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Full Length Research Paper

Evaluation of corn meal on performance, carcass characteristics and nutrient digestibility of male broiler chickens

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To study the effect of corn meal (CM) on performance, carcass characteristics and nutrient digestibility of chickens in a completely randomized design experiment with 4 × 2 factorial arrangement and 4 replicates per treatment, 384 Ross male broiler chickens in a 49 days period were evaluated. Treatments were 0 (CM0), 15 (CM15), 30 (CM30), or 45 (CM45) CM to replace corn and 2 levels of commercial NSP-degrading enzyme (0 and 0.025%). Corn meal had no effect ($P > 0.05$) on body weight gain, feed intake and carcass characteristics during the whole brooding period. Dietary corn meal level (CM45) had significant effect on digestibility of fat, apparent metabolizable energy (AME) and apparent metabolizable energy corrected for nitrogen (AME_n). However, enzyme supplementation significantly increased phosphorous digestibility ($P < 0.05$). Interaction between corn meal level and enzyme supplementation had significant effect on excreta dry matter (DM), organic matter (OM), crude protein (CP), AME and AME_n during 0 to 49 days of age. Together, the results suggested that replacement of corn by corn meal may affect the digestibility of OM, CP, AME, AME_n, and enzyme supplementation has some beneficial effects on theses traits.

Key words: Corn meal, enzyme, broiler chickens, performance, carcass characteristics, nutrient digestibility.

INTRODUCTION

Approximately, 20% of corn around the world is processed into cereals and other products for human consumption, of which only 20% is processed through the dry milling industry (Corn Refiners Association, 2004). Although, the primary objective of dry milling is to produce corn oil and flaking grits for human food products, the corn dry milling process produces a number of by-products that could have nutritional benefits for poultry and swine industry. Despite being low in total fiber (approximately 9.5% neutral detergent fiber), corn can contribute a large proportion of total fiber in the diet (Watson, 1987). The hull and germ fractions contribute 51 and 16% of the fiber within the corn kernel, respectively, of which 70 and 25% are hemi-cellulose and cellulose, respectively (Wursch et al., 1986; Ranere et al., 2009).

Corn is the main source of energy in formulating poultry rations. Its price is increasing because of the limited world yield in covering the demands for both humans and livestock (Zand and Froudi, 2011). So, it is important to search for other alternative cheap energy sources which can overcome this problem. The nutritive value of corn by-products depends on the technological processes used, such as milling, de-germing, oil extraction, and starch separation (Stock et al., 2000). Feed grade corn (second grade) is almost always used in poultry nutrition.

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Abbreviations: **CM,** Corn meal; **NSP,** non-starch polysaccharides; **SBM,** soybean meal; **AME,** apparent metabolizable energy; **BWG,** body weight gain; **FI,** feed intake; **FCR,** feed conversion ratio; **AME_n,** apparent metabolizable energy corrected for nitrogen, **NFE,** nitrogen-free extracts.

Table 1. Corn meal individual amino acid analysis.

Amino Acid	Content(%)[1]	AA (%) in Cp	Content (% as is)
Methionine	0.170	1.73	0.180
Cyctine	0.200	1.95	0.210
Methionine + Cyctine	0.370	3.68	0.390
Lysine	0.470	4.70	0.490
Threonine	0.380	3.73	0.390
Arginine	0.670	6.65	0.700
Isoleucine	0.300	2.93	0.310
leucine	0.790	7.81	0.820
Valine	0.470	4.68	0.490
Histidine	0.280	2.81	0.300
Phenylalanine	0.410	4.02	0.420
Glysine	0.520	5.11	0.540
Serine	0.450	4.50	0.470
Proline	0.650	6.46	0.680
Alanine	0.640	6.31	0.660
Aspartic Acid	0.730	7.26	0.760
Glutamic Acid	1.39	13.8	1.45
Total (without NH_3)	8.25	84. 5	8.87
Ammonia	0.180	1.80	0.190
Total	8.70	86.3	9.06

[1]Amino acids measured by Evonik-Degussa Company in Germany and figures standardized to a dry matter content of 88%.

More than 3% of this corn is broken and more than 5% is damage and evacuated the external material. Food grade corn (first grade) used in food industry after dry milling process for puffing snack production and the by-product named corn gluten meal. In this processing protein-ate kernel, high fiber bran and main part of corn oil with developed and new technology are separated from corn seed and used in poultry nutrition. This corn by-product is high in fiber and oil and its composition differs from whole corn in ways that would limit its nutritional value for poultry nutrition.

Dietary fiber negatively impacts energy and nutrient utilization by poultry and swine and as a consequence, increases waste production and nutrient excretion (Shi and Noblet., 1994; Canh et al., 1998; Davidson and McDonald, 1998). Although, the fiber content in a standard U.S. corn-soybean meal diet is considered to be relatively low (approximately 9% neutral detergent fiber - NDF), any means to further reduce this fiber would improve the overall nutritional value of the diet. Exogenous enzymes are added to poultry diets to manipulate conditions in the digestive tract and increase the nutrient value of feedstuffs (Classen, 1996; Meng and Slominiski, 2005). Fibrolytic enzymes have been used extensively in diets to reduce viscosity in the small intestine through the cleavage of soluble nonstarch polysaccharides. Additionally, these enzymes degrade cell walls and increase the digestibility and absorption of sugars from hemicellulose (Meng and Slominiski, 2005). Therefore, substrates (that is, starch) within the cell walls become available for degradation by endogenous enzymes (Classen, 1996). To date, research on these enzymes has not extensively examined their effect on corn or soybean meal (SBM) individually. Moreover, the potential for different responses based on the age and physiological development of the digestive tract is often ignored (McCracken and Quintin, 2000).

The objective was to determine performance, carcass characteristics and nutrient digestibility of broiler chickens fed corn meal originated from Argentinean food grade corn, with or without a dietary non-starch polysaccharides (NSP)-degrading enzyme for a period of 49 days.

MATERIALS AND METHODS

Broiler housing and experimental diets

This experiment was conducted to examine the effect of four levels of corn meal (CM) on performance, carcass characteristics and nutrient digestibility of male broiler chickens from hatching to 49 days of age in a completely randomised design (CRD) with eight dietary treatments. This study was carried out over a 7-week period, using a total of 384 day-old chickens of a commercial genotype (Ross 308). Treatments were 0 (CM0), 15 (CM15), 30 (CM30), or 45 (CM45) CM to replace corn and 2 level (0 and 0.025%) of commercial NSP-degrading enzyme (ENDOFEED W) prepared from GNC BIOFERM INC., Canada. Minimum activity of NSP-

Table 2. Ingredients (%) and calculated analysis of the experimental diets for broiler chickens.

Ingredient /Treatment[1]	Starter				Grower				Finisher			
	1,2	3,4	5,6	7,8	1,2	3,4	5,6	7,8	1,2	3,4	5,6	7,8
Corn	57.2	47.2	39.9	32.9	62.8	55.0	47.3	39.6	66.8	58.5	50.3	42.0
Corn meal	0.000	8.58	17.2	25.7	0.000	9.42	18.8	28.3	0.000	10.0	20.0	30.0
Soybean meal	31. 8	35.6	35.3	34.8	30.9	30.3	29.3	29.1	27.2	26.6	25.9	25.3
Fish meal	5.00	2.17	2.00	2.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dicalcium Phosphate	0.920	1.18	1.18	1.16	1.31	1.29	1.28	1.26	1.26	1.24	1.23	1.22
Carbonate	1.15	1.18	1.18	1.16	1.31	1.29	1.28	1.26	1.26	1.24	1.23	1.22
Vit. and min. premix[2]	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Salt	0.360	0.410	0.410	0.410	0.310	0.310	0.310	0.310	0.260	0.260	0.260	0.260
Corn oil	3.00	3.00	2.19	1.29	2.99	3.01	1.02	0.030	3.14	2.09	1.03	0.010
DL- Methionine	0.100	0.130	0.140	0.140	0.060	0.060	0.070	0.070	0.000	0.000	0.000	0.000
Calculated analysis												
AME_n (MJ/kg[3])	12.6	12.6	12.6	12.6	12.7	12.7	12.7	12.7	13.0	13.0	13.0	13.0
CP (%)	21.6	21.6	21.6	21.6	18.8	18.8	18.8	18.8	17.4	17.4	17.4	17.4
Fat (%)	5.70	6.10	5.80	5.50	5.60	5.30	4.96	4.60	5.90	5.50	5.20	4.80
Fibre (%)	3.60	4.50	5.10	5.80	3.60	4.30	5.10	5.80	3.40	4.20	5.00	5.70
Ca (%)	0.940	0.940	0.950	0.950	0.850	0.850	0.850	0.850	0.780	0.780	0.780	0.780
Av. P (%)	0.420	0.420	0.420	0.420	0.330	0.330	0.330	0.330	0.290	0.290	0.290	0.290
Lin. acid (%)	2.30	2.30	2.50	2.50	2.40	2.40	2.40	2.40	0.120	0.120	0.120	0.120
Na (%)	0.190	0.190	0.190	0.190	0.140	0.140	0.140	0.140	2.53	2.53	2.53	2.53
Arg (%)	1.41	1.42	1.42	1.41	1.22	1.22	1.22	1.22	1.11	1.11	1.10	1.10
Lys (%)	1.26	1.23	1.23	1.23	1.00	1.00	1.00	1.00	0.910	0.910	0.910	0.190
Met +Cys (%)	0.840	0.840	0.840	0.840	0.680	0.680	0.680	0.680	0.590	0.590	0.580	0.580
Try (%)	0.310	0.320	0.320	0.340	0.270	0.270	0.270	0.270	0.240	0.240	0.240	0.240

[1]Treatments are: **1,** 0% Corn meal. **2,** 0% corn meal+0.025% enzyme. **3,** 15% corn meal. **4,** 15% corn meal+0.025% enzyme. **5,** 30% corn meal. **6,** 30% corn meal+0.025% enzyme. **7,** 45% corn meal. **8,** 45% corn meal+0.025% enzyme. [2]Provided per kg of diet: vitamin A, 3,600,000 IU; vitamin D_3, 800,000 IU; vitamin E, 7,200 IU; vitamin K_3, 800 mg; vitamin B_1, 720 mg; vitamin B_2, 2,640 mg; vitamin B_3, 4,000 mg; vitamin B_5, 12,000 mg; vitamin B_6, 1,200 mg; vitamin B_9, 400 mg; vitamin B_{12}, 6 mg; vitamin H_2, 40 mg; choline chloride, 200,000 mg; Mn, 40,000 mg; Fe, 20,000 mg; Zn, 40,000 mg; Cu, 4,000 mg; Se, 80 mg. [3]To change MJ/kg to kcal/kg, multiply the values by 239.

degrading enzyme produced originally from *Aspergillus niger*, for *β*-Gluconases and arabinoxylanases where 440 and 1200 unit per gram of enzyme, respectively. Each of the 8 dietary treatments had four replicates of 12 birds per pen (1×1 m).

Individual (CM) amino acids analysis is illustrated in Table 1. The composition of dietary treatments is shown in Table 2. The mash form basal diets fed to broiler chickens were corn-SBM and formulated to provide NRC (1994) requirement of chickens during the starter (0 to 21 days), grower (21 to 42 days) and finisher (42 to 49 days) periods. Corn meal apparent metabolizable energy (AME_n) was

Table 3. Effect of corn meal on performance of broiler chickens.

Treatment[1] (%)	Starter			Grower			Finisher		
	FI (g/d/b)[2]	BWG (g/d/b)[3]	FCR[4]	FI (g/d/b)	BWG (g/d/b)	FCR	FI (g/d/b)	BWG (g/d/b)	FCR
CM0	1150	625	1.84[b]	2727	1093	2.50	4838	2039	2.37[b]
CM15	1137	614	1.85[b]	2661	997	2.68	4683	1912	2.45[ab]
CM30	1183	583	2.03[ab]	2741	1061	2.60	4876	1969	2.48[ab]
CM45	1207	571	2.12[a]	2659	1048	2.53	4788	1899	2.52[a]
± SEM	27.6	15.3	0.050	57.6	30.6	0.060	82.7	38.4	0.020
Enzyme									
-[5]	1164	586	1.99	2700	1022	2.65[a]	4797	1925	2.49[a]
+	1175	611	1.93	2694	1078	2.51[b]	4795	1985	2.42[b]
± SEM	19.5	10.8	0.030	40.6	21.6	0.040	58.5	27.1	0.020
Source of variations					**P values**				
Enzyme	0.670	0.120	0.240	0.920	0.080	0.050	0.980	0.120	0.008
Corn meal %	0.280	0.060	0.001	0.650	0.190	0.280	0.400	0.060	0.012
Corn meal× enzyme	0.950	0.650	0.600	0.730	0.490	0.070	0.880	0.350	0.019

[1]Treatment were 0 (CM0), 15 (CM15), 30 (CM30) or 45 (CM45) CM to replace corn and 2 levels (0 and 0.025%); [2]feed intake (gram per bird per day); [3]body weight gain (gram per bird per day); [4]feed conversion ratio. [5]-, without enzyme; +, with enzyme.

calculated as described by Jassen (1989):

$$AME_n = (36.21 \times CP) + (85.4 \times EE) + (37.26 \times \text{nitrogen-free extracts (NFE)})$$

and then included to its composition to prepare the diets using UFFDA software. The amino acid composition of corn meal is close to ground corn, but some of the other composition are different that are listed at the bottom of Table 1. The measured as fed basis of crude protein, moisture, ash, crude fat, NFE, calcium and total phosphorous of the corn meal were 9.7, 13.5, 2.5, 10, 54.3, 0.3 and 0.48%, respectively. Feed and water were provided *ad libitum* throughout the experiment.

Broiler chickens were monitored twice-daily for general health. Broilers were weighed by pen at days 0, 21, 42 and 49. One bird with close to the average body weight (±5 g) from each replicate of treatments was slaughtered at day 49 for carcass characteristics. Based on the remaining birds and feed at the end of each period, adjusted body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) measured during starter, grower and finisher periods. The experimental protocol was reviewed and approved by the Animal Care Committee of the Ferdowsi University of Mashhad, Iran.

Nutrient digestibility

Chromic oxide was supplemented at 3 g/kg of the diets, and digestibility was measured for 3 consecutive days of 19 to 21 of age. Chromic oxide-marked feeds were fed to chickens during 2 days adaptation period (days 17 to 18) and during three days collection period (days 19 to 21). Excreta samples were taken 3 times a day for 3 consecutive days, contaminants such as feathers and scales were removed carefully, pooled together and kept in -20°C for later analysis. Chromium oxide content of the feed and excreta was determined according to Fenton and Fenton method (Fenton and Fenton, 1979).

Statistical analysis

All data were analyzed by the analysis of variance (ANOVA) option GLM of SAS/STAT software (SAS Institute, 2001) and when treatment means were significant ($P < 0.05$), Duncan's multiple range tests was used to compare means. Before analysis, the univariate test was used to assess the normality of all data. Body weight gain, FI and FCR were analysed on a floor pen basis.

RESULTS

Corn meal level had no significant effect on BWG and FI during the starter, grower, finisher and overall periods ($P > 0.05$; Table 3). Corn meal increased ($P < 0.05$) FCR for the periods of 0 to 21 and 0 to 49 days of age. However, enzyme

Table 4. Effect of corn meal on nutrients and energy digestibility of broiler chicken.

Treatment[1] (%)	P (%)	Ca (%)	Fat (%)	DM (%)	OM (%)	CP (%)	AMEn (MJ/kg[2])	AME (MJ/kg)
CM0	45.7	40.1	77.9^{b2}	92.6	71.8	65.4	12.9^{ab}	13.0^{ab}
CM15	50.8	42.1	83.4^{a}	92.5	69.1	63.8	12.3^{b}	12.4^{b}
CM30	43.2	38.0	80. 7^{ab}	91. 5	68.9	61.3	12.3^{b}	12.4^{b}
CM45	46.0	40.4	82. 8^{a}	92.1	67.8	63.5	13.0^{a}	13.5^{a}
± SEM	3.06	2.07	1.33	0.480	1.66	2.50	0.190	0.192
Enzyme								
-[3]	40.1^{b}	39.5	81.6	92.3	69.8	63.0	12.5	12.6
+	52.7^{a}	40.7	80.9	92.0	69.0	64.0	12.8	12.9
± SEM	2.16	1.46	0.940	0.340	1.17	1.77	0.134	0.136
Interaction[4]								
1	44.7	37.6	77.5	92. 7^{ab}	71.6^{ab}	64.1^{ab}	12.8^{a}	12.9^{a}
2	42.1	42.5	78.4	92.5^{ab}	72.1^{ab}	66.7^{ab}	12.9^{a}	13.0^{a}
3	37.1	41.3	81.2	91.2^{b}	63.51^{b}	55.9^{b}	11.3^{b}	11.4^{b}
4	36.5	42.9	85. 7	93.8^{a}	74.7^{a}	71.7^{a}	13.4^{a}	13.5^{a}
5	46. 7	40.5	81.5	92.2^{ab}	70.2^{ab}	61.1^{ab}	12.3^{ab}	12.4^{ab}
6	59.5	35.5	79.8	90.7^{b}	67.6^{ab}	61.5^{ab}	12.3^{ab}	12.4^{ab}
7	49.2	38.7	85.9	93.3^{ab}	73.8^{a}	71.0^{a}	13.5^{a}	13.6^{a}
8	55.5	42.0	79.6	90.7^{b}	61.7^{b}	55.9^{b}	12.4^{ab}	12.5^{ab}
± SEM	4.33	2.93	1.88	0.680	2.35	3.54	0.268	0.272
Source of variations					**P values**			
Enzyme	0.000	0.569	0.612	0.974	0.974	0.717	0.126	0.123
Corn meal %	0.383	0.584	0.033	0.262	0.340	0.716	0.040	0.040
Corn meal× enzyme	0.224	0.367	0.057	0.001	0.000	0.022	0.000	0.000

[1]Treatment were 0 (CM0), 15 (CM15), 30 (CM30) or 45 (CM45) CM to replace corn and 2 levels (0 and 0.025%). [2]To change MJ/kg to kcal/kg, multiply the values by 239. [3]-, without enzyme; +, with enzyme. [4] Interactions are: 1) 0% corn meal. 2) 0% corn meal+0.025% enzyme. 3) 15% corn meal. 4) 15% corn meal+0.025% enzyme. 5) 30% corn meal. 6) 30% corn 3meal+0.025% enzyme. 7) 45% corn meal. 8) 45% corn meal+0.025% enzyme.

addition significantly increased FCR for the periods of grower (2.51 *vs* 2.65) and 0 to 49 days of age (2.49 *vs* 2.42) ($P < 0.05$). Interaction effect between CM and enzyme were not significant for BWG and FI during the brooding period. Although, CM level and enzyme had no significant effect on FCR during the starter and grower periods, this effect for the whole period (0 to 49 days of age) show significant differences ($P < 0.05$) for the CM45 diet.

Dietary CM increased ($P < 0.05$) the digestibility of fat, AME and AMEn (Table 4). This effect was more pronounced in CM45 compared to other treatment. Dietary enzyme supplementation significantly increased phosphorous digestibility ($P < 0.05$). When CM level increased in diet, enzyme supplementation increased phosphorous digestibility more than low level of the CM. Enzyme addition had no significant effect on digestibility of the other measured nutrients ($P > 0.05$). Interaction effect between corn meal levels and enzyme supplementation showed a significant effect on dry DM, OM, CP, AME and AMEn digestibility measured at 19 to 21 days of age. Dietary CM and enzyme supplementation had no ($P > 0.05$) effects on carcass traits.

DISCUSSION

The similarity in BWG and FI during the starter, grower and overall periods in our results was consistent with those reported by Abdelsamif et al. (1983) who found that substitution of corn, corn gluten, corn meal and broken corn partially or completely with soybean meal have no negative impact on FI and BWG.

However Zand and Forudi (2011) reported a reduction in FI which can be attributed to the large volume and light weight of waste corn which had the fast filling effect on gastrointestinal tract of the chickens. When the chicks consume fewer nutrients, weight gain might also be affected. In the current study, CM0 diet FCR increased during the 0 to 21 and 0 to 49 days.

Table 5. Effect of corn meal on relative carcass characteristics of broiler chickens at 49 days of age.

Treatment[1]%	% of live body weight				
	BW[2] (g/b/d)	Breast	Thigh	Gut	Gizzard
CM0	2131	19.7	26.8	8.07	2.54
CM15	2131	20.2	27.7	7.83	2.48
CM30	2160	20.8	27.2	8.39	2.70
CM45	1991	19.9	27.0	8.83	3.03
± SEM	73.3	0.500	0.330	0.360	0.150
Enzyme					
-[3]	2125	20.1	27.2	8.11	2.74
+	2084	20.2	27.1	8.45	2.63
± SEM	51.8	0.350	0.230	0.250	0.100
Source of variations	**P values**				
Enzyme	0.580	0.900	0.850	0.660	0.330
Corn meal %	0.370	0.510	0.330	0.340	0.070
Corn meal× enzyme	0.110	0.730	0.070	0.360	0.630

[1]Treatment were 0 (CM0), 15 (CM15), 30 (CM30) or 45 (CM45) CM to replace corn and 2 levels (0 and 0.025%); [2] body weight (gram per bird per day). [3] -, without enzyme; +, with enzyme.

This effect might be due to higher fiber and soluble NSP present in CM (Zanella et al., 1999). This reason might be true, because addition of NSP-degrading enzyme decreased the negative effect of CM on FCR and numerically increase it at 0 to 21 days of age and significantly ($P < 0.05$) at 21 to 42 and 0 to 49 days of age. The alleviating effect of NSP-degrading enzymes on nutrient digestibility of feeds containing NSPs in chickens are already confirmed (Bedford, 2002). The negative effect of CM on FCR in comparison to corn in addition to its fiber contents (Applegate, 2005) might also be attributed to the level of other nutrients and some amino acids seen in the CM (Table 1). Spite CM increased gizzard relative weight, this effect was not significant ($P > 0.05$). Relatively, heavier gizzard weight might be due to higher fiber and soluble NSP present in CM (Zanella et al., 1999). Larger gizzards were also observed in broilers fed high level of CM when compared with those of gizzards of birds fed the corn diet (Forbes and Covasa, 1995). This result is a consequence of the increased grinding activity of the gizzard. It is reported that the increase in relative pancreas weight in birds fed corn meal could be related to an increase in endogenous enzyme activities and more secretion required to digesting corn meal hemicelluloses (Almirall et al., 1995).

As dietary CM level increased, fat, AME and AME_n digestibility increased. In general, the ME level of corn-SBM diets depends on the digestibility of starch, soluble and insoluble NSP, and protein. An increased efficiency in the ME value of corn and corn-SBM based diets was observed when a multi-carbohydrase preparation was used (Meng and Slominiski, 2005), which was attributed to the improved digestibility of starch and NSP, but the retention of CP was not affected by enzyme supplementation. The decrease of AME and DM digestibility of the diets with enzyme addition seen in the current study was similar with those of the previous report (Meng and Slominiski, 2005). The AME_n prediction of corn meal claimed by Jassen (1989) formula and used in this experiment for diet formulation seems to be a correct estimation of this product and the values obtained from the chickens at 19 to 21 days of age (Table 5) confirm that.

Conclusion

Under the conditions of this study, it was concluded that corn meal at the used level had no effect on performance except for FCR during the 0 to 21 and 0 to 49 days of age. Increasing dietary corn meal level up to 45% increased fat, AME and AME_n digestibility of male broiler chicken during the experiment. It was also concluded that adding enzyme to corn meal in the diet increased nutrient digestibility. The use of corn meal can be useful in broiler chickens diet up to 45% replacement with corn, especially when the price of this product is also of concern.

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