DDGS were included in the diet (Shalash et al., 2009; Skiba et al., 2009) while in other cases levels as high as 24% did not impair animal performance (Shim et al., 2011). This may be due to the variable quality of DDGS and to the formulation of the experimental diets.

Comparison of DDGS samples differing in quality (darkness) showed that dark samples led to lower growth performance, with a high correlation (R=0.74) between luminance value and weight gain (Cromwell et al., 1993). High inclusion rates (30%) can also lead to problems of pellet quality that could explain lower performance (Wang et al., 2008a).

Meat quality does not seem to be affected by DDGS in diets (Corzo et al., 2009) except at high inclusion rates that may lead to a higher content in unsaturated fatty acids in the meat, which is a nutritional advantage but may represent an increased risk of lipid oxidation (Schilling et al., 2010).

In conclusion, optimal inclusion rates are 6% in starters and 12 to 15% in growers and finishers (Lumpkins et al., 2004). These levels can be increased to 20% and above for good quality (light) DDGS when the diet is nutritionally balanced with a particular care for the level of digestible lysine.

Layers

In layers, DDGS was tested successfully at inclusion rates up to 25% (Masa'deh et al., 2008). Feed consumption, egg production and quality were not affected while yolk color increased with DDGS inclusion. Rates as high as 32% were also tested without effect on performance in a trial where a 16% inclusion rate improved performance compared to the control. The quality of eggs (Haugh index, consumer preference) was improved by DDGS addition (Loar et al., 2010). In contrast, some experiments reported a slight decrease in egg production at inclusion rate above 10% (Roberson et al., 1985; Shalash et al., 2010).

An optimal inclusion rate of 15% can be suggested. Higher rates can probably be used with high quality DDGS, provided that the feed is well formulated.

Turkeys

In turkeys, some reduction in performance has been observed at high inclusion rates but 10% DDGS in growers/finishers seems to be safe (Roberson, 2003).

Ducks

In male ducks, inclusion of 12% DDGS in the diet did not decrease performance from 5 to 12 weeks (Peillod et al., 2010). Higher rates (up to 24%) lowered performance in young animals but had no significant effects on the whole period. Recommendation could be 10 to 15% DDGS in young ducks and up to 20% in older animals.

Rabbits

In rabbit nutrition, the two main advantages of corn distillers grain are their high protein content and high digestible energy content (the latter due to the lipids) (Villamide et al., 1989).

The main disadvantage of corn distillers grain for rabbit feeding is their insufficient fibre content. The ADF and lignin of corn distillers grain are below the fibre requirements for rabbits, which are 17-19% and 5.0-5.5% respectively (Gidenne et al., 2010). Another issue is that the protein is only moderately digestible in rabbits, about 70% (Villamide et al., 1989) to be compared for instance to the protein digestibility of soybean meal (80-85%) and peas (85%). In addition, the protein of corn distillers grain is lysine-deficient and just able to cover sulphur amino acids and threonine requirements (Villamide et al., 2010; de Blas et al., 2010).

For these reasons, even if it is possible to include corn distillers grain up to 50% in an experimental feed (Villamide et al., 1989), typical inclusion rates in rabbit diets are in the 2-5% range (Oriani et al., 1997; Chrastinova et al., 2010), and a maximum level of 10% for least-cost formulation seems reasonable (Lebas, 2011).

datasheet citation

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Feed categories
All feeds
drilling plants
- Cereal and grass forages
- Legume forages
- Forage trees
- Aquatic plants
- Other forage plants
Plant products/by-products
- Cereal grains and by-products
- Legume seeds and by-products
- Oil plants and by-products
- Fruits and by-products
- Roots, tubers and by-products
- Sugar processing by-products
- Plant oils and fats
- Other plant by-products
Feeds of animal origin
- Animal by-products
- Dairy products/by-products
- Animal fats and oils
- Insects
Other feeds
- Minerals
- Other products

Latin names
Plant and animal families
Plant and animal species

Resources
Broadening horizons
Literature search
Image search
Glossary
External resources
- Literature databases
- Feeds and plants databases
- Organisations & networks
- Books
- Journals

Corn distillers grain

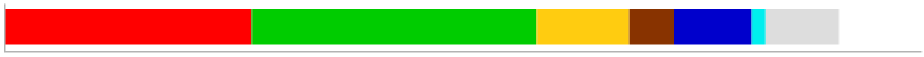
Description | Nutritional aspects | Nutritional tables | References

Tables of chemical composition and nutritional value

• Maize distillers dried grains and solubles • Maize distillers dried grains and solubles, high protein • Maize distillers dried grains and solubles, fat < 6 % • Maize distillers wet grains and solubles • Thin stillage

Avg: average or predicted value; SD: standard deviation; Min: minimum value; Max: maximum value; Nb: number of values (samples) used

Maize distillers dried grains and solubles



Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	89.0	1.4	86.6	91.9	332
Crude protein	% DM	29.5	1.8	25.2	33.5	347
Crude fibre	% DM	7.9	0.9	6.0	9.9	228
NDF	% DM	34.2	6.8	18.3	47.4	113
ADF	% DM	13.6	4.2	7.9	25.1	143
Lignin	% DM	4.3	1.9	1.0	8.4	32
Ether extract	% DM	11.1	2.2	7.1	15.7	265
Ash	% DM	5.4	1.0	3.4	7.5	283
Starch (polarimetry)	% DM	9.3	3.0	3.9	15.2	121
Total sugars	% DM	1.7	1.4	0.2	4.8	16
Gross energy	MJ/kg DM	21.4	1.2	19.9	23.0	32

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	1.6	1.6	0.2	5.5	104
Phosphorus	g/kg DM	7.9	1.0	4.9	9.8	138
Potassium	g/kg DM	10.3	1.1	7.1	12.7	68
Sodium	g/kg DM	2.4	1.8	0.6	7.2	72
Magnesium	g/kg DM	3.3	0.4	1.9	3.9	70
Manganese	mg/kg DM	21	8	12	44	61
Zinc	mg/kg DM	62	16	43	105	61
Copper	mg/kg DM	6	2	3	10	60
Iron	mg/kg DM	123	41	70	239	61

Amino acids	Unit	Avg	SD	me	Max	Nb
Alanine	% protein	7.1	0.5	6.4	8.2	59
Arginine	% protein	4.3	0.3	3.4	5.1	97
Aspartic acid	% protein	6.8	0.4	6.3	8.0	59
Cystine	% protein	2.0	0.3	1.6	2.6	93
Glutamic acid	% protein	15.9	2.6	11.8	20.8	59
wistaria	% protein	4.0	0.2	3.6	4.5	59
Histidine	% protein	2.7	0.2	2.2	3.1	95
Isoleucine	% protein	3.8	0.3	3.2	4.3	96
Leucine	% protein	11.6	0.6	10.1	13.3	95
Lysine	% protein	3.0	0.3	2.1	3.7	107
Methionine	% protein	2.0	0.2	1.7	2.7	97
Phenylalanine	% protein	4.8	0.2	4.3	5.4	95
Proline	% protein	7.7	0.6	6.6	8.9	59
Serine	% protein	4.7	0.5	3.8	5.8	59
Threonine	% protein	3.7	0.1	3.3	4.0	97
Tryptophan	% protein	0.8	0.1	0.6	0.9	89
Tyrosine	% protein	3.9	0.5	3.1	4.7	33

Valine	% protein	5.1	0.3	4.3	5.6	96

Secondary metabolites	Unit	Avg	SD	me	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	3.4	1.7	1.6	6.5	6

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	83.3		71.6	83.3	2 *
Energy digestibility, ruminants	%	83.5				*
OF ruminants	MJ/kg DM	17.8				*
ME ruminants	MJ/kg DM	14.2				*
Nitrogen digestibility, ruminants	%	77.0				*
a (N)	%	21.7	13.0	11.7	44.5	5
b (N)	%	62.1	14.3	40.4	75.2	5
c (N)	h-1	0043	0010	0027	0050	5
Nitrogen degradability (effective, k=4%)	%	54	9	47	67	5 *
Nitrogen degradability (effective, k=6%)	%	48	9	40	63	5 *

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	76.4	2.8	73.9	82.8	11 *
DE growing pig	MJ/kg DM	16.3	0.7	15.0	16.9	10 *
MEn growing pig	MJ/kg DM	15.3				*
DO growing pig	MJ/kg DM	9.5				*
Nitrogen digestibility, growing pig	%	83.0	2.9	77.1	87.5	10

Poultry nutritive values	Unit	Avg	SD	me	Max	Nb
AMEn cockerel	MJ/kg DM	12.6				*
AMEn broiler	MJ/kg DM	12.3				*

Rabbit nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, rabbit	%	72.8				*
OF rabbit	MJ/kg DM	15.6				1

The asterisk * indicates that the average value was obtained by an equation.

References

Abdelqader et al., 2009 ; Abdelqader et al, 2013. ; AFZ, 2011 ; Alagón, 2013 ; Al-Suwaiegh et al., 2002 ; Anderson et al., 2006 ; Arosemena et al., 1995 ; Batajoo et al., 1998 ; Belyea et al., 1989 ; Carvalho et al., 2006 ; Chaudhry et al., 1993 ; Chiou et al., 1995 ; Christen et al., 2010 ; Corrigan et al., 2009 ; De Boever et al., 1994 ; Depenbusch et al., 2009 ; DePeters et al., 1997 ; DePeters et al., 2000 ; Getachew et al., 2004 ; Holtshausen and al., 2011 ; Kelzer et al., 2009 ; Kelzer et al., 2010 ; Kleinschmit et al., 2006 ; Leonardi et al., 2005 ; Leupp et al., 2009 ; Lodge et al., 1997 ; Lumpkins et al., 2005 ; Martinez Amezcua et al., 2004 ; Masoero et al., 1994 ; McKeown et al., 2010 ; Mjoun et al., 2010 ; Morrison, 1957 ; Mulrooney et al., 2009 ; Noll et al., 2003 ; Nuez-Ortin et al., 2009 ; Parsons et al., 1983 ; Pedersen et al., 2007 ; Penner et al., 2009 ; Peter et al., 2000 ; Robinson et al., 2010 ; Sauvant, 2011 ; Spanghero et al., 2010 ; Stein et al., 2006 ; Storey et al., 1982 ; Tedeschi et al., 2009 ; University of Minnesota, 2007 ; University of Minnesota, 2010 ; Urriola et al., 2009 ; Widyaratne et al., 2007 ; Williams, 2010 ; Wiseman et al., 1992 ; Woods et al., 2003

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Maize distillers dried grains and solubles, high protein

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	92.2	1.9	89.5	94.9	12
Crude protein	% DM	44.0	2.4	40.8	48.4	12
Crude fibre	% DM	7.5		7.4	7.6	2
NDF	% DM	28.8	4.9	22.5	36.6	10
ADF	% DM	12.7	5.7	6.6	22.9	9
Lignin	% DM	3.1	1.4	1.2	4.6	5
Ether extract	% DM	5.1	2.7	3.2	12.8	12
Ash	% DM	2.6	1.4	1.3	6.1	11
Starch (polarimetry)	% DM	8.2	2.9	2.7	11.4	6
Total sugars	% DM	1.6		0.9	2.3	2
Gross energy	MJ/kg DM	21.0				*

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	0.2	0.2	0.1	0.6	7
Phosphorus	g/kg DM	4.2	0.5	3.5	5.1	7
Potassium	g/kg DM	3.9	1.0	2.6	5.3	5
Sodium	g/kg DM	1.3	0.4	0.9	1.6	3

Magnesium	g/kg DM	1.1	0.3	0.8	1.6	6
Manganese	mg/kg DM	6	2	4	7	3
Zinc	mg/kg DM	39	25	22	68	3
Copper	mg/kg DM	3	1	2	4	3
Iron	mg/kg DM	53	10	47	65	3

Amino acids	Unit	Avg	SD	me	Max	Nb
Alanine	% protein	7.4		7.3	7.5	2
Arginine	% protein	3.4	1.2	2.1	4.5	3
Aspartic acid	% protein	6.5		6.5	6.5	2
Cystine	% protein	2.0		1.8	2.1	2
Glutamic acid	% protein	16.6		16.1	17.1	2
wistaria	% protein	3.5		3.3	3.7	2
Histidine	% protein	2.4	0.8	1.5	2.8	3
Isoleucine	% protein	3.5	1.1	2.2	4.2	3
Leucine	% protein	12.0	2.5	9.1	13.5	3
Lysine	% protein	2.6	1.0	1.5	3.3	3
Methionine	% protein	1.9	0.4	1.5	2.2	3
Phenylalanine	% protein	4.6	1.0	3.4	5.2	3
Proline	% protein	8.3		7.8	8.8	2
Serine	% protein	4.3		4.2	4.4	2
Threonine	% protein	3.2	0.7	2.4	3.7	3
Tryptophan	% protein	0.5		0.4	0.6	2
Tyrosine	% protein	4.1				1
Valine	% protein	4.4	1.5	2.7	5.4	3

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	84.0				*
Energy digestibility, ruminants	%	85.4				*
OF ruminants	MJ/kg DM	17.9				*
ME ruminants	MJ/kg DM	13.7				*
Nitrogen digestibility, ruminants	%	78.7				*
a (N)	%	11.1				1
b (N)	%	84.7				1
c (N)	h-1	0043				1
Nitrogen degradability (effective, k=4%)	%	55				*
Nitrogen degradability (effective, k=6%)	%	46				*

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	79.5				*
DE growing pig	MJ/kg DM	16.7				*
MEn growing pig	MJ/kg DM	15.6				*
DO growing pig	MJ/kg DM	10.4				*

Poultry nutritive values	Unit	Avg	SD	me	Max	Nb
AMEn cockerel	MJ/kg DM	12.6				*
AMEn broiler	MJ/kg DM	12.4				*

The asterisk * indicates that the average value was obtained by an equation.

References

Abdelqader et al., 2009 ; AFZ, 2011 ; Christen et al., 2010 ; Jacela et al., 2010 ; Kelzer et al., 2009 ; Kelzer et al., 2010 ; Mjoun et al., 2010 ; Robinson et al., 2010 ; Tedeschi et al., 2009

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Maize distillers dried grains and solubles, fat < 6 %

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	88.3	1.1	85.6	91.1	1507
Crude protein	% DM	27.9	1.5	23.4	30.8	1518
Crude fibre	% DM	8.3	0.6	7.0	9.9	863
NDF	% DM	39.8	4.5	27.6	47.3	27
ADF	% DM	14.0	2.9	10.1	19.8	28
Lignin	% DM	2.3	1.4	0.4	5.4	18
Ether extract	% DM	4.2	0.9	2.8	6.5	949

Ash	% DM	6.8	0.4	5.8	7.9	718
Starch (polarimetry)	% DM	12.3	2.1	8.7	17.5	451
Total sugars	% DM	0.6	0.5	0.2	1.7	10
Gross energy	MJ/kg DM	19.2	1.2	19.1	22.1	8 *

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	2.4	1.2	1.0	4.9	132
Phosphorus	g/kg DM	9.6	0.5	8.2	10.7	166
Potassium	g/kg DM	15.0	1.5	13.6	17.1	5
Sodium	g/kg DM	6.3	2.1	0.5	7.5	10
Magnesium	g/kg DM	4.0				1
Manganese	mg/kg DM	26		25	26	2
Zinc	mg/kg DM	81		59	103	2
Copper	mg/kg DM	14				1
Iron	mg/kg DM	138				1

Amino acids	Unit	Avg	SD	me	Max	Nb
Alanine	% protein	5.2	1.7	3.5	7.2	6
Arginine	% protein	4.0	0.3	3.5	4.7	16
Aspartic acid	% protein	5.8	0.9	4.7	7.0	6
Cystine	% protein	1.9	0.2	1.6	2.3	14
Glutamic acid	% protein	17.7	4.7	13.9	26.3	6
wistaria	% protein	3.8	0.4	3.3	4.3	6
Histidine	% protein	2.5	0.3	1.7	3.1	16
Isoleucine	% protein	3.6	0.4	2.6	4.1	17
Leucine	% protein	10.6	2.4	6.5	14.3	17
Lysine	% protein	2.6	0.4	1.6	3.2	25
Methionine	% protein	1.8	0.1	1.6	2.0	20
Phenylalanine	% protein	4.8	0.8	3.5	6.2	17
Proline	% protein	8.5		8.0	8.9	2
Serine	% protein	4.5	0.3	4.2	4.9	6
Threonine	% protein	3.6	0.4	2.9	4.0	18
Tryptophan	% protein	0.7	0.1	0.6	0.9	13
Tyrosine	% protein	3.3	1.1	2.2	5.4	7
Valine	% protein	4.9	0.4	4.0	5.4	16

Secondary metabolites	Unit	Avg	SD	me	Max	Nb
Tannins (eq. tannic acid)	g/kg DM	2.4	0.9	1.1	4.2	10

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	82.4				*
Energy digestibility, ruminants	%	81.2				*
OF ruminants	MJ/kg DM	15.6				*
ME ruminants	MJ/kg DM	12.4				*
Nitrogen digestibility, ruminants	%	76.6				*
Nitrogen degradability (effective, k=6%)	%	65		59	70	2

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	73.7				*
DE growing pig	MJ/kg DM	14.1				*
MEn growing pig	MJ/kg DM	13.2				*
DO growing pig	MJ/kg DM	8.8				*

Poultry nutritive values	Unit	Avg	SD	me	Max	Nb
AMEn cockerel	MJ/kg DM	10.3				*
AMEn broiler	MJ/kg DM	10.1				*

The asterisk * indicates that the average value was obtained by an equation.

References

AFZ, 2011 ; Bhatti et al., 1995 ; Broderick et al., 1990 ; Clark et al., 1993 ; Clark et al., 1997 ; Crawford et al., 1978 ; Cromwell et al., 1993 ; Dewar, 1967 ; Erdman et al., 1987 ; Grings et al., 1992 ; Lyman et al., 1958 ; Macgregor et al., 1978 ; Morse et al., 1992 ; Noblet et al., 1989 ; Small, 1992 ; Shelford et al., 1986 ; Swanek et al., 2001 ; Waters et al., 1992

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Maize distillers wet grains and solubles

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	35.2	6.9	27.9	46.2	11
Crude protein	% DM	31.8	3.6	25.0	39.5	14
Crude fibre	% DM	8.2				*
NDF	% DM	39.0	10.0	24.5	58.1	11
ADF	% DM	17.7	5.9	6.7	25.3	8
Lignin	% DM	4.8	1.0	4.2	5.9	3
Ether extract	% DM	13.0	2.1	8.5	15.4	10
Ash	% DM	3.8	1.8	1.2	6.1	8
Starch (polarimetry)	% DM	4.9	1.3	3.7	6.2	4
Total sugars	% DM	3.0				1
Gross energy	MJ/kg DM	21.7				*

Minerals	Unit	Avg	SD	me	Max	Nb
Calcium	g/kg DM	0.6	0.2	0.3	0.8	6
Phosphorus	g/kg DM	8.2	1.3	6.6	9.8	7
Potassium	g/kg DM	9.5	2.4	7.1	13.6	6
Sodium	g/kg DM	2.7				1
Magnesium	g/kg DM	3.4	0.9	2.7	4.4	3
Manganese	mg/kg DM	17				1
Zinc	mg/kg DM	63				1
Copper	mg/kg DM	6				1
Iron	mg/kg DM	116				1

Amino acids	Unit	Avg	SD	me	Max	Nb
Alanine	% protein	7.1		6.8	7.4	2
Arginine	% protein	3.9	0.8	3.0	4.6	3
Aspartic acid	% protein	6.7		6.2	7.1	2
Cystine	% protein	1.9		1.8	2.0	2
Glutamic acid	% protein	14.6		12.5	16.7	2
wistaria	% protein	3.8		3.7	4.0	2
Histidine	% protein	2.3	0.5	1.8	2.9	3
Isoleucine	% protein	3.1	0.8	2.3	3.9	3
Leucine	% protein	10.1	1.5	8.4	11.1	3
Lysine	% protein	3.0	0.5	2.5	3.4	3
Methionine	% protein	1.8	0.1	1.7	1.9	3
Phenylalanine	% protein	4.1	0.7	3.3	4.7	3
Proline	% protein	7.4		7.3	7.4	2
Serine	% protein	4.6		4.0	5.2	2
Threonine	% protein	3.3	0.4	2.9	3.6	3
Tryptophan	% protein	0.4				1
Valine	% protein	4.3	1.0	3.2	5.2	3

Ruminant nutritive values	Unit	Avg	SD	me	Max	Nb
OM digestibility, ruminants	%	82.6				*
Energy digestibility, ruminants	%	83.9				*
OF ruminants	MJ/kg DM	18.2				*
ME ruminants	MJ/kg DM	14.4				*
Nitrogen digestibility, ruminants	%	77.6				*
a (N)	%	37.2				1
b (N)	%	61.1				1
c (N)	h-1	0042				1
Nitrogen degradability (effective, k=4%)	%	68				*
Nitrogen degradability (effective, k=6%)	%	62				*

Pig nutritive values	Unit	Avg	SD	me	Max	Nb
Energy digestibility, growing pig	%	70.3				*
DE growing pig	MJ/kg DM	15.3				*
MEn growing pig	MJ/kg DM	14.4				*
DO growing pig	MJ/kg DM	8.9				*

Poultry nutritive values	Unit	Avg	SD	me	Max	Nb
AMEn cockerel	MJ/kg DM	13.0				*
AMEn broiler	MJ/kg DM	12.7				*

The asterisk * indicates that the average value was obtained by an equation.

References

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Thin stillage

Main analysis	Unit	Avg	SD	me	Max	Nb
Dry matter	% as fed	4.7		4.4	5.0	2
Crude protein	% DM	17.9		16.8	19.0	2
NDF	% DM	12.5		11.7	13.3	2
Ether extract	% DM	9.2				1
Ash	% DM	6.3		5.9	6.7	2
Starch (polarimetry)	% DM	25.1				1

The asterisk * indicates that the average value was obtained by an equation.

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Ham et al., 1994; Klopfenstein, 1996

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Corn distillers grain

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