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Maize is a critically important source of food, feed, energy and forage in the USA

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ABSTRACT

Maize production in the U.S. was about 316 million metric tons in 2010. That amount is expected to increase in the future due to greater yields/hectare and more hectares planted. From 1950 until 2006 the supply of maize grain was much greater than demand. Government programs supplemented farmers, enabling them to produce abundant amounts of maize grain at low prices. The low prices of maize grain encouraged feeding large amounts to livestock and poultry. As late as 2000, 60% of maize grain produced was fed to livestock and poultry. The development of the fuel ethanol industry has changed both the price of maize grain and the usage by livestock and poultry. In 2010 only 42.9% of U.S. maize grain was fed to livestock and poultry while 41.8% was used for fuel ethanol production, and 11.2% for food. There are two byproducts from fuel ethanol production that replace some of the maize grain, especially in cattle production—distillers grains and maize gluten feed. Both of these byproducts are very well utilized by cattle. Depending upon plant production logistics, distillers grains has 110–140% the feeding value of the maize grain replaced and maize gluten feed has 100–110% the feeding value of maize grain. Values are less for lactating dairy cows but both byproducts serve as excellent protein sources. Byproducts replace 35–45% of the maize grain used to produce fuel ethanol. Essentially all of the cattle in the U.S. are "finished" on diets containing 80–85% concentrates. In the past the concentrates were comprised primarily of maize grain but now are a mixture of maize and byproducts. In the US the forage part of the corn plant is utilized in three ways. Some is harvested as whole plant maize silage. The silage is used as both an energy source and a roughage source in feedlot diets. Maize silage is also used to "background" cattle. This term is used to describe a growing phase based on forages prior to cattle being placed on "finishing" diets. The second use of maize forage (referred to as residue) is residue harvest after grain harvest and fed as a roughage source in finishing diets or mixed with wet byproducts and fed as an energy source to "background" cattle or beef cows. The other use of the maize "residue" is through grazing after grain harvest. Beef cows or backgrounding calves are placed on the maize fields after grain harvest where they select the higher quality forage components and any residual grain left in the field after harvest. Residual grain in residue is of high quality and selected first by the cattle. The husk is palatable and highly digested while the leaf is palatable but not as digestible. Quality of the diet declines with time of grazing because the higher quality parts are selected first. Generally, about 15% of the residue is consumed leaving 85% for erosion control and soil organic matter. Under this system beef cows need little supplementation while growing calves need supplementation of both protein and energy to yield economical growth.

1. Historical increase in corn production

In 1935, 33.4 million ha of maize were harvested in the U.S., mostly by hand. The average yield was 1519 kg/ha for a total of 50.9 million metric tons production (NASS, 2010). Farms were small, labor requirements were high and most farms had several livestock species including some cattle. From 1935 to 1945 the U.S. became engaged in a World War which dramatically increased food demand. At the same time hybrid seed maize was being produced and sold commercially and the Haber–Bosch technology was being utilized to produce nitrogen fertilizer for maize. By 1950, maize acres had declined but yields had increased to 2400 kg/ha and total production had increased to 60 million metric tons.

Because of the "war effort" to produce maize and because of technological developments, maize production exceeded demand. In 1956, the U.S. government addressed the "farm problem", excessive maize grain, by encouraging farmers to "Soil Bank" cropland,

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paying them to not produce maize. The same farmers realized that it was profitable in most cases to feed the inexpensive maize grain to cattle—marketing the maize through the cattle. Feeding the maize grain to beef cattle led to the "high quality" beef that U.S. consumers have become accustomed to.

Until 2006, the "farm problem" was too much maize grain. The inexpensive maize further encouraged cattle feeding with segmentation of the cattle feeding into feedlots, separating it from farming. For example, about 3.3 million cattle were fed for harvest (finished) in 1965 in Iowa. At the time, only 3.9% of the cattle were produced in feedlots of 1000 head capacity or larger. By 1980, about 2.7 million cattle were finished in Iowa of which 37.6% were finished in feedlots of 1000 head capacity. Over the same period, the number of cattle finished yearly in Texas increased from 1.1 million in 1965 to 4.2 million in 1980 with 98.7% in feedlots over 1000 head capacity. In 2007, 84.5% of the U.S. cattle were fed in feedlots over 1000 head capacity, 73.2% in feedlots over 5000 head capacity and 60% in feedlots over 16,000 head capacity (NASS, 2010). This growth in cattle feeding was supported primarily by inexpensive maize grain. Americans are currently consuming 29 kg/person of "high quality" beef each year. This "high quality" beef is somewhat unique to the U.S. and a very few developed countries such as Japan. This beef (maize-fed) contains more fat than forage fed beef. Bradford et al. (1999) report that only 11.5% of the beef produced in the world is produced in "industrial" systems such as the feedyards in the U.S.

Maize production has continued to increase so that in 2006 the yield was 9103 kg/ha (149 bu/ac) and total production was 267 million tons (10.5 billion bushels). Because of technological advances, maize production has increased by nearly 125 kg/ha each year. With the growth of the ethanol industry and the anticipated expansion of that industry, the demand for maize has increased. During the last half of 2006, the price of maize grain increased from about \$79/metric ton to above \$157/metric ton. With more acres planted to maize and good yields, the price of maize grain in 2007 declined to \$118–148/metric ton. In the past year the price has risen to \$257/metric ton. Therefore, the cattle, swine and poultry industries are faced with the prospect of producing meat under the constraints of high priced maize after 60 years of "inexpensive maize". The "farm problem" has changed from too much maize to a debate of food versus fuel.

As late as 2000, 60% of maize grain produced was fed to livestock and poultry. The development of the ethanol industry has changed both the price of maize grain and the usage by livestock and poultry. In 2010, only 42.9% of U.S. maize grain was fed to livestock and poultry while 41.8% was used for fuel production and 11.2% for food (NASS, 2010). With 318 million tons of maize grain production and a U.S. population of 312 million, that is over one ton of maize grain produced per person or about 2.8 kg for each person daily. With wise allotment, this should be sufficient maize grain for food, feed and ethanol production.

2. Maize in livestock and poultry diets

Swine and poultry diets are based primarily on maize grain and soybean meal. Some distillers grains (DDGs) are being used but the diets for these species have not changed markedly. Because ruminants can utilize a greater variety of feedstuffs, including forage and byproducts, our discussion will focus primarily on beef and dairy cattle as they are the primary users of maize forages in addition to grain. Most of the beef cattle in the U.S. are "finished" on a diet containing large quantities of maize grain. Further, essentially all feedlots employ nutritionists to assist them in making decisions on diet formulation and purchase of feedstuffs. These nutritionists may be independent and paid for consulting services or they may be employed by a feed company and paid indirectly through the purchase of feed supplements. A few nutritionists are employed by the feedlot full-time. Most nutritionists have Ph.D. degrees and are critically important to the decision making process concerning maize purchase, usage and processing as well as substitution with byproducts.

Vasconcelos and Galyean (2007) surveyed nutritionists in the U.S. and the results give a general description of cattle feeding in the U.S. They reported that maize grain content of the feedlot diets was 75–80% of the diet dry matter. In a similar survey done in 2001, the mean value was 80% (Galyean and Gleghorn, 2001). The amount of roughage (forage) ranged from 4.5 to 13.5% of diet dry matter. Most common roughages were alfalfa hay and maize silage. Roughage levels had not changed from those reported in 2001.

Essentially all of the maize grain is processed (Vasconcelos and Galyean, 2007) with steam-flaking being the most common method of processing. Dry rolling and high-moisture maize grain harvest and storage are also common. The high-moisture maize grain is usually harvested at 26–30% moisture, rolled and placed in a bunker silo followed by covering with plastic. The majority of the U.S. feedlots are in the Plains States in the central part of the country. Steam flaking is used more commonly in the Southern Plains while high-moisture processing and storage and dry rolling is practiced more in the Northern Plains.

Maize is produced in most states but the greatest amounts are produced in the northern states (Corn Belt). Many of the cattle feedlots are located in the Southern Plains so there is a surplus of maize grain in the Corn Belt and a deficit in the Southern Plains. Therefore, maize grain is shipped to the Southern Plains, usually in 100 car unit trains. Because of the surplus of maize grain in the Corn Belt, the fuel ethanol industry developed in the Corn Belt states of Iowa, Nebraska, Minnesota and Illinois.

3. Maize use for ethanol

There are two processes for producing fuel ethanol from maize grain (Stock et al., 2000). The wet milling process was developed primarily to produce starch and sweeteners (maize sugar) for human consumption. Sweetener production continues but essentially all wet milling plants also produce fuel ethanol. In this process, maize oil and maize gluten meal are also produced. The resulting byproduct is maize gluten feed which contains the fiber from the maize kernel plus the steep liquor, the fermented liquid used in the initial steeping and washing processes (i.e. wet milling).

In the dry milling process, the maize grain is milled and the starch is hydrolyzed with enzymes and fermented with yeast to produce ethanol. The byproduct is distillers grains (DG) which can be marketed as a wet byproduct (30–35% dry matter; WDGs) or dried to produce dry distillers grains with solubles (88–92% DM; DDGs). In both wet and dry milling, the starch is converted to ethanol. The remaining byproducts are high in fiber, protein and, in the case of DDGs, lipid. Because it was perceived that the energy value of maize grain was due to the starch, it was assumed the byproducts would be lower in net energy than maize grain. Because of the higher protein contents of gluten feed and DG, they were used primarily as protein sources in ruminant diets. The maize byproducts are usually priced lower than maize grain and therefore could be economical sources of energy for cattle in addition to being good protein sources (Klopfenstein et al., 2008a).

Cattle are accustomed to eating moist feeds such as grass, silage and high moisture maize grain. Therefore, it was logical to feed the DG to feedlot cattle in the wet form. Bremer et al. (2011) reported a meta-analysis showing the response by feedlot cattle to increasing amounts of WDGs in the diet (Table 1). Daily gains and feed efficiency increased as the amount of WDGs increased in the diet. Based on the feed efficiency values for the diets, the feeding value