RESEARCH REPORT

ANIMAL SCIENCE

Title: Defining the energy content (DE, ME, and NE) of drought-stressed corn and identifying risk factors that lower energy – **NPB #12-193**

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Industry summary:

Record-breaking heat and lack of rainfall during the 2012 growing season resulted in drastically reduced corn yield and the prospects of a very poor quality corn crop. Unfortunately, there was no information in the literature describing the nutritional value of drought-stressed corn fed to growing pigs. It was impossible to provide the feed and pork industries with recommendations on the feeding of drought-stressed corn. Therefore, the objective of this study was to develop information on drought-stressed corn and make it available to the feed and pork industries. Because corn is a major source of energy in pig diets, energy was the focus of this study. We used 28 corn samples from the 2012 crop which were collected across the Midwest using yield as an initial screen for drought impact. Yields ranged from <50 to >200 bu/acre. It was assumed that corn collected from low yield fields would be the most drought-stressed and thus provide us with the best range of samples to support our evaluation. Additionally, 2 corn samples from the 2011 crop were used in this study to serve as controls. Each corn sample was screened for mycotoxins, tested for 1,000 kernel weight and NIR values, and graded by an official U.S. grain inspection agency before use in this study. Corn samples were analyzed in the lab for neutral detergent fiber (NDF), crude protein (CP), and fat (EE) content. A total of 60 individually-housed barrows with an average initial weight of approximately 35 kg were randomly assigned to one of the 30 diets. This was repeated 4 times to provide 8 observations per treatment. Diet and fecal samples were analyzed in order to determine digestible energy (DE) content of the corn samples. Metabolizable energy (ME) and net energy (NE) were then calculated using equations provided by the NRC. Relationships were evaluated between DE and a variety of measured traits including: NIR values, yield, test weight, 1,000 kernel weight, total damaged kernels, broken kernels and foreign material, NDF, EE, and CP.

The mean DE content of the 2011 and 2012 corn samples were 3.72 and 3.68 Mcal/kg of dry matter (DM), respectively, and varied among samples by approximately 8%. The mean ME content of the 2011 and 2012 corn samples were 3.50 and 3.47 Mcal/kg DM, respectively, and varied among samples by approximately 5%. The mean NE content of the 2011 and 2012 corn samples were 2.61 and 2.57 Mcal/kg DM, respectively, and varied among samples by approximately 8%. Test weight, broken kernels and foreign material, density (measured using NIR), starch (measured using NIR), and fat (measured using both NIR and wet chemistry) were similar for both 2011 and 2012 crop samples. CP did tend to be slightly higher in the corn grown in 2012 (9.18%) compared with the 2011 control samples (8.56%). Neutral detergent fiber was significantly higher in

the corn grown in 2012 (8.19%) when compared with 2011 (6.92%). Total damaged kernels were also significantly higher in the 2012 (1.65% vs 0.90). Mean 1,000 kernel weights of the 2011 and 2012 corn samples were 338 and 284 grams, respectively, and varied among samples by approximately 120%. Yield, the criterion used for the initial screening of drought-impact on the corn, ranged from 39 to 236 bu/acre among samples. Overall, there were no major differences in energy values (DE, ME, NE) between the 2011 control samples and the 2012 samples when fed to growing pigs. The variation in energy of corn grown under drought-stressed conditions was no different than what we expect to see in variation during a "normal" year. Additionally, no relationships were found between DE and any corn quality measurement, physical or chemical, which may be due to only observing relatively small variation in energy digestibility among the corn samples. Therefore, we can conclude that corn grown under drought-stressed conditions, irrespective of yield, can be utilized in swine diets and fed the same as corn grown under "normal" conditions without concern of large energy differences. This agrees with the industry remarks that performance problems were not observed when feeding corn grown in 2012.

Keywords:

Corn, drought, digestibility, energy, pigs

Scientific abstract:

Record-breaking heat and lack of rainfall during the 2012 growing season resulted in drought-stressed growing conditions. An experiment was conducted to investigate the impact of these conditions on nutrient composition and energy (DE, ME, and NE) in corn, and determine if relationships exist between corn quality measurements, nutrient content, and digestibility of energy. Twenty-eight samples of corn from the 2012 crop, plus 2 samples of corn from the 2011 crop to serve as a positive control, were collected across the Midwest using yield as an initial screen for drought impact. Yields ranged from <50 to >200 bu./acre. Each sample was graded by an official U.S. grain inspection agency and analyzed for 1,000 kernel weight, NIR values, EE, NDF, and CP content. Diets were formulated using each of the 30 corn samples plus vitamins, minerals, and 0.4% titanium dioxide as an indigestible marker. Diets were fed at a level of approximately 2.6 times the estimated energy required for maintenance (NRC 2012) based upon the average initial BW of the pigs at the beginning of 4 collection periods. Each of the 4 collection periods consisted of 6 days adjustment to the test diet followed by 3 days of fecal sample collection followed by 5 days of feeding a fully balanced grower diet; the latter was fed to ensure that the low amino acid test diets did not impair digestion functions in subsequent collection periods. Sixty individually-housed barrows (PIC 359 X C29; initial BW=34.2±0.18 kg) were randomly allotted in an incomplete crossover design with 30 diets and 4 periods. Diet and fecal samples were analyzed for DM, titanium dioxide, and GE in order to determine DE values. ME and NE values were then calculated from DE values using methods developed by Noblet and Shi (1993) and Noblet *et al.* (1994) respectively. Mean DE, ME, and NE values between the 2011 and 2012 corn samples were not different (3.72 vs. 3.68 Mcal/kg respectively, $P>0.10$; 3.50 vs. 3.47 Mcal/kg respectively, $P>0.10$; and 2.61 vs 2.57 Mcal/kg respectively, $P>0.10$). Comparing 2011 with 2012, there were no statistically significant differences in EE (4.07% vs 3.96%; $P>0.10$), CP (8.56 vs 9.18%; $P>0.10$), or starch (70.5 vs 69.5%; $P>0.10$). However, NDF was higher in the 2012 corn samples (8.19%) when compared to 2011 (6.92%); $P=0.0154$. The percentage of total damaged kernels tended to be higher in the 2012 corn (1.65%) as compared to 2011 (0.90%); $P=0.684$. There were no differences in any of the other physical characteristics measured. There were very weak correlations between both NDF and DE (R^2= -0.26; $P=0.008$) and between density and DE (R^2=0.26; $P=0.007$). No other relationships were found between any single corn quality measurement, physical or chemical, and DE ($P>0.10$). In conclusion, energy of corn grown under drought-stressed conditions was not different from corn grown in the previous year under "normal" conditions.

Introduction:

Record-breaking heat and lack of rainfall during the 2012 growing season resulted in drastically reduced corn yield predictions and the prospects of a very poor quality corn crop. Severe stress during the corn grain fill period can result in kernel abortion and/or low yields. Stress during grain fill results in potentially lower starch concentration in kernels, which would likely result in lowered energy digestibility when fed to swine; however, this reduction has not been quantitatively evaluated.

Objectives

The overall objective of this study was to develop sound, quantitative data on the feeding value of corn that has a reduced test weight due to drought stress.
Specific objectives:

1) To determine the energy, nutrient composition, and digestibility of energy of low weight corn fed to growing pigs.
2) To determine if relationships exist between corn quality measurements, nutrient content, and digestibility of energy.

Modifications of objectives from original proposal: Upon the initial search for drought-stressed corn samples based upon test weights, we found that corn samples did not vary. This was due to test weight being based on a volumetric sample. Therefore, we decided to change our initial selection criterion for drought-stress to be based upon yield (bu./acre). We categorized level of drought stress for the initial selection based upon yields ranging from <100, 100-125, 125-150, 150-175, and >175 bu/acre. Care was taken to select roughly the same number of samples from each category.

Materials & Methods:

The protocol for this experiment was approved by the Institutional Animal Care and Use Committee of Iowa State University. U.S. 9-12-7441-S

Animals, Housing and Experimental Design:

This experiment was conducted in room 102 at the Iowa State University Swine Nutrition Farm. 60 individually-housed crossbred barrows (PIC 359 × C29; initial BW = 34.2±0.2 kg) were randomly allotted to an incomplete crossover design with 30 diets and 4 periods. Through the 4 periods, no pig received the same diet twice. Each period consisted of 6 days adaptation to treatment followed by 3 days of fecal collection. Pigs were fed a fully balanced grower diet for the 5 days between each replicate to ensure that the low amino acid test diets did not impair digestive function in subsequent collection periods. Water was provided *ad libitum* throughout the experiment. Test diets were fed at a level of about 2.6 times the estimated energy required for maintenance (NRC, 2012) based upon the average weight of the pigs at the beginning of each collection period.

Dietary treatments:

Approximately 40 corn samples were collected from across the Midwest using yield as an initial screen for drought-stress. Corn samples were collected as evenly as possible within the following yield (bu./acre) categories: <100, 100 to 125. 125 to 150, 150 to 175, >175. The 40 samples were then tested by the Iowa State University Veterinary Diagnostic Laboratory for aflatoxin contamination, and any sample exceeding 20 ppb was discarded. Additionally, each sample was graded by an official US grain inspection agency for moisture content, test weight, total and heat-damaged kernels, and broken and foreign material. Dr. Hurburgh then tested the samples for 1,000 kernel weight and density. 28 corn samples from the 2012 crop and 2 corn samples from the 2011 crop (to serve as controls) were then selected for use in this study.

Thirty diets were formulated using one of each of the corn samples plus vitamins, minerals, and 0.4% titanium dioxide as an indigestible marker. Vitamins and minerals were supplied at levels formulated to exceed the requirements of 30- to 60-kg pigs as defined by NRC (2012).

Data and Samples:

Diet and fecal samples were homogenized, dried (fecal samples only), ground, and analyzed for: dry matter by drying overnight, titanium dioxide by spectrophotometry, and energy by bomb calorimetry. Diet samples alone were assayed for CP, EE, ADF, NDF, and starch. Apparent total tract digestibility coefficients and DE values were then calculated. ME and NE values were calculated from DE using the methods of Noblet and Shi (1993) and Noblet *et al.* (1994) respectively.

Statistical Analysis:

Data were analyzed using the MIXED procedure of SAS (Version 9.3; SAS Inst., Cary, NC). The individual animal and corn sample were the experimental units for analyzing the data from the digestibility trial and analysis of the chemical constituents, respectively. Correlation coefficients were reported using Pearson coefficients. Differences were considered statistically significant with $P < 0.05$ and trends with $P < 0.10$.

Results:

Objective: *To determine the energy, nutrient composition, and digestibility of energy of corn grown under drought-stressed conditions when fed to growing pigs.*

Mean DE, ME, and NE values for the corn grown under drought-stressed conditions in 2012 were 3.68, 3.47, and 2.57 Mcals/kg, respectively, which did not differ from our control samples (P>0.10). The variation among samples in DE, ME, and NE were approximately 8, 5, and 8% respectively. Mean CP, EE, NDF, and starch for the drought-stressed corn were 9.18, 3.96, 8.19, and 69.5% respectively. Samples varied in CP by 39%, EE by 66%, NDF by 44%, and starch by 6%. Mean ATTD of energy for the corn grown under drought-stressed conditions was 83.1% and varied by approximately 6%.

Objective: *To determine if relationships exist between corn quality measurements, nutrient content, and digestibility of energy in corn grown under drought-stressed conditions.*

There were very weak correlations between both neutral detergent fiber and DE (R^2= -0.26; P=0.008) and between density and DE (R^2=0.26; P=0.007). No other relationships were found between any single corn quality measurement, physical or chemical, and DE (P>0.10).

Discussion:

Drought-stressed growing conditions in 2012 resulted in a large variation in numerous corn quality measurements. Many fields yielded much lower than would be expected in a typical year, and 1,000 kernel weights varied by approximately 120%. However some quality measurements, such as test weight, did not appear to be affected by the drought conditions in 2012. Despite the large variation in some quality measurements, energy content and digestibility of energy did not appear to be correlated. This suggests that energy content cannot be estimated using yield or any other quality measurements that were measured in this study.

The energy content of the corn grown in 2012 did not differ significantly from what we would expect to see in a typical year. Additionally, the variation in energy content (5-8%) among corn samples that year did not differ from what would be observed in a "normal" year. This agrees with the industry remarks that performance problems were not observed when feeding corn grown in 2012 to growing pigs. Interestingly, this is different from what was observed by the industry in 2009, an abnormally wet year, when many performance problems were reported.

Most nutrients were observed in similar concentrations in the 2012 corn samples as compared to the 2011 control samples with the exception of NDF and CP, which tended to be higher in the 2012 corn. However, when nutrient concentrations are compared to a larger database, such as the NRC, all mean 2012 nutrient values are either comparable to those reported in the NRC, or are within the standard deviation that is reported.

Overall, we can conclude that corn grown in drought-stressed conditions is comparable in energy and nutrient concentration to corn grown in a "normal" year. Despite lower quality measurements, such as yield or 1,000 kernel weight, feeding values appear to remain unaffected. Therefore, corn grown under drought-stressed conditions can be utilized in swine diets and fed the same as corn grown in a "normal" year

Implications

- No correlation was observed between yield and energy content, meaning corn from fields yielding <50 bu/acre were no different in energy content than corn from fields yielding <200 bu/acre. Therefore, yield is not a good proxy for energy content of corn grown under drought-stressed conditions and at least for the 2012 crop year, drought stress did not reduce the energy content of corn.

- Corn grown in a drought-stressed year can be utilized in swine diets and fed to pigs without concern for large energy or digestibility differences as compared to a "normal" year, which agrees with the industry remarks that performance problems were not observed when feeding corn grown in 2012.

- The variation in energy (DE, ME, and NE) of corn grown in a drought-stressed year is no different than what we would expect in variation during a "normal" year.

Table 1.1. Nutrient, chemical, and physical composition of corn samples

Item	2011 crop	2012 crop	2012 range	SEM	*P*-value
n	2	28	--	--	--
ATTD of GE, %	84.3	83.1	80.6 – 85.6	0.81	0.15
CP, %	8.56	9.18	7.98 - 11.07	0.379	0.11
EE, %	4.07	3.96	2.91 - 4.83	0.183	0.58
NDF, %	6.92	8.19	7.02 - 10.14	0.489	0.0154
Starch, % (NIR)	70.5	69.5	67.4 - 71.6	1.203	0.40
Protein, % (NIR)	8.52	9.38	8.01 - 11.28	0.738	0.26
Oil, % (NIR)	4.03	3.94	3.39 - 4.44	0.261	0.75
Density, g/cc	1.27	1.27	1.26 - 1.30	0.024	0.90
1000 kernel wt., g	337	284	176 - 386	55.8	0.34
Test wt., lbs./bu.	59.3	58.6	55.3 - 61.0	1.500	0.64
TDK, %	0.90	1.65	0.2 - 7.9	0.398	0.0684
BCFM, %	0.75	0.71	0.2 - 2.0	0.657	0.95
Yield, bu./acre	--	127	39 - 236	--	--

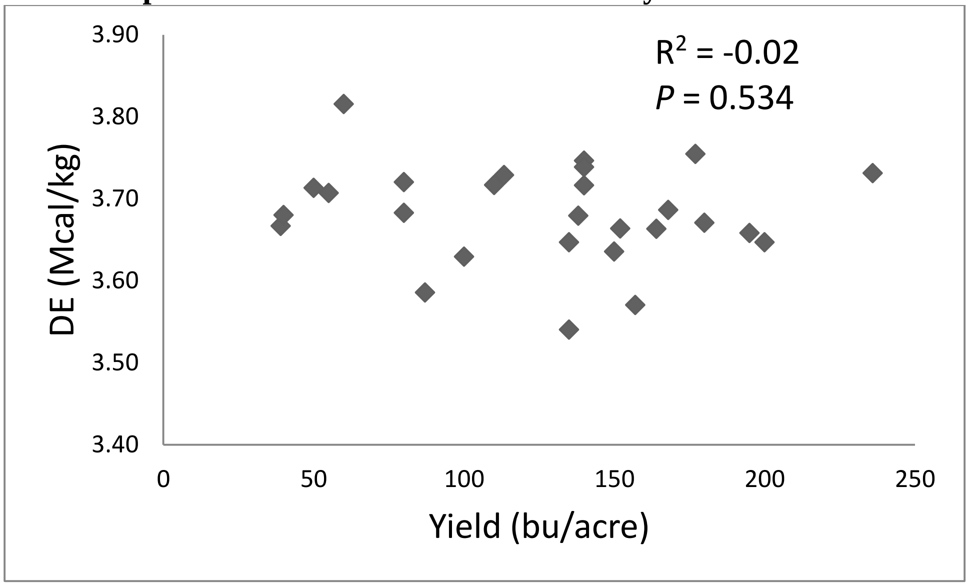
[1]All percentage values presented on a dry matter basis

Table 1.2. Energy values of corn samples

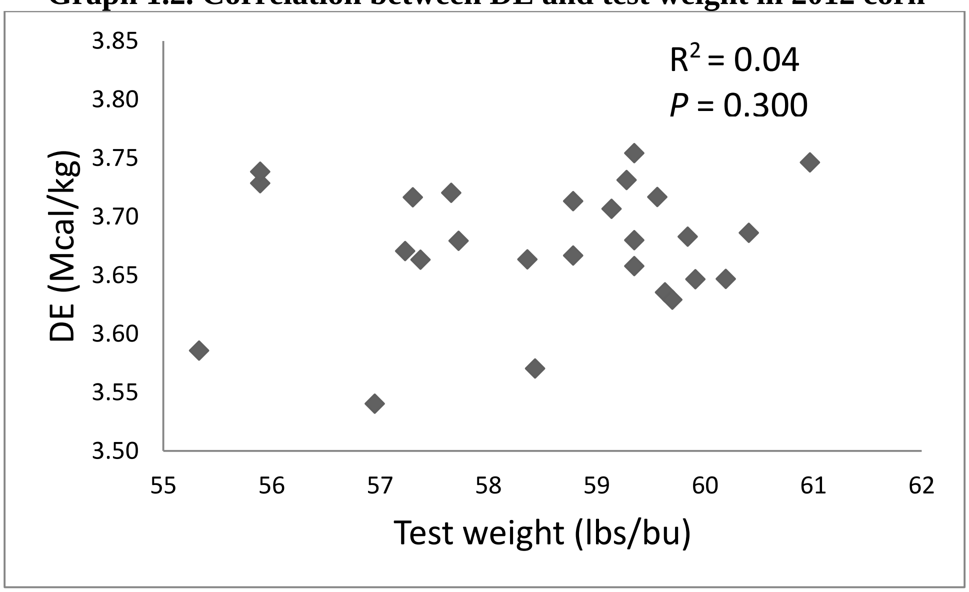
	2011 crop	2012 crop	2012 range	SEM	*P*-value
DE, Mcal/kg[1]	3.72	3.68	3.54 – 3.82	0.042	0.36
As-fed	3.34	3.30	3.18 – 3.43		
ME, Mcal/kg[1,2]	3.50	3.47	3.38 – 3.56	0.027	0.27
As-fed	3.14	3.12	3.03 – 3.20		
NE, Mcal/kg[1,3]	2.61	2.57	2.46 – 2.66	0.029	0.19
As-fed	2.34	2.30	2.21 – 2.39		

[1]Dry matter basis
[2]Calculated using Noblet and Perez (1993) and Noblet and Shi (1993)
[3]Calculated using Noblet *et al.* (1994)

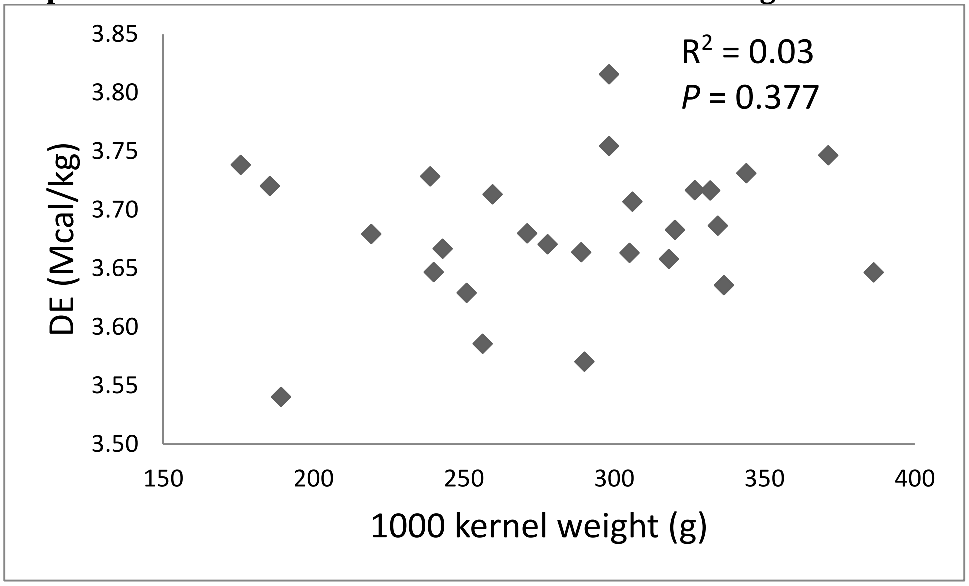
Graph 1.1. Correlation between DE and yield in 2012 corn



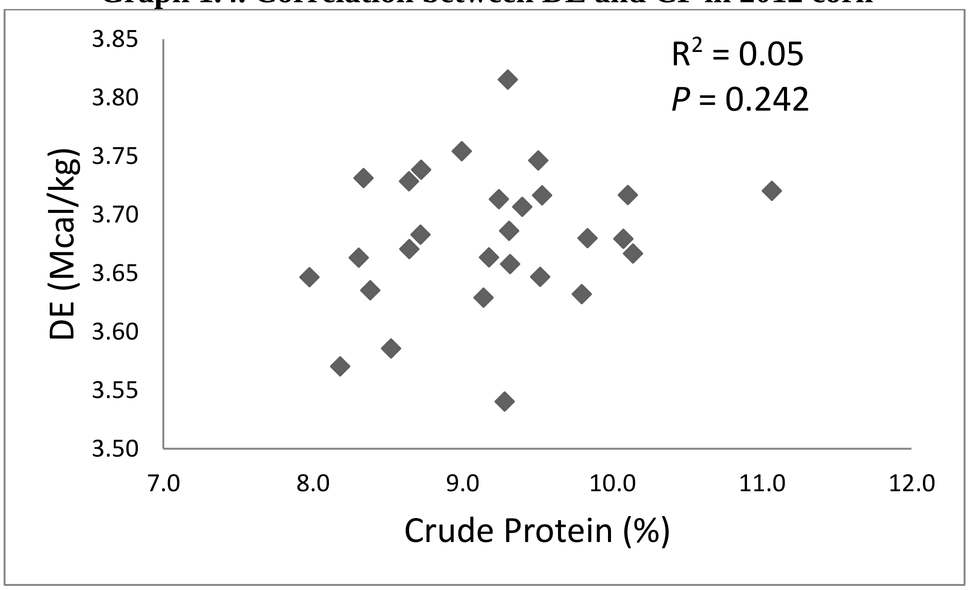
Graph 1.2. Correlation between DE and test weight in 2012 corn



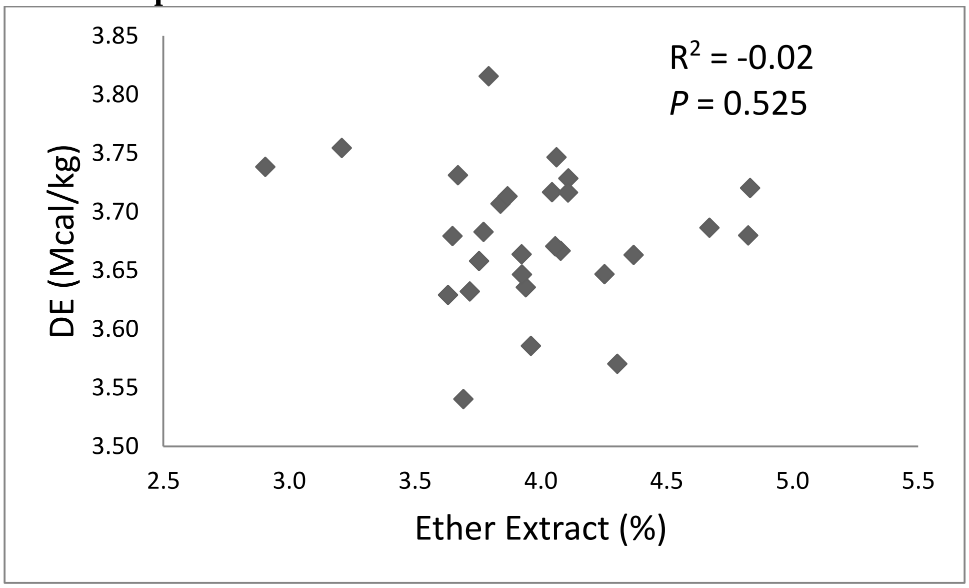
Graph 1.3. Correlation between DE and 1000 kernel weight in 2012 corn



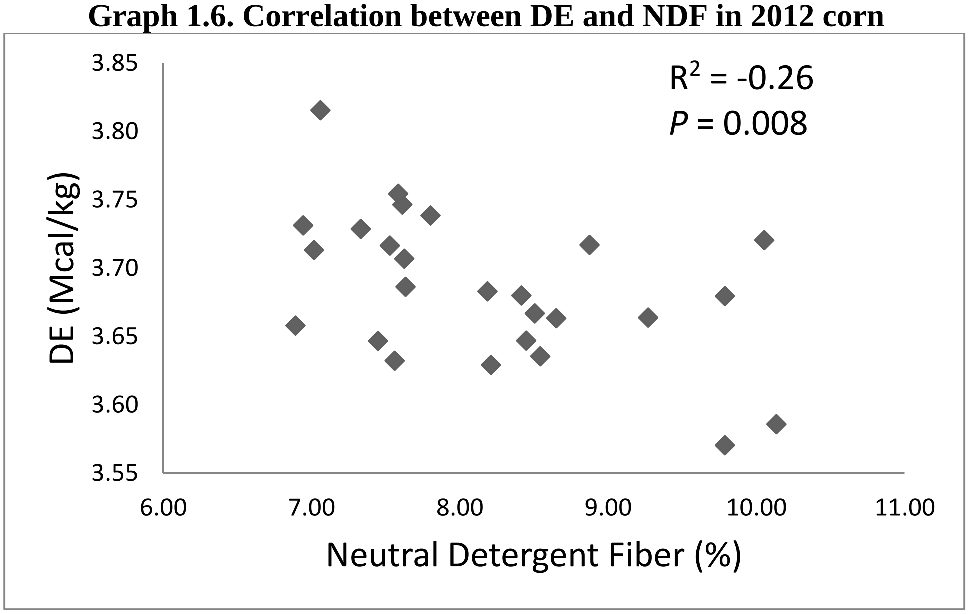
Graph 1.4. Correlation between DE and CP in 2012 corn



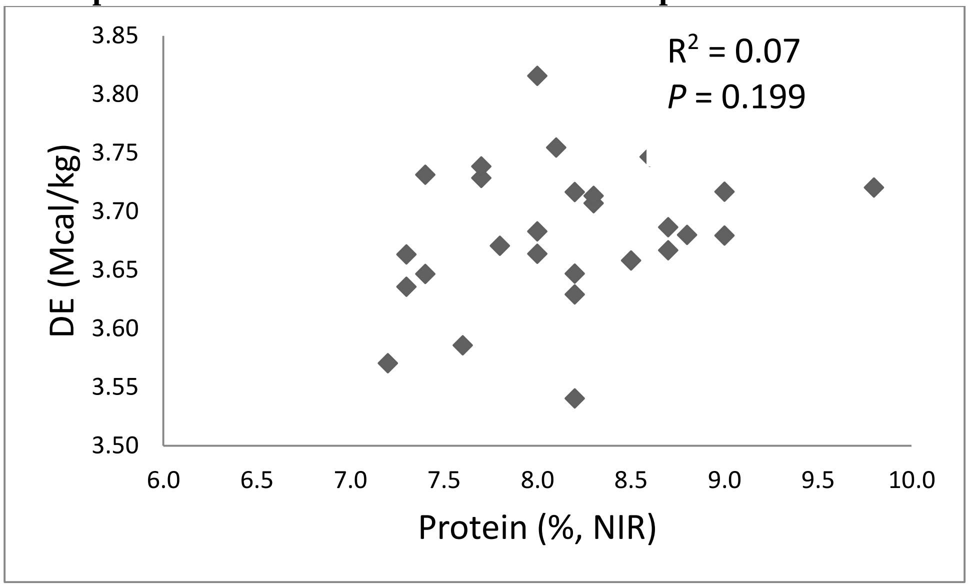
Graph 1.5. Correlation between DE and EE in 2012 corn



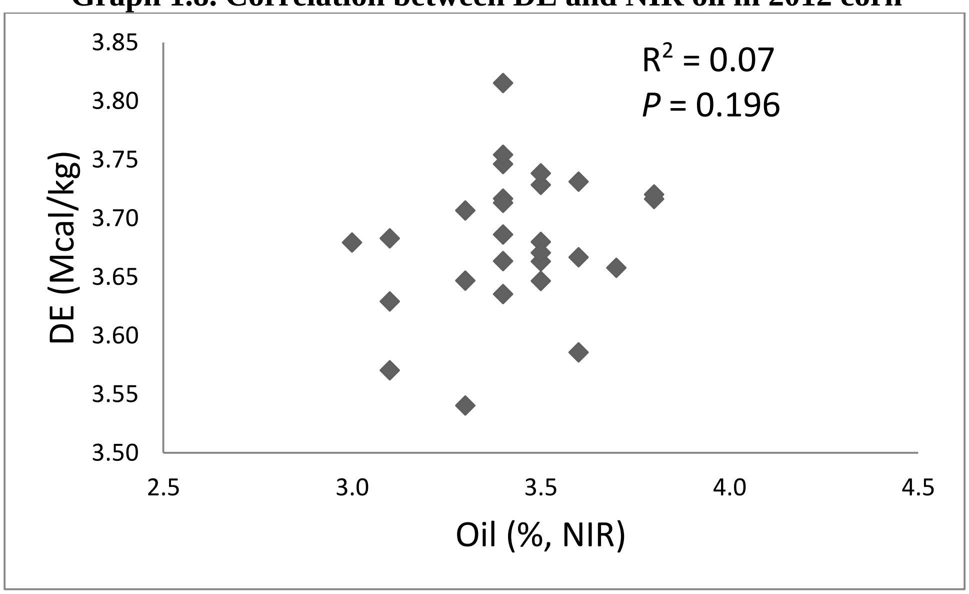
Graph 1.6. Correlation between DE and NDF in 2012 corn



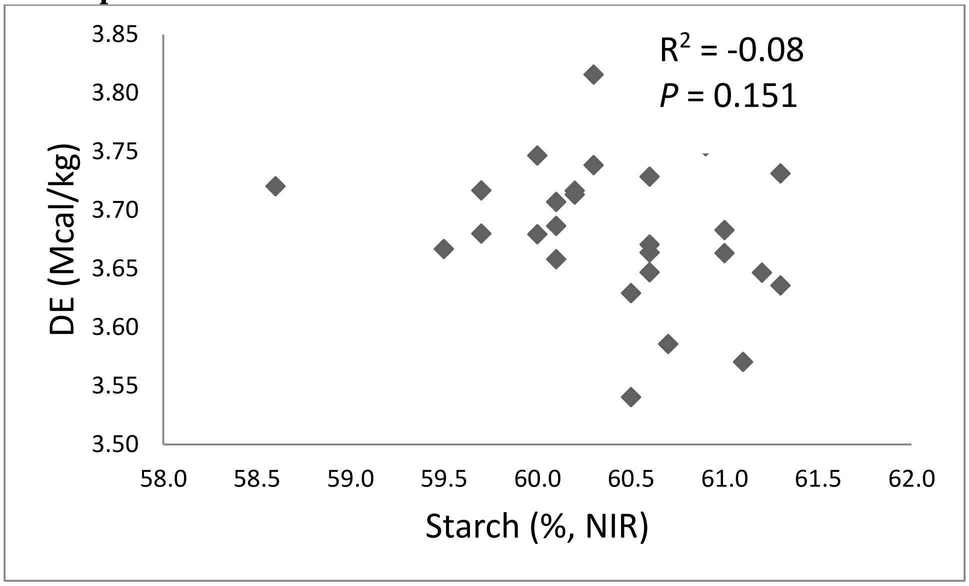
Graph 1.7. Correlation between DE and NIR protein in 2012 corn



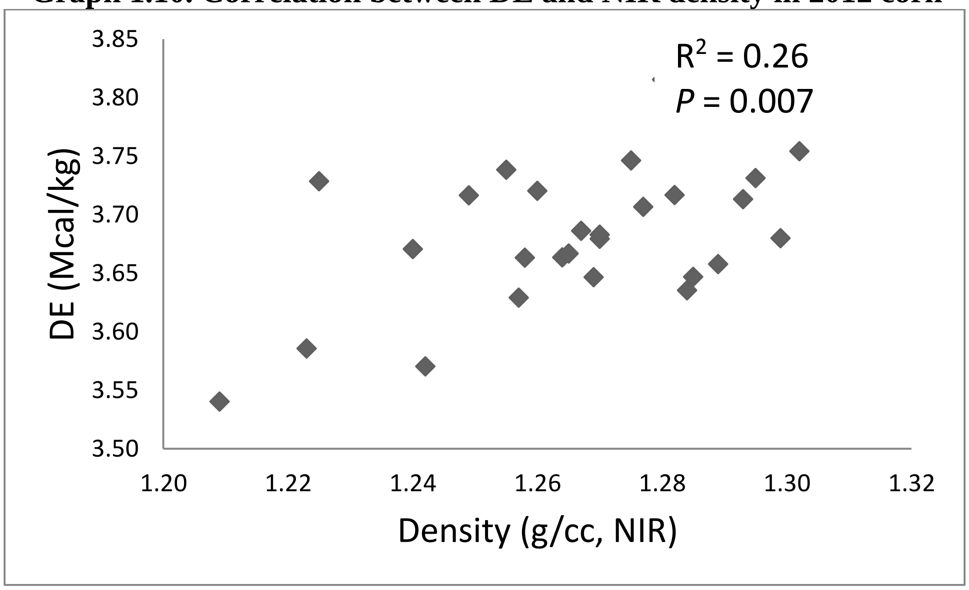
Graph 1.8. Correlation between DE and NIR oil in 2012 corn



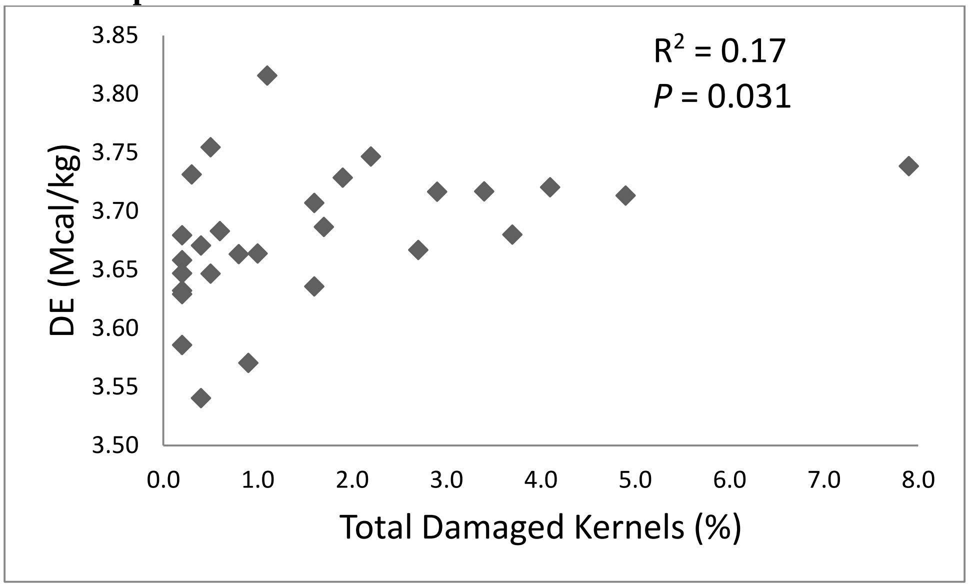
Graph 1.9. Correlation between DE and NIR starch in 2012 corn



Graph 1.10. Correlation between DE and NIR density in 2012 corn



Graph 1.11. Correlation between DE and TDK in 2012 corn



Graph 1.12. Correlation between DE and BCFM in 2012 corn