Corn Hybrid Kernel Trait Variation Affects Laying-Hen Egg Production

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Summary and Implications

When nutritionists formulate diets, reference values are typically used to determine the nutritive content of the ingredients and the resultant diet. However, different corn hybrids have different chemical and physical traits which change the nutritive value of the corn relative to reference values. Using different corn hybrids as dietary ingredients can affect the nutritive value of the diet, which, in turn, may affect laying-hen performance. In this study, the effects of corn kernel chemical and physical traits on egg production performance were investigated. The results show that chemical differences among corn hybrids elicit production performance differences. Additionally, physical characteristics of the kernels correlate with performance differences.

Introduction

Laying-hen diets are typically based on a corn and soybean meal mixture, with the majority of the diet composed of corn. The chemical properties of the corn kernels (i.e., starch content, protein content, amino acid profile, lipid content, etc.) are mainly responsible for the nutritive value of the corn, and diets are formulated using these nutritive values. However, the physical traits of the corn may also influence its nutritive value, and thus the overall nutritive value of the diet. When formulating diets, nutritionists typically use standard nutritional values, which means that actual nutrient content of the diet may be different than that calculated. Moreover, the corn's physical traits (e.g., test weight, density, kernel size, etc.) may also influence the nutritive value of the corn and, therefore, of the diet. Hence, when assessing the value of corn grain, both chemical and physical traits should be considered. We postulated that corn hybrids are sufficiently different in their chemical and physical composition that the use of different hybrids could cause measurable egg-production performance differences when used as the only variable in a corn–soybean meal diet.

The objectives of this study were to determine egg-production performance changes in laying hens fed diets containing different corn hybrids and to correlate the physical and chemical traits of the corn kernels with the differences in egg-production performance.

Materials and Methods

A total of 240 52-week-old Hy-Line W-36 laying hens, obtained from a commercial facility, were allotted to cages (2 hens per cage, 96 in^2/hen) in a randomized complete block design. The location within the barn served as the blocking criterion. The hens were allowed a 1-week acclimatization period, after which data were collected for 14 weeks (i.e., from 53–67 weeks of age). During the acclimatization period, hens were fed a common diet formulated to meet or exceed the nutrient requirements recommended by the National Research Council (**NRC**) (1994). The hens were allowed free access to feed and water throughout the experiment, and were supplied lighting on an 18 hours light:6 hours dark cycle.

Experimental Diets

A single corn-soybean meal diet was formulated using NRC-published nutrient values for all ingredients (including corn) to contain inadequate amounts of essential amino acids so that small effects of corn kernel traits on egg production could be detected. Because corn contributes little calcium and nonphytate phosphorus to the diet and because calcium and phosphorus are essential for eggshell formation, the diet was formulated to contain at least 100% of the recommended contents of these nutrients (Table 1). The 6 dietary treatments were created using 6 different corn hybrids—thus the only difference among the experimental diets was the corn hybrid used. The corn was ground in a hammer mill with a 20/64-in screen immediately before diet mixing.

Corn Growth Conditions and Hybrid Kernel Traits

The 6 corn hybrids (commercially available Golden Harvest H-8906, H-8194RR, H-8445Bt, H-8562, H-8913Bt, and H-8803Bt) were grown in the same field in Webster County, Iowa, in the 2004 growing season. The corn was planted on April 27, 2004, and harvested on November 22, 2004. All cultivation practices (including fertilization rates and chemical application) were identical among the 6 hybrids. Each hybrid was planted in 60 rows, but only the middle rows were used in the experiment to minimize the use of cross-pollinated corn in the study. After harvest, 800–

900 bushels of each corn hybrid were transported individually to Ames, dried, and stored in 1000-bushel gravity-flow grain bins.

Before chemical analyses, representative samples of each corn hybrid were ground through a 1-mm screen. The moisture content was determined in duplicate for each hybrid by drying at 135°C for 2 hours. Ether extract lipid content was determined in duplicate using a Goldfisch lipid extraction apparatus. The total nitrogen content was determined in duplicate using the micro-Kjeldahl method on a Kjeltech 1028 distilling unit, and the crude protein content was calculated as nitrogen × 6.25. The amino acid content was determined by ion-exchange chromatography at the University of Missouri, Columbia.

The physical traits were determined on a representative sample of each hybrid. The test weight of each hybrid was determined in triplicate using a Fairbanks test weight apparatus and corrected to a dry matter content of 88% to account for differences in moisture content. The 1000-kernel weight was measured in triplicate by multiplying the weight of 200 corn kernels by 5. The seed density was determined in triplicate using a Micrometrics AccuPyc 1330 pycnometer. The Stenvert hardness (i.e., Stenvert grinding time, Stenvert grinding resistance, and the percentage of hard and soft kernels) was determined at the University of Nebraska, Lincoln. The particle size of representative samples of the ground corn used in the diets was determined at Kansas State University with USA Standard testing sieves.

Egg Production Data

Egg production was recorded daily during the 14-week-long study. Feed consumption (measured as feed disappearance) and egg weight from all eggs collected in a 24-hour period was recorded weekly. Egg mass was calculated as egg weight × egg production. Feed utilization was calculated as grams of egg mass produced per kilogram of feed consumed. Egg specific gravity, a measure of eggshell thickness, was determined in week 14 of the experiment (i.e., at 67 weeks of age). Body weights of laying hens were recorded at the start and end of the trial.

Data Analyses

Data were subjected to analysis of variance (**ANOVA**) according to a randomized complete block design with 20 blocks. Factors in the model were block, corn hybrid, and initial body weight (the latter used as a covariate to account for differences among treatments in the hens' starting body weight). The effects of the 6 corn hybrids were evaluated using Fisher's least significant difference. Because the corn kernel physical and chemical traits were expected to have small effects on egg production, P-values of less than or equal to 0.1 were considered significant. Egg-production performance measures were correlated with the analyzed chemical and physical traits using linear regression. JMP 5.1 software was used for all statistical analysis.

Results and Discussion

Corn Kernel Physical and Chemical Traits

The physical traits are reported on an as-is (wet) basis, whereas the chemical traits are reported on an equal dry matter basis (i.e., 88%) to account for differences in moisture content (Table 2). The physical traits of the corn hybrids tested in this study were representative of 2004 strip plot grain quality data from Webster County, Iowa determined by the Iowa Grain Quality Initiative. The values for test weight, lipid content, crude protein and seed density of the 6 corn hybrids used in this study were all comparable to the reported means of test weight (57.5 lb/bu), lipid content (3.6%), crude protein (7.3%), and seed density (1.26 g/cm^3) for corn grown in Webster County in 2004. However, the crude protein and amino acid contents of the 6 hybrids used in this study were lower than the NRC (1994) values for corn used in diet formulation.

Egg Production Performance

Despite the amino acid deficient diets, the hens' rate of egg production and egg weights were comparable to those reported in the 2003–2005 Hy-Line W-36 management guide. Nevertheless, egg production differed by up to 8.7% ($P < 0.1$) depending on which hybrid was fed (Table 3), which correlated with seed density (Table 4). This result was likely due to the digestibility of the ground corn, because of the relationship between seed density and starch type. Seeds containing more of the highly branched amylopectin (as opposed to the more unbranched or linear arrangement of amylose) is more digestible due to the branching of the amylopectin molecules, which provides more access points for starch-digesting enzymes. Further tests of the hybrids to determine the starch content and type are necessary to determine the relationship between seed density and the amount and type of starch present in the kernels.

Egg weights only differed 2.7% among hens fed different corn hybrids ($P < 0.1$), however egg mass differed by up to 7.7% depending on which hybrid was fed ($P < 0.1$), both of which correlated with the corn's lysine content. Though some studies show that dietary methionine content affect egg size, no correlation was seen between methionine content of the corn and either egg weight or egg mass in this study. Because egg mass is a combination of egg weight and egg production, egg mass could be expected to be correlated with kernel traits affecting these performance measures. While egg mass differences correlated with lysine content of the corn, they did not correlate with the seed density of the corn. Therefore, it appears that amino acid content exerts a greater impact on egg mass when compared to seed density.

Feed consumption differed by up to 5.2% depending on which hybrid was fed, and the differences correlated with lysine and methionine content of the corn ($P < 0.1$). The correlation between the corn's essential amino acid content and the hens' feed consumption was not expected, because hens will generally consume feed to meet their energy needs, not to meet amino acid requirements. However, there was no correlation between the lipid content of the corn, which has a large impact on the energy content, and feed consumption.

Feed utilization differed by up to 5.6% depending on which hybrid was fed ($P < 0.1$) and correlated with the lipid content of the corn ($P < 0.1$). Dietary treatments containing corn with relatively greater lipid content should result in a diet that is more energy dense. Because hens generally will consume feed to meet their energy needs, a relatively smaller amount of feed will be consumed by hens fed diets containing relatively higher energy density. When these feed consumption differences are compared to the corresponding egg mass values, a higher feed utilization ratio results. However, feed consumption differences among the corn hybrids evaluated did not correlate with the lipid content of the corn ($P > 0.10$).

The specific gravity of eggs collected in week 14 ranged from 1.069–1.073 ($P < 0.1$), a difference of 0.004 in specific gravity or 0.4%. Because the diet was formulated to meet or exceed calcium and phosphorus contents recommended by NRC (1994), this result was unexpected. There was no correlation between the egg specific gravity differences and any physical or chemical traits evaluated in this study.

This study was designed to determine whether the physical characteristics of corn kernels would affect egg-production performance. We showed that there are small, but significant, relationships between physical characteristics of the corn and egg-production performance and that the contribution of physical traits to egg-production performance was, in one instance, as important as that of the chemical composition of the corn. Therefore, hybrids grown for use in laying-hen diets should take both physical and chemical characteristics into account.

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Table 1. Diet composition (as-is basis). The single diet, formulated to contain inadequate amounts of selected nutrients (see text), was formulated using nutrient values published by the National Research Council for all ingredients (including corn). Each of the 6 corn hybrids was then used to make the 6 dietary treatments.

Item	Amount
Ingredient	
Corn (%)	69.10
Soybean meal, 48% crude protein (%)	16.00
Soybean crude oil (%)	2.26
DL-Methionine (%)	0.16
Dicalcium phosphate (%)	1.24
Limestone[1] (%)	10.28
Salt, iodized (%)	0.36
Tracemineral premix[2] (%)	0.30
Vitamin premix[3] (%)	0.30
Total (%)	100.00
Calculated composition	
Crude protein (%)	13.47
ME_n[4] (kcal/kg)	2,871
Ether extract (%)	5.00
Neutral-detergent fiber (%)	8.06
Acid-detergent fiber (%)	2.80
Crude fiber (%)	2.14
Calcium (%)	4.20
Phosphorus, non-phytate (%)	0.33
Potassium (%)	0.54
Sodium (%)	0.16
Chloride (%)	0.25
Lysine (%)	0.65
Methionine (%)	0.37
Methionine and cystine (%)	0.49
Threonine (%)	0.50
Tryptophan (%)	0.17

[1]A 50:50 mix of fine (mean = 0.14 mm) and coarse (mean = 2.25 mm) particles.
[2]Supplied per kilogram of diet: Selenium; 0.3 mg; magnesium; 150 mg; zinc 90 mg; iron; 60 mg; copper; 15 mg; iodine, 1 mg.
[3]Supplied per kilogram of diet: Vitamin A, 15,000 IU; vitamin E, 40 mg; vitamin D_3, 4,500 IU; vitamin K_3, 2.5 mg; thiamin, 3.5 mg; riboflavin, 10 mg; vitamin B_6, 6 mg, vitamin B_{12}, 0.03 mg; folic acid, 2 mg; biotin, 0.36 mg; niacin, 75 mg; pantothenic acid, 21 mg; choline, 600 mg.
[4]Nitrogen-corrected metabolizable energy.

Table 2. Corn kernel physical and chemical traits used in the laying-hen study.

Item	Hybrid					
	H-8906	H-8194RR	H-8445Bt	H-8562	H-8913Bt	H-8803Bt
Physical trait (as-is basis)						
Test weight (lb/bu)	60.6	65.2	61.1	63.6	64.7	65.4
Test weight (lb/bu, 88% dry matter[1])	53.4	57.4	53.8	55.9	56.9	57.5
1,000-kernel weight (g)	384.0	329.4	349.5	433.9	397.8	313.3
1,000-kernel weight (g, 88% dry matter[1])	337.9	289.9	307.5	381.9	350.1	275.7
Stenvert hardness (% hard)	67.9	66.2	68.8	64.8	69.6	74.1
Stenvert hardness (% soft)	70.0	75.9	73.0	72.8	71.9	76.1
Stenvert grinding resistance (rpm)	2600	2460	2425	2435	2490	2435
Stenvert grinding time (s)	6.5	6.0	5.5	5.5	6.0	7.0
Seed density (g/cm^3)	1.237	1.263	1.207	1.232	1.227	1.252
Particle size of ground corn, mean (µm)	868	706	742	657	764	688
Moisture (%)	13.8	14.2	13.7	13.9	14.0	13.7
Chemical trait (88% dry matter basis[1])						
Crude protein (%)	5.4	6.0	5.3	6.7	6.1	5.7
Ether extract (%)	3.3	3.7	3.7	3.5	2.9	3.6
Alanine (%)	0.40	0.49	0.43	0.50	0.48	0.48
Arginine (%)	0.28	0.32	0.30	0.32	0.34	0.31
Aspartic acid (%)	0.37	0.43	0.40	0.45	0.42	0.42
Cysteine (%)	0.13	0.14	0.12	0.14	0.13	0.14
Cystine (%)	0.06	0.07	0.06	0.07	0.07	0.07
Glutamic acid (%)	0.93	1.15	1.01	1.19	1.18	1.14
Glycine (%)	0.23	0.27	0.25	0.28	0.27	0.26
Histidine (%)	0.17	0.18	0.17	0.20	0.19	0.18
Isoleucine (%)	0.18	0.23	0.20	0.22	0.23	0.21
Leucine (%)	0.62	0.79	0.67	0.81	0.77	0.77
Lysine (%)	0.19	0.22	0.21	0.22	0.24	0.21
Methionine (%)	0.11	0.13	0.11	0.12	0.13	0.13
Phenylalanine (%)	0.26	0.32	0.28	0.33	0.32	0.31
Proline (%)	0.48	0.53	0.55	0.67	0.57	0.63
Serine (%)	0.23	0.28	0.25	0.30	0.29	0.30
Threonine (%)	0.19	0.23	0.20	0.24	0.23	0.23
Tryptophan (%)	0.05	0.05	0.06	0.06	0.06	0.06
Tyrosine (%)	0.16	0.21	0.17	0.20	0.19	0.20
Valine (%)	0.28	0.32	0.30	0.33	0.33	0.30

[1]Data reported on an 88% dry matter basis to account for differences in moisture content among the 6 hybrids.

Table 3. Laying hen (53–67 weeks of age) performance measures by corn hybrid used in their diets.

Item	Hybrid						
	H-8906	H-8194RR	H-8445Bt	H-8562	H-8913Bt	H-8803Bt	SEM[1]
Initial body weight (kg)	1.47[b]	1.52[ab]	1.52[ab]	1.53[ab]	1.51[b]	1.58[a]	0.02
Final body weight (kg)	1.51	1.51	1.52	1.51	1.54	1.53	0.06
Change in body weight (g/hen)	–9.9	–10.7	–2.3	–8.4	22.8	5.7	22.3
Feed consumption (g/hen/day)	98.1[bd]	97.2[cd]	98.8[ad]	97.7[cd]	101.6[ab]	100.6[ac]	2.40
Egg production (%)	77.1[bd]	81.4[ac]	80.3[bc]	78.1[bc]	80.2[bc]	84.5[a]	1.96
Egg weight (g/egg)	61.6[ab]	60.7[b]	62.5[a]	61.3[ab]	61.6[ab]	61.0[ab]	0.94
Egg mass (g)	47.6[bd]	49.4[acd]	50.0[acd]	47.9[bc]	49.3[ab]	51.5[a]	1.31
Feed utilization (g egg mass/g feed)	0.484[cd]	0.508[ab]	0.506[ab]	0.491[abd]	0.489[bc]	0.513[a]	10.51
Egg specific gravity	1.071[bcd]	1.072[d]	1.073[ad]	1.069[b]	1.072[acd]	1.073[a]	0.001

[a,b,c,d]Means with different superscripts within the same row are different ($P < 0.1$).
[1]Pooled standard error of the mean, n = 20.

Table 4. Correlations between kernel traits and laying-hen performance measures. Only traits that correlated significantly with production parameters are shown.

Corn kernel trait	Response	P-value	Correlation coefficient (r)	Proportion of variation explained by trait (r^2)
Seed density	Egg production	0.072	0.164	0.027
Lysine content	Feed consumption	0.001	0.296	0.088
	Egg weight	0.043	0.184	0.034
	Egg mass	0.017	0.217	0.047
Methionine content	Feed consumption	0.079	0.161	0.026
Lipid content	Feed utilization	0.041	0.187	0.035