ABSTRACT
Nutrient composition of commercial corn grain appears to have changed little in the last 10 to 15 years. Although the data for sorghum grain and barley are more limited, no dramatic changes in nutrient composition were apparent. Flaking corn appears to reduce the crude protein concentrations, perhaps because water used for starch gelatinization is not released during drying. Harvesting and storing corn grain as high-moisture increases the protein solubility and rumen degradation of corn grain protein. In contrast, flaking corn decreases protein solubility and ruminal protein degradation. Flaking corn may increase phosphorus availability by increasing ruminal phytase activity.

INTRODUCTION
Nutrient composition of grains can be quite variable. Although the variation is less with grains than with forages or byproduct feeds, grains comprise the majority of most feedlot diets so small changes in nutrient composition become very important. The sources of variation in nutrient composition can be divided into processing and non-processing factors. Most of the processing effects relate to energy value of the grains. Because several speakers have discussed how processing variables affect the energy values of different grains, that topic will not be discussed here. Effects of processing on protein and mineral availability will be discussed later.

NON-PROCESSING VARIATION
Non-processing factors that can affect the nutrient composition of grains include, but are not limited to, year, variety, fertilization, and management factors. In the last 10 to 15 years grain producers have made substantial changes in varieties (genetics), fertilization programs, and management practices. This review will examine whether such changes have altered grain composition.

Grain nutrient composition data collected for the 1996 Beef NRC publication (NRC, 1996) were from grains produced in the early 1990s. Data were collected from approximately 40 different laboratories in North America. Grain samples from most states and Canadian provinces were included in that database. The Dairy One feed analysis laboratory in Ithaca, New York provides excellent public access to a database that can be used to examine nutrient variation. This laboratory receives grain samples from throughout the United States and Canada. These data have not been screened to remove outliers, so the standard deviations are greater than found in other data sources. The Dairy One data base is robust because it contains a large number of samples analyzed for many nutrients that were received between May 2000 and June 2006. All nutrients are expressed on a dry matter basis and can be accessed at http://www.dairyone.com/Forage/FeedComp/disclaimer.asp. Through comparing the nutrient composition data from the 1996 Beef NRC and the current Dairy One database, large changes in nutrient profile over the last 10 to 15 years can be detected.

Corn is the primary grain fed to cattle and has the largest number of samples in the data base. With over 3500 samples in both data sets, corn in the Dairy One data set averaged 9.51% crude protein; in the early 1990s corn averaged 9.80% protein (Table 1). Whether this is a trend or just random variation, is impossible to determine. However, when we select corn varieties for increased yield or alcohol production, a decrease in protein concentration would not be surprising.

Based on more than 2200 samples, corn NDF values also have tended to decrease (10.8% vs. 9.78%) during the past 15 years. Since most of the fiber is in the seed coat, it is possible that as we select for increased yield, kernel size could increase resulting in the seed coat being a smaller fraction of the weight.
Table 1. Current corn nutrient composition compared with that reported in the 1996 Beef NRC

<table>
<thead>
<tr>
<th>Item</th>
<th>Dairy One&lt;sup&gt;a&lt;/sup&gt;</th>
<th>1996 Beef NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Dry matter %</td>
<td>4135</td>
<td>90.32</td>
</tr>
<tr>
<td>Crude protein %</td>
<td>3578</td>
<td>9.51</td>
</tr>
<tr>
<td>Ether extract, %</td>
<td>1829</td>
<td>4.35</td>
</tr>
<tr>
<td>Neutral detergent fiber, %</td>
<td>2250</td>
<td>9.78</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>1923</td>
<td>0.04</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>1916</td>
<td>0.32</td>
</tr>
<tr>
<td>Magnesium, %</td>
<td>1902</td>
<td>0.12</td>
</tr>
<tr>
<td>Potassium, %</td>
<td>1906</td>
<td>0.41</td>
</tr>
<tr>
<td>Sulfur, %</td>
<td>1451</td>
<td>0.10</td>
</tr>
<tr>
<td>Zinc, ppm</td>
<td>934</td>
<td>23.6</td>
</tr>
<tr>
<td>Copper, ppm</td>
<td>934</td>
<td>2.83</td>
</tr>
<tr>
<td>Manganese, ppm</td>
<td>926</td>
<td>9.02</td>
</tr>
</tbody>
</table>

<sup>a</sup>http://www.dairyone.com.
<sup>b</sup>Standard deviation.

Mean mineral concentrations were very similar for corns raised in the early 1990s and those analyzed in more recent years (Table 1). In general, the standard deviations tended to be larger for the Dairy One data set than was reported in the 1996 Beef NRC. It is not known whether the mineral content of corn is becoming more variable, or whether some samples in the Dairy One data set may have been contaminated with other grains.

Sorghum grain is the second most common grain fed to cattle in the U.S. Because of the small number of samples analyzed, it is more difficult to detect compositional changes (Table 2). Mean crude protein has decreased from 12.6% in the 1996 Beef NRC to 10.35% in the current Dairy One database. With only 128 samples assayed for crude protein in the current data, one must be cautious about concluding that sorghum grain protein concentrations are decreasing. Mineral concentration data were not compared because of the small number of samples analyzed.

Table 2. Current sorghum grain nutrient composition compared with that reported in the 1996 Beef NRC

<table>
<thead>
<tr>
<th>Item</th>
<th>Dairy One&lt;sup&gt;a&lt;/sup&gt;</th>
<th>1996 Beef NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Dry matter, %</td>
<td>147</td>
<td>89.07</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>128</td>
<td>10.35</td>
</tr>
<tr>
<td>Ether extract, %</td>
<td>58</td>
<td>3.46</td>
</tr>
<tr>
<td>Neutral detergent fiber, %</td>
<td>109</td>
<td>11.43</td>
</tr>
</tbody>
</table>

<sup>a</sup>http://www.dairyone.com.
<sup>b</sup>Standard deviation.

Barely is fed commonly to cattle in the Northern U.S. and Canada. Mean crude protein concentrations of barely decreased from 13.20 to 12.72% between the early 1990s and the current samples (Table 3). With 769 and 1884 samples for the Dairy One and Beef NRC data sets respectively, this difference may be of actual trends. In contrast, mean NDF concentrations tended to increase (18.10 vs. 19.49%) over the past 15 years. Drought stress that has occurred in the barley producing areas of the U.S. the past few years may explain this trend.
Table 3. Current barley nutrient composition compared with that reported in the 1996 Beef NRC

<table>
<thead>
<tr>
<th>Item</th>
<th>Dairy One(^a)</th>
<th>1996 Beef NRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Dry matter, %</td>
<td>992</td>
<td>90.04</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>769</td>
<td>12.72</td>
</tr>
<tr>
<td>Ether extract, %</td>
<td>492</td>
<td>2.56</td>
</tr>
<tr>
<td>Neutral detergent fiber, %</td>
<td>627</td>
<td>19.49</td>
</tr>
</tbody>
</table>

\(^a\)http://www.dairyone.com.

\(^b\)Standard deviation.

PROCESSING VARIATION

Processing of grains would not be expected to change nutrient concentrations. However, analysis of 3,578 samples of cracked corn, 10,350 samples of high-moisture corn, and 278 samples of flaked corn, revealed, crude protein concentrations that averaged 9.51, 9.18, and 8.38%, respectfully in the Dairy One database. Flaking should not volatilize nitrogen resulting in a reduction in crude protein. However, testimonials indicate that flaking will lower crude protein concentrations. It is possible that during starch gelatinization, water is added to the starch matrix that is not lost during drying. Measured as an increase in dry weight, this would dilute the nitrogen and thereby reduce the crude protein concentration. An increase in mass of 13.5% would be required to dilute the protein from 9.51 to 8.38%. An increase in weight of this magnitude seems unlikely. The relatively low number of flaked corn samples (278) may be part of the explanation. However, region of origin of the flakes, selection for high test weight, using high starch hybrids for flaking, scalping of grain prior to flaking, and un-representative sampling of flakes, also might be involved.

Storage and processing of grains can affect the degradation of protein in the rumen. Using in the *Streptomyces griseus* enzymatic digestion procedure (Dairy One, 2006), rumen protein degradation for 1,027 samples of cracked corn, 7,299 samples of high-moisture, and 74 samples of flaked corn averaged 31.5, 41.8 and 25.8%, respectfully (Dairy One, 2006). In the 2001 Dairy NRC (NRC, 2001), readily degraded “A” fraction proteins were estimated to comprise 23.9, 27.9 and 1.7% of the protein in cracked, high-moisture, and flaked corns, respectfully.

Little data in the scientific literature shows grain processing changes the amount or availability of other nutrients. However, this may not always be the case. Guyton et al., (2003) showed that dairy cows fed steam flaked corn had greater ruminal phytase activity resulting in less phosphorus being excreted in the feces compared to cows fed dry ground corn. Using rumen fistulated cows they found that flaking the corn increased the degradation of phytate added to the rumen. The mechanism by which flaking corn might increase ruminal phytase activity is not known.

LITERATURE CITED


QUESTIONS AND ANSWERS

Q: Larry, do you believe the Dairy NRC with regard to availability of protein from flaked grain for the A, B, and C fractions you mentioned? I assume that these were determined in situ and they seem questionable to me. Protein in the lower 8’s for flaked grain seems reasonable based on geographical issues, but if 15% of the protein is not digestible, that doesn’t leave much for the animal.

A: The C fraction is 15% of the total crude protein. With 9 or 10% protein in corn, 1.5% protein would be indigestible. Those numbers are a percent of the total protein. Those numbers presumably are a result of a literature review of a variety of work, some being animal work and some being solubility work. One can argue how much variation there is and how repeatable those numbers are.
Q: Larry, if you consider the response of steam flaked corn diets to high urea levels, a higher level of the C indigestible protein fraction makes sense.

A: Excellent point. Others here will be discussing the impact of distillers’ grains and possible associative effects with different grain processing methods. If we are supplementing flaked grain with high ruminal starch availability but low protein availability with something like distillers’ grains that have slow protein degradability in the rumen, it makes sense that we may restrict digestion in the rumen. Part of the interaction between grain processing (flaking) and utilization of high fiber byproducts with lower values with flaked grain may relate to the slow rate of ruminal protein degradation from grain byproducts.

Q: Larry, how much of the difference between the flaked and normal grain in starch and protein content is due to sampling problems with flaked grain? Based on personal sampling of these materials, as one grabs a sample of the flaked grain, the fat content often is only half that of the whole grain before it is flaked. How much of a problem is sampling of flaked grain?

A: Sampling always is an issue. Certainly, labs only can analyze the sample that is submitted. Sampling is of concern, particularly when small amounts are submitted. DairyOne appears do to an excellent job of subsampling and analysis. Certainly, sampling is a greater problem with flaked than whole grain or ground grain. Sampling presents an error that is hard to characterize.

Q: Larry, we see similar reductions in the field when we compare protein level in whole grain and compare it to protein level in flaked grain. Starch chemists indicate that at 100% gelatinization, one may gain 8% to 10% dry matter as starch. If we have 50% gelatinization with flaking, the increased starch content can be causing that reduction in protein because protein will be a smaller piece of a larger pie. I personally question that idea, but if that is not happening, someone needs to explain how I can take a 14% whole corn and add 6% moisture to it but come up with a 9 to 10% inventory gain when none of my other commodities are out of whack. So I have to believe that the starch content grows during flaking, as bizarre as that sounds.

A: Protein is simply measured as Kjeldahl nitrogen. Unless we are changing nitrogen by processing the starch, I don’t know why changes in gelatinization of the starch structure should affect the amount of nitrogen. To my knowledge, there is no reason believe that steam flaking will volatilize nitrogen. Only 279 samples are in this data set, so some differences may be due to the relatively small number of samples in the data set. We may be changing the starch structure, but that should not change the nitrogen level of the grain.

Additional comment from Tim McAllister: The questioner has a good point. This may relate to my discussion about how enzymes degrade starch. An enzymatic procedure is used to measure starch. Gelatinized starch is more susceptible to enzymes, so recovery will be greater for material that is more gelatinized. Anybody who has attempted to measure starch in the laboratory can attest that starch analysis is not a simple procedure; one does not get consistent results from sample to sample.