Iowa Beef Center

ETHANOL COPRODUCTS FOR BEEF CATTLE

First in a series of six ethanol coproducts publications from the Iowa Beef Center

The Processes and Products

Rapid expansion of the ethanol industry in Iowa within the last ten years is one factor supporting a revitalization of cattle feeding in the Northern Plains and upper Midwest, particularly in Iowa and Nebraska. Iowa is home to approximately 20% of the U.S. ethanol plants that produce about 25% of the nation's ethanol, corn oil, corn sweeteners, and coproducts. These products have been proven to serve as a high quality, cost effective alternative to feeding corn. Recently, the ethanol industry has adapted new technology processes such as oil extraction and cellulosic ethanol production which are affecting the nutrient composition of the coproducts. This publication reviews the processes and their effects on nutrient value.

Dry Milling Process

In 2013, the dry corn milling industry used 4.6 billion bushels of corn (33% of the U.S. corn supply) to produce approximately 13.3 billion gallons of ethanol and 39 million tons of distillers grains. Nearly half of the coproducts produced were consumed by beef cattle, which is 15% more than any other livestock species. The export market of the U.S. coproducts has rapidly increased in recent years. In 2013, approximately 25% of the total coproducts were exported to countries such as China, Japan, South Korea, and Vietnam.

Corn is nearly two-thirds starch, which is the primary substrate for alcohol fermentation. Nutrients in the remaining one-third of the corn kernel (the unfermented portions: protein, oil, fiber, and ash) are concentrated approximately three-fold into distillers grains. For example, if the corn is 4% fat, the distillers grains are expected to contain approximately 12% fat. The ethanol process begins by grinding the grain prior to fermentation where enzymes, yeast, and water are added for conversion of starch to sugar in order to produce ethanol and carbon dioxide. After distillation, or removal of ethanol, the resulting product, known as the stillage, is often centrifuged to separate the distillers grains from the

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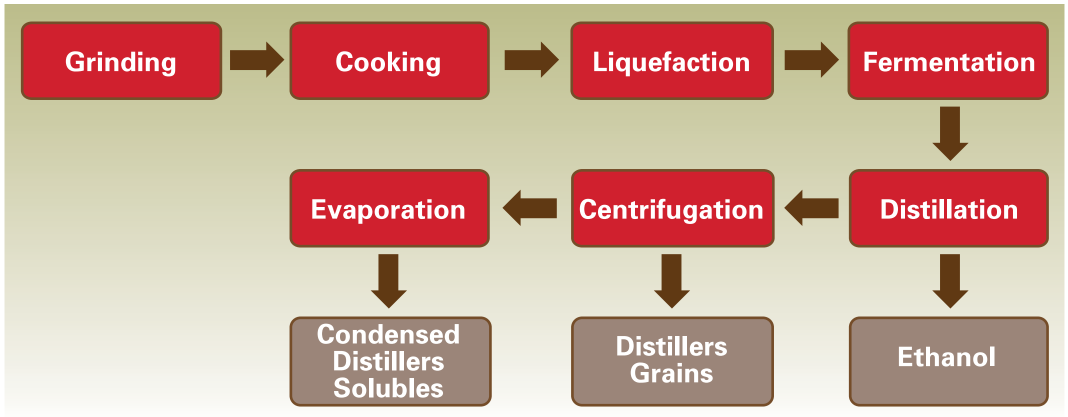
distillers solubles (Figure 1). Recently, the industry has adapted technology to extract more of the corn oil (fat) from the solubles during this step. Regardless of whether oil extraction occurred, the solubles can then be condensed to about 30% dry matter (corn condensed distillers solubles). Typically, the solubles are added back to the distillers grains; however, nutrient composition of the coproducts varies greatly depending on the ratio of solubles to distillers grains and the extent of which distillers grains were dried.

Figure 1. Dry milling process



In a traditional dry milling process, one bushel of corn produces 17 pounds of dried distillers grains and 2.8 gallons of ethanol. The combination of oil extraction and secondary cellulosic fermentation potentially could reduce the coproduct production per bushel of corn by as much as 20%, and thus concentrate the nutrient composition of protein and minerals.

Dry Milling Products

Distillers Grains

Distillers grains contain the remaining nutrients after the corn starch is fermented to alcohol; therefore, the original nutrients in the corn are concentrated approximately threefold. Distillers grains can be marketed as wet, modified, or dried depending on moisture level. Wet coproducts are often 30%–40% dry matter and are marketed locally for livestock feed since they have a short shelf life. While the dried distillers grains (85%–95% dry matter) have an extended shelf life and can be transported longer distances, some feeding value may be lost. They are more expensive on a dry matter basis compared to wet distillers grains due to drying costs. Drying the distillers grains to 40%–50% dry matter allows modified distillers grains to have an intermediate shelf life and feeding value compared to wet and dried distillers grains.

Traditionally, wet distillers grains are higher in both protein and energy compared to corn gluten feed because the gluten and oil remain in the distillers grains. However, the recent changes in the ethanol industry such as oil extraction have impacted the nutrient content of wet distillers grains. Dried distillers grains are a good bypass protein source for cattle.

Corn Condensed Distillers Solubles

Distillers solubles can be added to the distillers grains, or condensed and used as a liquid cattle feed supplement. Condensed distillers solubles appear to be slightly higher in energy and similar in protein to wet distillers grains when adjusted for moisture. The protein level is similar to, or slightly lower than, distillers grains at approximately 25%. Because condensed distillers solubles are 70% moisture, feeders in the upper Midwest should use heated or underground tanks to prevent the product from freezing.

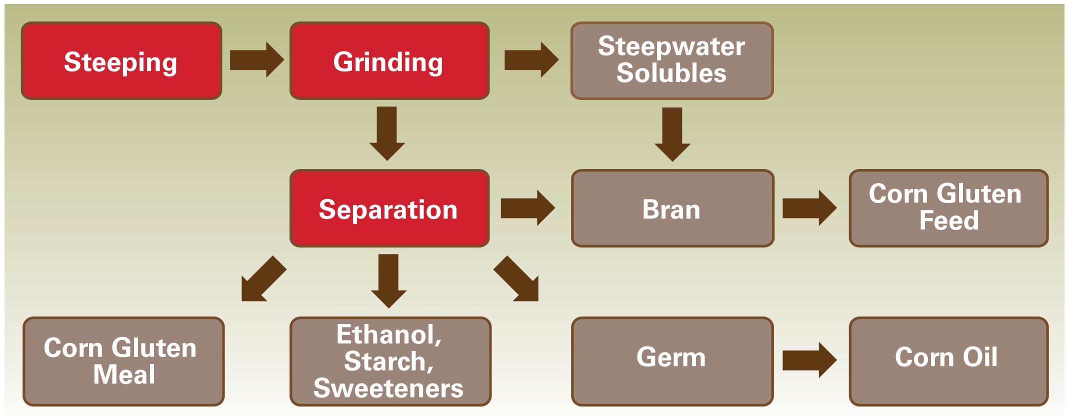
New Generation Dry Milling Processes

It has been estimated that 85% of the U.S. ethanol plants now have the capability to extract oil during production resulting in decreased oil (fat) content in distillers grains. This is being accomplished through three main methods (see Figure 1 for reference of the traditional dry milling process).

1. Pre-fermentation fractionation involves separation of the germ (which contains approximately 45% of the corn oil), endosperm, and bran prior to fermentation. In this fractionation process, only the endosperm is fermented for ethanol and high protein distillers grains are produced.
2. Partial oil removal via centrifugation occurs from the thin stillage prior to evaporation of corn condensed distillers solubles.
3. The whole stillage can go through a secondary fermentation prior to centrifugation resulting in lower fat and typically higher fiber distillers grains. This process includes the use of specialized enzymes and occurs after distillation prior to the centrifugation of the whole stillage.

Although the first two methods of oil removal have been successful, due to cost and advancement in technology, the industry is moving beyond oil extraction towards fiber extraction by converting corn kernel fiber into cellulosic ethanol. Some of the first fiber extraction processes developed include a secondary fermentation preceded by a pretreatment of whole stillage with cellulosic enzymes, yeast, and heat, and based on recent research at Iowa State University (ISU) (Lundy and Loy, 2014: IBCR 200B), is expected to have a similar feeding value compared to modified wet distillers grains plus solubles.

Figure 2. Wet milling process



Wet Milling Process

While wet mills were once the dominant ethanol process in the state, now only about 15% of Iowa's ethanol plants are wet mills. Although the primary product of the dry milling plants is ethanol, wet mills produce corn sweeteners as well as ethanol. The wet milling process is complex and produces a variety of products and coproducts. Corn is steeped for 30 to 40 hours to begin the process of breaking the kernel down into its components (fiber, starch, and gluten). The germ is separated for the extraction of corn oil. The bran is screened, and the starch is separated from the gluten. The steepwater solubles are condensed to the consistency of molasses and mixed with corn bran to produce corn gluten feed (Figure 2).

Wet Milling Products

Corn Gluten Feed

Corn gluten feed has been a popular feedlot cattle protein and energy source because it is an intermediate level protein product that is rich in highly digestible fiber. It is the highest volume coproduct of the wet corn milling industry. Dry corn gluten feed is often pelleted and marketed to domestic and European dairy industries. Corn gluten feed actually contains no gluten but instead is composed of a mixture of corn bran and condensed steepwater solubles. It may contain corn germ meal as well as other coproduct streams from the plant.

Corn gluten feed can vary in composition due to the ratio of condensed steepwater condensed distillers solubles to corn bran. This will vary from plant to plant depending on the markets available. Corn gluten feed that is higher in bran will be lower in protein, phosphorus, and sulfur.

Corn Gluten Meal

Corn gluten meal is golden yellow and is mainly gluten, the high protein portion of the corn kernel. Corn gluten meal primarily is used in the swine and poultry industries and is high in xanthophyll, a yellow pigment which imparts yellow color to poultry meat and eggs. Corn gluten meal is a high bypass protein source and although expensive may be useful in beef diets that require bypass protein, such as rations for lightweight calves.

Condensed Steepwater Solubles

Condensed steepwater solubles are an excellent source of soluble protein for liquid beef supplements. Most condensed steepwater solubles are used in corn gluten feed; however, it has the consistency of molasses and can also be used in liquid supplements. This product is about 25% protein and can be extremely high in phosphorous and sulfur.

Nutrient Values

Table 1 shows the average of reported nutrient values for common dry milling corn coproducts. The average mineral concentrations separated by fat levels of dry milling corn coproducts are shown in Table 2. Unless otherwise noted, the values were derived from commercial lab analysis of samples collected from ethanol plants and beef producers across the state. Table 3 lists the average nutrient values of select wet milling corn coproducts.

In general, coproducts from both the wet and dry milling processes concentrate many of the nutrients of corn into a nutritious, palatable livestock feed. Please note that the nutrient values listed in Table 1 are average values from samples collected in Iowa, and variation does exist, especially from plant to plant and region to region. Routine feed analysis is an important management practice. The exception may be the energy value; it is important to note that the energy values in these tables are derived from the results of cattle performance trials (Lundy and Loy, 2014: IBCR 200B). Using these energy values will typically be more accurate than calculated energy values from nutrient composition alone.

Due to the variation of processing methods, distillers grains are becoming more commonly defined as ***normal***, ***low fat***, or ***de-oiled*** distillers grains based on the amount of fat in the coproduct. Normal distillers grains generally have between 9%–14% fat and are a product of the traditional ethanol process where no corn oil extraction has occurred.

When the solubles are centrifuged off prior to being added back to the stillage, low fat distillers grains are produced and generally contain between 5%–8% fat. De-oiled distillers grains are usually a product of oil extraction through a solvent procedure, and typically result in a 2%–6% fat product.

For beef cattle in Iowa, distillers grains have proven to be a viable alternative to feeding corn as well as an excellent source of protein, energy, and several minerals. Ruminal protein degradability is important in some cattle diets (Lundy and Loy, 2014: IBCR 200B) and can differ due to moisture and even oil content of distillers grains (typical range 40%–60% rumen degradable protein). Some feed laboratories now include an in vitro test for rumen protein degradability. In some diets, the concentration of certain minerals such as sulfur and phosphorous and other nutrients may be excessive and require special management. For more information on sulfur effects on beef cattle related to corn coproducts, see Drewnoski et al., 2014: IBCR 200F.

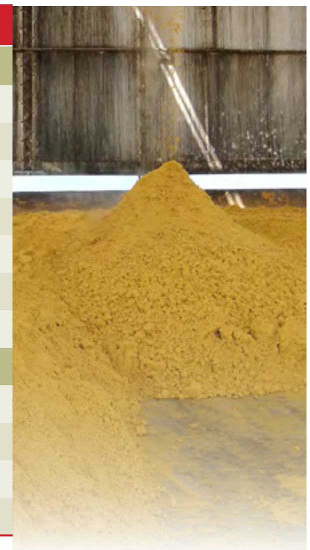
Table 1. Nutrient value of selected dry corn milling coproducts (%, dry matter basis)[1]

	DDGS[2]			MDGS[3]		WDGS[4]			CCDS[5]	
	Normal[6]	Low fat[7]	De-oiled[8,9]	Normal	Low fat	Normal	Low fat	De-oiled[10]	Normal	De-oiled
Dry matter	91.76	89.66	89.25	49.03	49.27	35.47	38.04	33.01	34.26	33.17
Crude protein	30.13	31.41	27.86	30.83	31.57	30.97	32.63	34.67	17.00	24.46
Starch	2.69	4.72	–	2.68	2.55	3.55	4.77	–	–	–
Fat	9.71	7.36	3.57	10.56	7.63	11.49	7.78	2.72	22.60	9.59
ADF[11]	13.90	12.35	16.91	11.89	13.93	13.92	17.46	14.14	–	–
NDF[12]	28.12	26.69	33.75	26.62	26.40	26.63	31.28	34.08	–	–
Ash	5.40	4.99	4.64	5.67	6.26	5.65	3.97	2.33	8.67	9.40
TDN[13]	93.00	90.80	88.20	97.00	94.20	100.00	96.70	93.50	104.00	94.80
NEm[14], *mcal/lb*	1.05	1.03	0.99	1.11	1.07	1.15	1.10	1.06	1.20	1.08
NEg[15], *mcal/lb*	0.77	0.74	0.72	0.80	0.77	0.93	0.80	0.77	0.87	0.78

1 Values reported are an average of distillers grains samples collected from Iowa ethanol plants and beef producers unless otherwise noted
2 Dried distillers grains plus solubles; normal, *n* = 5; low fat, *n* = 8
3 Modified distillers grains plus solubles; normal, *n* = 9; low fat, *n* = 3
4 Wet distillers grains plus solubles; normal, *n* = 4; low fat, *n* = 7
5 Corn condensed distillers solubles; normal, *n* = 1; de-oiled, *n* = 6
6 9%–14% fat
7 5%–8% fat
8 2%–6% fat
9 Values reported from Swine NRC (2012)
10 Values reported from Poet Dakota Gold (2013)
11 Acid detergent fiber
12 Neutral detergent fiber
13 Total digestible nutrients. Calculations for normal oil levels based on feeding trial values (Bremer et al., 2011), adjusted for relationship to energy values and oil content (Lundy and Loy, 2014: IBCR 200B)
14 Net energy required for maintenance. Calculations for normal oil levels based on feeding trial values (Bremer et al., 2011), adjusted for relationship to energy values and oil content (Lundy and Loy, 2014: IBCR 200B)
15 Net energy required for gain. Calculations for normal oil levels based on feeding trial values (Bremer et al., 2011), adjusted for relationship to energy values and oil content (Lundy and Loy, 2014: IBCR 200B)

Table 2. Mineral concentrations of dry corn milling coproducts based on fat levels[1]

	Normal[2]	Low fat[3]	De-oiled[4, 5]
Macro, % dry matter basis			
Calcium	0.06	0.05	0.03
Chlorine[6]	–	30.83	–
Phosphorus	0.98 (0.81 – 1.11)[7]	0.84 (0.59 – 1.14)[7]	3.55
Magnesium	0.38	0.32	0.15
Potassium	1.39	1.17	0.42
Sulfur	0.75 (0.39 – 1.26)[7]	0.67 (0.21 – 0.96)[7]	0.67
Sodium	0.20	0.19	0.06
Micro, ppm			
Copper	5	6	9
Iron	82	147	80
Manganese	17	17	8
Zinc	70	52	47



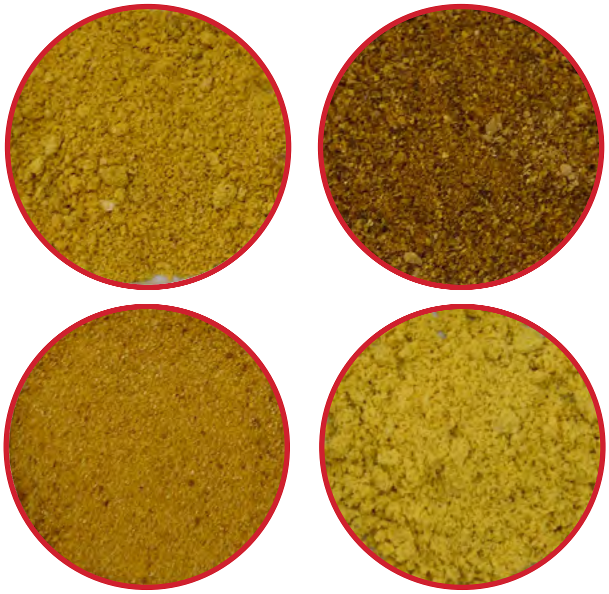
[1] Values reported are an average of distillers grains samples collected from Iowa ethanol plants and beef producers unless otherwise noted
[2] 9%–14% fat, *n* = 18
[3] 5%–8% fat, *n* = 18
[4] 2%–6% fat
[5] Source: Poet Dakota Gold (2013)
[6] No analysis values reported for normal and de-oiled
[7] Average concentration (range of reported concentrations)

Table 3. Nutrient value of selected wet corn milling coproducts (%, dry matter basis)[1]

	Corn gluten meal	Dry gluten feed	Wet gluten feed	Steepwater solubles
Dry matter	90	87 – 90	42 – 60	50
Crude protein	60	18 – 22	12 – 20	23
Fat	2.5	2 – 5	1 – 4	–
ADF[2]	5	13	11 – 14	–
NDF[3]	–	35	35 – 44	–
Ash	1.8	6.5 – 7.5	4	8
TDN[4]	75	80	80 – 82	91
NEm[5], *mcal/lb*	0.81	0.88	0.88 – 0.91	1.03
NEg[6], *mcal/lb*	0.59	0.64	0.64 – 0.66	0.89
Macro, % dry matter basis				
Calcium	0.07	0.05	0.03 – 0.10	0.40
Phosphorus	0.48	1	0.50 – 1.00	1.80
Potassium	0.20	1.50	0.90 – 1.50	2.40
Magnesium	0.08	0.50	0.30 – 0.50	0.80
Sulfur	0.65	0.30	0.30 – 0.50	0.60
Sodium	0.06	0.15	0.10	0.11
Micro minerals, *ppm*				
Copper	24	13	4 – 10	15
Iron	282	363	72 – 120	110
Manganese	7	58	12 – 20	29
Zinc	31	250	45 – 75	70

[1] Sources: Corn Refiners Association (2006), ADM (2008), and Loy and Wright (2003)
[2] Acid detergent fiber
[3] Neutral detergent fiber
[4] Total digestible nutrients
[5] Net energy required for maintenance
[6] Net energy required for gain

Various Distillers Grains



The variation of nutrient composition of distillers grains between ethanol plants in Iowa has become a challenge for beef producers. Therefore, it's important for producers to work closely with their nutritionist and coproduct suppliers and have up-to-date nutrient analysis of their coproducts used in rations to ensure consistent delivery of feed to their animals to optimize performance.

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