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Different Cereal Grains Alter the Daily Metabolizable Energy Intake of Broiler Chickens

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Abstract: The main objective of this research was to determine if broiler chickens accurately regulated caloric intake when fed diets with different cereal grains. Control corn, drought corn, hulless barley, sorghum and wheat were analyzed for protein, ether extract and fiber. Diets were formulated to provide equal amounts of protein, calcium, NPP and ether extract. Other grains were substituted for control corn at 17, 34 or 51% of the diet. These diets were fed to broiler chicks from 1-19 days of age. During the last 2 days of the experiment, a balance trial was used to determine the AME of the feed. Chicks fed the control corn diet had the best performance and highest daily energy intake. Chicks fed the sorghum diets had the worst performance and lowest daily energy intake. Chicks fed the wheat diets had the second lowest performance and daily energy intake. Density of the individual grains and of the complete diets was only slightly different. Particle size of the diets was larger for the barley diets than the others, even though all grains were ground through the same hammer mill screen. A secondary objective was to determine if results from a preference test with mature White Leghorn roosters would parallel results from the chick experiment. Each rooster was offered a choice of a diet with control corn or one of the other diets fed to chicks. This was done for 3 days with the positions of the diets changed from left to right on alternate days. The roosters did not show a preference for any of the diets offered.

Key words: Broilers, cereal grains, density, energy intake, particle size

INTRODUCTION

Numerous ingredients can provide energy for animals. The composition of the ingredients in turn, affects the amount of energy an animal consumes each day. This is well-illustrated in the case of the dairy cow which evolved by eating forages but which now is often fed a considerable portion of its ration as concentrate. Cows consumed increasing amounts of energy as the digestibility of their dry matter intake increased from 52-66% (Conrad *et al*., 1964). This effect was attributed to physical factors. When dry matter digestibility was between 67 and 80%, cows ate less of the more digestible rations. This effect was attributed to physiological factors.

The terminology was later changed. Physical factors was changed to distension and physiological factors was changed to chemostatis (Fig. 1, Van Soest, 1994). Ingredients of low digestibility limited the ability of an animal to consume energy because digestion was slow. With more digestible ingredients, digestive system capacity no longer limited energy intake. Hormonal regulation was then indicated to explain the results that were obtained. Birds normally eat ingredients that are very digestible. Several chemostatic mechanisms have been proposed to explain the regulation of energy intake (NRC, 1987). These are glucostatic, thermostatic, lipostatic, aminostatic and ionostatic. All of these have some merit and some shortcomings.

One explanation for how a chicken might achieve precise regulation of daily energy intake is based on the autonomic and endocrine hypothesis (Kuenzel, 2000). The hypothalamus is the center of the autonomic system. Lesions of the ventromedial hypothalamus are hypothesized to decrease sympathetic activity, in turn leading to increased lipogenesis; however lesions of the lateral hypothalamus are hypothesized to increase sympathetic activity, causing the animal to decrease lipogenesis and possibly lose weight. How changes in feed intake might affect the hypothalamus is not addressed.

Alteration of feed intake is an effect that has been related to specific hormones. Ghrelin causes hunger and stimulates food intake (Tschop *et al*., 2000; Toshini *et al*.,

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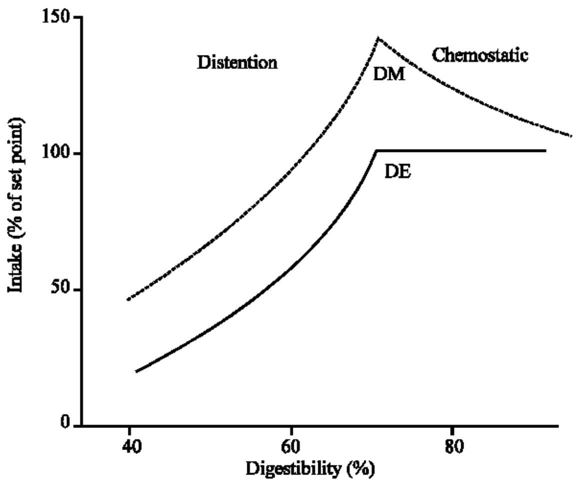

Fig. 1: Relation between intake of Dry Matter (DM) and the Digestible Energy (DE) in the feed ingested. Data fitting this model are obtained when a concentrate diet is diluted with a bulky filler or coarse forage

2006). Several hormones have been identified that decrease food intake over a short period of time. These are cholecystokinin (Gibbs *et al*., 1973), oxyntomodulin (Dakin *et al*., 2001), glucagon-like peptide-1 (Turton *et al*., 1996) and leptin (Zhang *et al*., 1994). A combination of leptin and insulin (Schwartz *et al*., 2000) may sense body fat content to alter feed or food intake over a longer period of time.

Several observations suggest the need to re-examine the concept that chemostatic factors accurately regulate energy intake. One is obesity in humans and the accompanying costs for treating associated health problems (Ogden *et al*., 2006). Another is obesity in companion animals that have easy access to food and limited physical activity (Laflamme, 2006). A third observation is that broiler chickens had significant differences in metabolizable energy intake when fed diets with different proportions of proximate analysis fractions (Latshaw, 2008).

If chickens do not precisely regulate caloric intake, palatability of the feed might cause increased or decreased consumption. Taste of the feed is one factor that might be considered as part of palatability. Mammals can detect sweet, salt, sour, bitter and umami (Reed *et al*., 2006). Birds have fewer taste buds than mammals but limited studies indicate that chickens can detect the same tastes as mammals except for sweet (Mason and Clark, 2000). Failure to detect sweet is due to the loss of the T1R2 sweet receptor gene (Shi and Zhang, 2006).

Another component of palatability might be ease of ingesting the feed. Chickens eat more of a feed that is in the form of pellets than if it is in the form of meal or mash (Latshaw, 2008). Smaller particle size and dustiness of mash may require more effort for ingestion and swallowing reducing feed intake.

Most commercial feeds for meat-type chickens are formulated to provide a prescribed ME content per weight of feed. The implication is that meat chickens regulate energy intake precisely, regardless of the energy source. The research reported here was to investigate if this assumption is correct when different cereal grains are used as the main energy source. Corn is the most common cereal grain used in the United States and in the world. In 2008, the following amounts (million metric ton) were produced in the world: Corn, 823; wheat, 690; barley, 158 and sorghum, 66 (FAOSTAT, 2010). Cereal grains were fed in broiler starter diets and compared for their effect on production characteristics and daily ME intake.

MATERIALS AND METHODS

Grains were obtained from available sources. Corn, sorghum and wheat were obtained through regular feed ingredient suppliers. Drought corn was obtained by observing fields in an area that had low rainfall during the growing season. When a field was located that was visibly affected by drought, the owner was contacted about supplying enough corn for this experiment. It was estimated that the yield was only about half of normal. Kernels were noticeably smaller than kernels from corn from a normal yielding field. Barley was a hulless variety (clearwater).

Grains were analyzed for protein (Official Method 990.03), ether extract (Official Method 963.15) and fiber (Official Method 973.18). The analyses were according to AOAC (2000) procedures.

All grains were obtained as whole kernels and were ground through the same hammer mill screen. Density of the whole grains and the mixed diets was determined. Diets were formulated to supply 22% protein, 1.16% lysine, 0.85% methionine plus cystine, 1.0% calcium, 0.45% NPP and 6.35% ether extract. Each grain was included in the diet at 17, 34 or 51% at the expense of control corn and soybean meal. This was done by mixing the control diet and the grain diets with 51% substitution and then blending the intermediate diets. The 17% grain diet used two thirds of the control diet and one third of the 51% grain diet but the 34% grain diet reversed the proportions. Distribution of the particle size in all diets was determined (ASAE (1969) using US sieve numbers 4, 8, 16, 30 and 50.

Diets were fed to Ross 708 broilers in battery pens for 19 days. Each pen had 6 chicks and each diet was fed to

4 pens of chicks. At the end of 19 days, feed intake, body weight and the number of males and females in each pen was recorded.

From days 17-19, a digestion trial was completed to determine the ME of the feed. Feed consumption was measured and excreta were collected in manure pans lined with plastic. After 48 h, the sheet was removed and the excrement was spread evenly on the sheet in a room with a dehumidifier. When the manure was dry, it was collected in a plastic bag, weighed and frozen until used for bomb calorimetry.

A preference test of the diets was completed using mature White Leghorn roosters. Each rooster was in a cage and was offered feed in two cups. One cup had the control corn-soybean meal diet and the other cup had an experimental diet. No record of feed consumption was made of the 1st day. For the 2nd day, the positions of the feed cups in relation to right or left were switched and feed consumption from each cup was recorded. For the 3rd day, the cup positions were again switched and feed consumption was recorded. About 4 different roosters were offered each experimental diet at 4 different times with 2 weeks between replications. The amount of experimental feed consumed was compared to the total amount of feed consumed.

Statistical analysis: The General Linear Model of SAS (1996) was used to analyze data with grains as independent variables. Pens were the experimental unit in the chick study and individual roosters were the experimental unit in the preference test. Data were evaluated for linear and quadratic effects of increasing grain substitution for corn. Overall results of substituting 17, 34 or 51% grain for corn were also compared. Levels of significance are provided in Table 1-5.

RESULTS

Control corn had the lowest protein content, followed by the drought corn while barley had the highest content (Table 1). Sorghum had the highest ether extract and wheat had the lowest ether extract content. Fiber content of the barley was the lowest and was highest in the drought corn.

Density (g/cc) of the whole grains was as follows: Control corn, 0.727; drought corn, 0.715; barley, 0.712; wheat, 0.707 and sorghum, 0.738. All of the grains had higher protein content than the control corn, so less soybean meal was used to provide 22% protein in the diets (Table 2). Sorghum, wheat and barley diets required supplemental lysine in order to provide the same percentage of lysine that was provided by the corn diets.

Table 1: Analyzed nutrient content of grains

Grains	Protein (%)	Ether extract (%)	Fiber (%)
Corn	7.90	7.00	4.94
Barley	14.13	3.39	1.91
Drought corn	9.72	6.43	7.20
Sorghum	11.12	7.30	6.80
Wheat	12.88	3.02	4.02

Table 2: Diet composition (%) when grains were substituted for 51% corn

Ingredients	Corn	Barley	Drought corn	Sorghum	Wheat
Corn	60.37	14.84	11.31	13.33	13.03
Drought corn	0.00	0.00	51.00	0.00	0.00
Sorghum	0.00	0.00	0.00	51.00	0.00
Wheat	0.00	0.00	0.00	0.00	51.00
Barley	0.00	51.00	0.00	0.00	0.00
Soybean meal	34.78	27.45	32.58	30.79	29.03
Dicalcium phos	1.77	1.55	1.73	1.68	1.71
Limestone	1.33	1.49	1.36	1.38	1.36
Salt	0.40	0.40	0.40	0.40	0.40
Soybean oil	1.00	2.84	1.29	0.85	3.03
Vitamin and TM[1]	0.20	0.20	0.20	0.20	0.20
D, L-methionine	0.15	0.14	0.13	0.24	0.14
Lysine-HCl	0.00	0.09	0.00	0.13	0.10

[1]The vitamin and Trace Mineral (TM) premix provided the following per kg of diet: Retinyl palmitate = 3000 IU; Cholecalciferol = 1000 ICU; DL-alpha-tocopherol = 10 IU; Menadione sodium bisulfite = 1 mg; Thiamin = 1.8 mg; Riboflavin = 3.6 mg; Niacin = 25.0 mg; Pantothenic acid = 10.0 mg; Pyridoxine = 3.5 mg; Folacin = 0.5 mg; Biotin = 0.15 mg; Vitamin B_{12} = 0.01 mg; Choline, 500 mg; Ethoxyquin = 50 mg; Copper = 8 mg; Iron = 80 mg; Manganese = 60 mg; Selenium = 0.1 mg and Zinc, 40 mg

Table 3: Results when chicks were fed diets with different types and levels of cereal grains

Grains	Inclusion (%)	Feed in take (g)	Chick weight (g)	Feed/ gain	AME (kcal kg^{-1})	Energy (kcalday^{-1})
Corn	-	754.0	593	1.280	3025.0	121.0
Barley	17	763.0	581	1.310	2923.0	121.0
	34	754.0	582	1.290	2963.0	118.0
	51	731.0	586	1.250	2882.0	109.0
Drought corn	17	725.0	563	1.280	2980.0	114.0
	34	751.0	573	1.310	2983.0	118.0
	51	732.0	555	1.320	2986.0	115.0
Sorghum	17	749.0	574	1.310	3006.0	115.0
	34	661.0	516	1.280	2971.0	103.0
	51	638.0	517	1.240	2846.0	97.0
Wheat	17	702.0	538	1.310	2969.0	110.0
	34	697.0	538	1.300	2971.0	109.0
	51	695.0	546	1.270	2972.0	109.0
SEM	-	26.90	23.9	0.031	28.6	4.4
Probability (P>f)						
Sorghum linear		0.01	0.09	0.010	0.01	0.01
Barley linear		NS	NS	0.020	NS	0.09

Density (g/cc) of the mixed diets containing 51% grain was as follows: Control corn, 0.643; drought corn, 0.655; barley, 0.680; wheat, 0.640 and sorghum, 0.642.Sorghum inclusion generally depressed performance of chicks (Table 3). Increasing the percentage of sorghum in the diet caused a linear decrease in the feed intake of chicks which also decreased chick weight, feed/gain ratio, AME of the diet and energy intake/chick per day. Lower chick weight was probably caused by decreased feed intake. The effect on feed/gain was due to the lower body weight of chicks that were fed diets with increased sorghum inclusion. The lower AME content of sorghum-containing diets indicated that sorghum was less digestible than

Table 4: Comparison of results by level of grain inclusion and by kind of grain substitution for control corn

Comparison	Sources	Feed intake (g)	Chick weight (g)	Feed/gain	AME (kcal day^{-1})	Energy (kcal day^{-1})
Grains	17	735	564	1.30	2997	115
	34	716	551	1.30	2972	112
	51	699	551	1.27	2936	108
Corn		754	593	1.28	3025	121
Barley		749	583	1.29	2943	116
Drought corn		736	565	1.30	2957	115
Sorghum		683	536	1.28	2921	105
Wheat		698	541	1.29	2967	109
SEM		14.6	13	0.01	15.4	2.4

Table 5: Percentage of each diet that was collected on each sieve

		U.S. sieve number					
Grains	Inclusion %	4	8	16	30	50	Pan
Corn	-	5.78	32.88	36.61	9.82	12.32	2.51
Barley	17	6.58	34.74	37.94	7.28	11.78	1.68
	34	9.75	39.34	32.02	9.84	7.67	1.38
	51	13.77	42.61	26.07	11.51	5.28	0.76
Drought corn	17	8.04	35.97	31.86	10.55	7.25	6.33
	34	5.35	33.38	36.84	10.08	9.17	5.18
	51	7.48	37.12	36.05	6.55	8.20	4.60
Sorghum	17	4.81	35.23	37.08	8.02	8.06	6.80
	34	4.46	34.56	37.26	9.98	10.99	2.75
	51	2.30	30.09	39.72	12.54	9.88	5.47
Wheat	17	5.27	35.99	37.08	8.04	6.17	7.43
	34	5.42	36.38	35.38	9.31	10.05	3.46
	51	6.08	40.40	31.39	10.24	7.17	4.72

the corn it replaced. A decrease in daily energy intake was due to a combination of lower daily feed intake and lower AME content of the sorghum diets.

Effects of barley inclusion were not as conclusive as those for sorghum inclusion. The feed/gain decreased with increasing barley substitution for corn. Daily energy intake decreased slightly ($p = 0.09$) with increasing barley inclusion. Drought corn and wheat inclusion caused no linear effects on performance criteria when they were substituted in the diet for control corn.

Results in Table 4 indicate that broiler performance was lower when other grains were substituted for corn. Feed intake, chick weight, AME and daily energy intake were lowest for sorghum when results from the 17, 34 and 51% substitutions were averaged. The performance of chicks fed wheat-substituted diets was next lowest.

Grains had different particle sizes when ground through the same hammer mill screen (Table 5). Diets with increasing amounts of barley had larger particle sizes, as indicated by higher retention on sieves with larger hole sizes and less retention on sieves with smaller holes. Except for barley, other grains appeared to have more small particles than corn with a higher percentage of grain present in the pan below the sieve with the smallest holes.

In the preference experiment with mature roosters, there were no significant differences. Roosters chose about as much feed from the cup with the control corn diet as they did from any of the other 12 diets offered.

DISCUSSION

Results from this experiment indicate that the source of grain in broiler starter diets altered the ME consumed by a chick each day. The results also suggest that performance was related to energy intake. Chicks fed diets with sorghum showed a linear decrease in ME/kg, energy per day, feed intake and chick weight with increasing sorghum inclusion (Table 3). Previous research indicated that the tannin content of sorghum did not affect broiler performance when sorghum was part of a balanced diet (Armstrong *et al.*, 1973). Increasing wheat inclusion did not cause a linear decrease in these criteria; however average daily energy from these diets was second lowest as were feed intake and chick weight (Table 4). Daily energy intake of chicks fed diets with barley and drought corn was less than that of chicks fed control corn but more than that of chicks fed sorghum and wheat.

Changes in energy intake are important because of the effect on energy used for production (Latshaw and Moritz, 2009). For example, suppose half of the energy of a broiler diet is used for maintenance and half for production. A 1% decrease in total energy intake results in a 2% decrease in production. That occurs because maintenance remains the same, regardless of energy intake, so all of the decrease in energy intake is at the expense of production.

An explanation for the results with broiler chicks was not available from other criteria recorded in this research. Mature roosters did not indicate that the diets with sorghum and wheat were objectionable which would have been indicated by a preference for the control corn diet.

No large differences in the density of individual grains or of diets containing 51% of the grains were recorded, although the barley diet was slightly more dense than the other diets. A low density and poor chick performance might have suggested digestive tract distension as a factor limiting intake.

Differences in fineness of diets with different grains were suggested only for the barley diets (Table 5). Feed intake and chick weight were high even though the ME of the diets was lower than that of other grains, except for sorghum (Table 3 and 5). A coarser grind of wheat increased feed intake and weight gain without affecting AME of the diet (Amerah *et al.*, 2007). In the present study, particle size was larger than the particle size for both the coarse and medium grinds in the research cited.

CONCLUSION

Results from this experiment show that broiler chicks do not consume the same amount of daily energy from diets with different cereal grains. Mature roosters did not indicate any objectionable taste or palatability of the various diets. Based on results from this experiment, no reason for the difference in energy intake was determined.

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