Corn Quality: Concerns When Grain Does Not Reach Maturity

The 2020 growing season brought challenges to Iowa corn growers. Drought and the August derecho wind damage are the two primary events that may have impacted corn quality and feed value. Grain that does not reach maturity or is stressed during the growing season (weather, nutrients, disease, weed competition) may be more prone to quality issues, and thus require different considerations for handling and storage. This paper is for swine producers who grow corn and manufacture feed on-farm, feed mills, and nutritionists.

Corn is the primary energy source in swine diets. If the energy value of corn is compromised, this can directly affect feed conversion, impact growth rate, and merit diet reformulation. Corn also can introduce molds and mycotoxins into swine diets, which in turn can impact growth performance and sow herd productivity. While performance may be impacted, market pigs can tolerate some quality issues better than the breeding herd or young pigs. The breeding herd and nursery diets need high quality corn free of contaminants.

Corn that does not reach maturity prior to harvest is prone to quality issues:

- Lower test weight.
- Broken kernels/fines/foreign material.
- Insect damage.
- Molds potentially leading to mycotoxins.

Soil fertility, weed pressure and insect damage may affect variation within a field for yield, moisture, and grain quality; whereas, adverse weather (drought, flooding, or wind damage) or fungus/mold pressure may impact a field, farm, county, or region. This leads to variation of corn quality entering the combine, then entering the dryer, and then long-term storage. Feed mills may experience more variation than on-farm mills based on the number of corn sources. How can corn quality be evaluated, how can pig performance be impacted, and what management practices may minimize negative impacts?

Producer Pre-harvest Considerations:

Scout corn fields and seed varieties.

- Standability, moisture, mold, and insect damage.
- Poor quality – test for mycotoxins.

Select grain bins for quality corn.

- Corn for feed versus sale.
- Prioritize high quality corn for breeding herd and nursery diets.

Producer Harvest Considerations:

Combine settings to minimize fine

- Fines have higher levels mold/mycotoxins.
- Fines impact dryer efficiency and storage aeration.
- Poor quality–screen corn

Monitor grain dryer

- High drying temps >180ºF, can increase fines and reduce test weight.
- Cool corn <40ºF quickly to limit continued mold growth
- Proper moisture for storage type.
- Poor quality corn–dry corn 1 to 2 points lower moisture to prolong storage.

Drying does not destroy or remove mycotoxins, it reduces further production.

Recalibrate volumetric feed mills.

Feed bulk density changes.

- Check gestation feed drops.
- Bulk bin, feeder hold less feed.

Swine Producers: Growing Corn and Manufacturing Feed

Stressors during maturity may or may not affect the yields; however, these may affect grain quality. Excess moisture and drought may promote fungal damage to the individual kernels. Weakened pericarp may increase broken kernels and fines, thus increasing the potential for mycotoxin loads due to fungal growth on the pericarp and/or exposed endosperm. This will affect grain quality as well as nutrient composition.

Stressed corn plants are more susceptible to insect damage and molds, and are more prone to further kernel damage during combining and handling. The fines and small broken kernels may carry a higher mold/mycotoxin load and impact air flow in the dryer and storage bin.

Corn Kernel Development[1]

Kernel components include the pericarp (seed coat), embryo (germ), and endosperm. The germ is a primary store of protein, minerals, and fat. The germ can be observed in the milk (R3) stage and grows and "hardens" through the dough (R4) stage. The endosperm contains primarily soft starch through milk (R3) and dough (R4) stage, which transforms to hard starch during dent (R5) stage. The endosperm stores starch and protein. If the seed is germinated, the growth of the embryo is supported by the enzymatic breakdown of the endosperm to solubilize sugars and amino acids. From time of germination, a seedling can survive for up to 14 days on the endosperm[2].

Awareness of kernel development identifies how premature end-of-kernel growth can impact nutrient fill into the kernel. Harvested kernels containing a percentage of soft starch will have a lower density (lower test weight) than mature kernels with hard starch. The germ, primary store of corn oil, is fully developed before the endosperm is fully developed.

Broken Kernels and Foreign Material

A southern Minnesota feed mill sampled received corn loads for broken kernel and foreign material (BKFM) to evaluate grinding characteristics, flow ability, mycotoxin contamination, and nutrient content of corn. Three BKFM classifications were established: low, average 1.1%; medium, average 4.4%; and high, average 7.9%. The 26 loads of "high BKFM" evaluated mycotoxin contamination by screening half of the samples to compare uncleaned, cleaned, and fines corn components. Corn fines were 20 times higher in vomitoxin and six times higher in zearalenone content compared with uncleaned corn. Cleaning the same corn sample reduced vomitoxin content by two-thirds and lowered zearalenone content by about three-quarters (Table 1)[3]. Thus, screening corn is a practical and economical method to reduce, though not eliminate, mycotoxins if corn is found to be contaminated. It would be possible to lower mycotoxin content of corn from levels considered excessive for pigs to levels that could be safely fed.

Table 1. Effects of Corn quality on mcoytoxin content.

	Clean	Unclean	Fines	P-Value	SEM
FM%	0	7.9	100		
Vomitoxin, ppm	138a	425a	2856b	0.01	218
Zeralenone, ppm	12a	61a	385b	0.01	26

NeoGen AccuScan Gold (Lansing, Michigan)

Mold and Mycotoxins

Mycotoxins in corn are produced by certain molds that infect the ears of corn. Molds may be present without the production of mycotoxins, but mycotoxins cannot be produced in the absence of molds. Ear rot molds favor different environmental conditions, so each may occur in different years or different locations in a growing season. Patience and Ensley, Iowa State University, publication[4] "Mycotoxin Contamination of Corn: What It Is, What It Does To Pigs And What Can Be Done About It" is an excellent resource for more insights regarding mycotoxins. In the publication, Table 2 highlights the mycotoxins of greatest interest to pork producers.

In addition, monitor DDGS sources for mycotoxin levels. Aflatoxin, fumonisin, and other mycotoxins are concentrated three times in DDGS relative to the level in the corn used for ethanol production.

Table 2. Maximum recommended mycotoxin concentration in grown-finish pig diets.

Mycotoxin	Maximum Concentration
Aflatoxin	200 ppb in finisher diets
DON (Vomitoxin)	1 ppm in Grower Finisher diets
Fumonisins	10 ppm in finisher diets

Effect of Low Test Weight Corn on Swine Performance

Lee Johnston, University of Minnesota, summarized five trials from the 1990s and provided this conclusion[5]: "Assuming corn is not contaminated with mycotoxins, and other factors are not compromising quality of the corn, low test weight corn seems to be comparable in feeding quality to normal test weight corn for pigs. It appears that corn with test weight as low as 45 lb./bu can support pig performance similar to corn with test weights of 56 to 59 lb./bu."

Trial data is included for grow-finish from Minnesota (Table 3)[6] and South Dakota (Table 4)[7] and nursery data from Michigan (Table 5)[8]. South Dakota State University researchers found that adding fat (extruded soybean or soy oil) to corn-based diets containing very low test weight corn (36 or 44 lb./bu.) had no effect on daily gain but did improve daily feed intake and feed efficiency of growing-finishing pigs.[9]

Table 3. Performance of growing pigs fed corn of varying test weights- Minnesota, 1993

	1991	1992		
Trait		10	13	16
Test wt. lb./bu.	57	49.5	47.5	48.5
Gain, lb./day	1.65	1.58	1.63	1.49[a]
Feed intake, lb./day	5.69	5.50[b]	5.81[b]	5.47[b]
Gain/feed	3.46	3.48	3.57	3.69

Initial pig weight = 77 lb. ; final weight = 229 lb.
[a]Different from 1991 corn (P<.01)
[b]Quadratic effect with 1992 corn (P<.01)

Table 4. Performance of growing pigs fed corn of varying test weights - GTA feeds, South Dakota, 1993

	Test weight, lb./bu.			
Trait	40	45	50	55
Gain, lb./day	1.76	1.76	1.71	1.77
Gain/feed	.33	.32	.33	.34

Initial pig weight = 43 lb. ; final weight = 252 lb.

Table 5. Performance of growing pigs fed corn of varying test weights- Michigan, 1993

	Test weight, lb./bu.			
Trait	42	47	51	59
Gain, lb./day	1.43[b]	1.32[c]	1.41[b]	1.41[b]
Feed intake, lb./day	2.91[b]	2.69c	2.87[b]	2.84[b]
gain/feed	.49	.50	.49	.49

Initial pig weight = 29 lb. ; 4-week trial
[b,c]Means within a row with unlike superscripts differ (P<.05) Retrospective anamysis: corn source contained 2 ppm vomitoxin

A trial evaluated the effects of drought-affected corn and non-starch polysaccharide enzyme inclusion on nursery pig growth performance also showed lower test weight did not impact pig performance. Trial data for only corn sources are provided (Table 6)[10]. Corn type did not affect the apparent total tract digestibility of DM, ash, CP, or crude fat ($P > 0.10$), but pigs fed diets manufactured from normal corn had greater ($P < 0.05$) apparent total tract digestibility of crude fiber than those fed diets manufactured from drought-affected corn. This may be attributed to greater xylan concentration in drought-affected corn. Authors concluded drought stress did not alter the non-starch polysaccharide concentration of corn beyond xylan concentration, so it was not surprising enzyme inclusion showed little benefit to nursery pig growth performance.

Table 6. Effects of drought effected corn of nursery pig performance. Iowa corn and Kansas trial, 2012

Trait	Normal	Drought
Corn, Test weight lb./bu.	55.9	54.3
Corn, moisture %	12.6	12.4
Corn, CP %	8.5	9.4
Corn, Crude fat %	3.2	3.2
ADG, lb./day		
d 10 to 25	0.75	0.73
d 25 to 35	1.21	1.21
d 10 to 35	0.93	0.93
ADFI, lb./day		
d 10 to 25	1.01	0.99
d 25 to 35	1.85	1.79
d 10 to 35	1.34	1.32
G:F		
d 10 to 25	0.74	0.73
d 25 to 35	0.65	0.68
d 10 to 35	0.69	0.70
ADFI, lb./day		
DM	85.3	85.2
CP	78	85.2
Crude fat	85.3	85.2
Crude fiber	53.7	48.0

Initial pig weight = 14.8 lb. ; 25 day reial

Corn Test Weight Correlation with Energy Level

In 1992, OMAFRA Feed Quality Laboratory tested the quality of poultry metabolizable energy value of 90 corn samples (1992 harvest; avg test weight 49 lb./bu). Based on the metabolizable energy findings, they concluded the 1992 harvest averaged 5% lower than previous years' "normal test weight" corn. However, among the overall 90 samplings, there was a poor relationship between test weight and the energy value; suggesting factors such as hybrid differences, maturity at time of killing frost, harvest moisture level, drying temperature, and handling damage all may have contributed significantly to the variability.[11] That same year, Nick Dale (University of Georgia) evaluated 26 corn samples of varied test weights (free of insect and mold damage) for true metabolizable energy (TMEn) and protein content for poultry[12]. He summarized there was a slight, but significant positive correlation between test weight and TMEn. However, there was considerable sample variation of TMEn content within test weight, suggesting there is limited need for reformulation to poultry diets for energy content when corn is above 50 lb./bu. There was no significant effect of bushel weight on crude protein content.

A trial evaluated the digestibility and fermentation differences between high and low energy corn samples and the response to xylanase supplementation in pigs[13]. Corn source: high energy (3.74 Mcal DE/kg, 6.5% NDF. and 7.1% TDF on DM basis) and low energy (3.60 Mcal DE/kg, 8.3% NDF. and 8.6% TDF on DM basis) did not affect apparent ileal digestibility of gross energy or dry matter. High energy diets had greater apparent total tract digestibility of gross energy; however, no difference for total digestible dietary fiber. The energetic differences among these corn samples appeared to be driven by fermentability in the hindgut. Supplementing xylanase improved digestibility irrespective of the digestibility energy content of corn.

The year 2012 brought drought conditions to most of the US Corn Belt. Iowa temperatures averaged 6.8°F above normal and rainfall was 24.8% below normal. Iowa State University researchers evaluated 28 corn samples from the 2012 drought-stressed crop and two normal corn samples from 2011 to investigate the impact of growing on corn composition and energy content, and determine if relationships exist among corn quality measurements, chemical composition, and digestibility of energy[14].

While physical measurement of the drought-stressed corn had a wide variation of yield (36.4 to 220 bu./ac.) and 1,000 kernel weight (176 to 386 g), kernel density and test weight were virtually the same (Table 7). Overall, the data on chemical composition of the drought-stressed corn was not very different compared with typical corn (Table 8).

Table 7. Physical measurements of 2012 corn samples.[a]

	CNTRL[b]		DS[c]	DS Range
P-Value				
No. of samples	2	28		
Kernem Density, g/cm^3	1.27	1.27	1.26-1.30	.904
1,000 kernel wt. g .344	337	284	176-386	
Test Weight, lb./bu.	59.3	58.6	55.3-60.9	.653
BKFM[d]. %	0.8	0.7	0.2-2.0	.953
Yield, bu./ac.		118.5	36.4-220.2	

[a] All values presented on an as-is basis,
[b] CNTRL = 2 corn samples from 2011 crom (from ames, Iowa)
[c] DS = 28 corn samples drom 2012 drought stress crop (from Iowa and Illinois)
[d] BKFM = Broken Kernel Foreign Material

Table 8. Chemical composition 2012 corn samples.[a]

	CNTRL[b]		DS[c]	DS Range
P-Value				
No. of samples	2	28		
CP. %	8.5	9.18	7.98-11.07	.108
Ether Extract, %	4.07	3.96	2.91-4.83	.579
ADF, %	1.89	2.23	1.82-3.14	<.001
NDF. %	6.92	8.19	7.02-10.14	.015
Starch, %	70.5	69.5	67.4-71.6	.419

[a] All values presented on a DM basis
[b] CNTRL = 2 corn samples from 2011 crom (from ames, Iowa)
[c] DS = 28 corn samples drom 2012 drought stress crop (from Iowa and Illinois)

Diets formulated using each of the corn samples were fed to individual barrows to determine DE values (data not shown). Authors concluded no statistically significant correlations were observed between DE and starch or ADF content, or between DE and test weight.

Corn Crude Protein Correlation with Lysine

Research has shown there is low correlation between protein and lysine content of corn. Lee Johnston's review on this subject reported the correlation ranged from 0.64 to 0.73 between corn protein and lysine[15], indicating it is not necessary to reformulate swine diets due to variations in corn protein content.

Factors That Influence Corn Test Weight[16,17,18]

Test weight is a volumetric measurement (official bushel measures 1.244 cubic feet). Some associate test weight with grain yield; yet research has shown there is a poor relationship between corn test weight and grain yield[19]. Multifactorial events or conditions can impact final test weight, including:

- Severe photosynthetic stress during dough (R4) and dent (R5) stages of grain fill reduces kernel weight and can cause premature kernel black layer formation. Decreased kernel weight can result from severe drought and heat stress during grain fill; extensive European corn borer tunneling (especially in the ear shanks); loss of photosynthetic leaf area by nutrient deficiency, hail, insects, or disease (blight, fungus) during grain fill; and killing fall frosts prior to normal black layer development.
- Hybrid differences.
- Physical characteristics of the kernel – such things as size, density, shape, and "slickness" of the outer kernel layer.
- Relationship grain moisture and test weight. As kernel moisture decreases, grain test weight increases. Why? The reason is two-fold: as grain dries it also shrinks, allowing for more kernels to "pack" into a volume bushel. Additionally, dry corn is naturally more slippery, or slick, which tends to allow for better packing. Factors such as hybrid, mechanical condition of the grain, and drying temperature come into play. Grain with a high percentage of damaged kernels will increase less than high quality grain. Grain dried at temperatures in excess of 180°F also will have less of an increase.

Feed Mill and Nutritionist Considerations:

Establish incoming corn quality standards (48 lb. test weight, 5% BKFM, etc.).

Prioritize grain bins for quality corn.

- Corn for swine feed versus sale.
- Prioritize quality corn for breeding herd and nursery diets.

Consider screening incoming corn.

- Fines have higher levels of mold/mycotoxins.
- Fines impact dryer efficiency and storage aeration.

Considerations

- Acknowledge swine and corn genetics have progressed since most of the cited trials were conducted. Given corn is a dietary energy source and pigs eat based on energy need, the relationships discussed likely are still valid. If pigs now are more energy sensitive, there could be changes in feed intake and feed efficiency while growth performance is maintained. Monitor group feed budgets and closeouts for performance changes.
- Corn quality (free of mold/mycotoxins, heat damage, broken kernels, fines, etc.) may have greater impact on feed value then corn test weight (>45 lb./bu.).
- Recalibrate volumetric feed mills. Manufacturing diets based on volume, rather than pounds, with light test weight corn will result in lower total pounds of feed, which is higher in lysine than intended.
- Adding 2-3% fat to diets with very low test weight (<45 lb./bu.) may be needed to maintain similar SID Lys:NE g/Mcal ratio of diet with normal (56 lb./bu.) corn.
- Light test weight corn may change feed bulk density. Thus, monitor/change gestation feed drops, and watch for reduced holding capacity of bulk bins and feeders.
- Monitor particle size of ground corn. Light test weight corn typically will have a high percentage of small kernels, and may have a higher percentage of broken kernels and more foreign material. These factors could generate a different average particle size when ground with a hammer or roller mill.

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Resources

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