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Effect of dietary level of maize- and rye distiller dried grains with solubles on nutrient utilization and digesta viscosity in laying hens

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ABSTRACT

An experiment on 55 Lohman Brown hens examined the effect of different dietary levels of maize- and rye distillers dried grains with solubles (mDDGS and rDDGS, respectively) on nutrient digestibility, content of metabolizable energy in the diet and balance of nitrogen, calcium, phosphorus, and zinc. Experimental diets were isocaloric and isonitrogenous and contained 0, 5, 10, 15, or 20% mDDGS or rDDGS. Diets with 20% mDDGS or rDDGS were also supplemented with NSP-hydrolysing enzymes.

It was found that 5, 10 or 15% mDDGS in a diet had no effect on apparent digestibility of nutrients, dietary metabolizable energy content, or balance of N, Ca and Zn; 20% mDDGS decreased the digestibility of crude fat and lowered the level of metabolizable energy in the diet, whereas 15 or 20% rDDGS negatively affected organic matter and crude fat digestibility and the dietary metabolizable energy level. A 15 or 20% inclusion of mDDGS or rDDGS had, however, a positive effect on phosphorus balance. Addition of feed enzymes increased nutrient utilization in diets containing 20% DDGS.

KEY WORDS: laying hens, maize DDGS, rye DDGS, nutrient digestibility, metabolizable energy

INTRODUCTION

Distillers dried grains with solubles (DDGS) is a by-product of ethanol production. Growing interest in fuel ethanol production will lead to increases in the amounts of DDGS available to the feed industry. In our previous studies it was

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concluded that maize- and rye DDGS (mDDGS and rDDGS) are useful feed ingredients for laying hens (Świątkiewicz and Koreleski, 2006a,b). Dietary levels up to 15% mDDGS and 10% rDDGS did not unfavourably affect laying performance, egg quality, and flavour of boiled eggs when were used in hens from 26 to 68 weeks of age. Inclusion of mDDGS in the diet positively influenced egg yolk colour. High dietary levels of DDGS (15% rDDGS and 20% mDDGS) did, however, negatively affect laying rate and feed conversion. Similar conclusions on the use of maize DDGS in laying hen diets were drawn by Lumkins et al. (2005) and Roberson et al. (2005).

During fermentation, cereal starch is converted to ethanol and CO_2 and the concentration of the remaining nutrients in DDGS increases 2-3-fold, so DDGS contains high levels of non-starch polysaccharides (NSP). For this reason, performance reduction in hens fed diets with high DDGS contents could be a result of decreased nutrient utilization. The aim of our experiment was to determine the effect of different levels of mDDGS or rDDGS in diets for laying hens on nutrient digestibility, metabolizable energy content, balance of nitrogen, calcium, phosphorus, zinc, and on digesta viscosity.

MATERIAL AND METHODS

The experiment was carried out on 55 Lohman Brown laying hens at 39 weeks of age. The experimental design consisted of 11 treatments with 5 replicates (birds) each. Hens were offered water and feed *ad libitum* and were exposed to a 14 L:10 D lighting schedule, with the dark period at night.

Prior to formulating experimental diets it was determined (AOAC, 1990) that mDDGS and rDDGS contain 35.3 and 33.8% crude protein, 3.9 and 3.6% crude fat, 10.8 and 11.9% crude fibre, 1.7 and 1.5% crude ash, 0.64 and 0.67% Lys, 0.68 and 0.62% Met, 0.08 and 0.07% Ca, 0.543 and 0.495% P, respectively.

All experimental diets were isocaloric and isonitrogenous and contained different levels (0, 5, 10, 15 or 20 %) of mDDGS or rDDGS. The diets with the highest level of mDDGS or rDDGS were also supplemented with NSP-hydrolysing enzymes (Table 1). The experimental diets were fed to hens before the beginning of the balance study (from 26 weeks of age).

At 39 weeks of age the hens were divided into individual balance cages. After a one-week adaptation period, total collection of excreta was carried out during 5 days and feed consumption for each hen was recorded. Excreta were stored in plastic bags at -20ºC for three weeks and after thawing were dried at 50ºC to a constant weight, weighed, and finely ground. The proximate composition of diets and excreta was analysed by standard procedures (AOAC, 1990), gross energy, by

Table 1. Composition and nutrient content of experimental diets, g · kg^{-1}

Ingredients	Dietary treatment										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Maize	350	300	290	260	250	250	300	290	280	260	260
Wheat	244.9	284.5	284.6	304	298.2	298.2	284.5	277.7	270.9	275.3	275.3
Soyabean meal	230	190	150	110	75	75	190	155	120	85	85
Maize DDGS	-	50	100	150	200	200	–	–	–	–	–
Rye DDGS	-	-	-	-	-	-	50	100	150	200	200
Grass meal	30	30	30	30	30	30	30	30	30	30	30
Rapeseed oil	33	33	32	32	32	32	33	34	35	35	35
Limestone	89	89	89	89	89	89	89	89	89	89	89
Dicalcium phosphate	14	14	14	14	14	14	14	14	14	14	14
NaCl	3	3	3	3	3	3	3	3	3	3	3
L-lysine (78%)	-	0.5	1.5	2.3	3.2	3.2	0.5	1.3	2.2	2.9	2.9
DL-methionine (99%)	1.1	1	0.9	0.7	0.6	0.6	1	1	0.9	0.8	0.8
Vitamin-mineral premix[1]	5	5	5	5	5	5	5	5	5	5	5
NSP-hydrolysing enzymes[2]	-	-	-	-	-	+	-	-	-	-	+
Metabolizable energy, MJ · kg^{-1} [3]						11.45					
Crude protein[4]						170					
Crude protein[5]	167	165	165	168	167	169	168	164	166	168	168
Lys[4]						7.80					
Met[4]						3.70					
Ca[4]	36.0										
Ca[5]	35.7	35.7	35.8	35.5	35.8	35.6	35.7	35.5	35.6	35.5	35.6
Total P[4]	6.00										
Total P[5]	5.88	5.90	5.92	5.86	5.90	5.90	5.87	5.90	5.88	5.85	5.89

[1] Lutamix BASF, supplied to 1 kg of diet, IU: vit. A 10 000; vit. D_3 3000; mg: K_3 2; B_1 1; B_2 4; B_6 1.5; B_{12} 0.01; Ca-pantotenate 8; niacine 25; folic acid 0.5; choline-Cl 250; Mn 100; Zn 50; Fe 50; Cu 8; J 0.8; Se 0.2 and Co 0.2; [2] Ronozyme WX (endo-1,4-β-xylanase activity of 1000 FXU/g) and Ronozyme VP (endo-1,3(4) –β-glucanase activity of 50 FBG/g and also pentozanase, hemicellulase and pectinase activity). Each preparation was added to the diet in amount of 200 mg · kg^{-1}; [3] calculated according to European Table (1989) as a sum of ME content of components; [4] calculated according to the chemical composition of feed components; [5] analysed

using an adiabatic oxygen bomb calorimeter, total phosphorus, calorimetrically by the molibdeno-vanadate method (AOAC, 1990), Ca and Zn, by flame atomic absorption spectrophotometry (AOAC, 1990). The total tract apparent digestibility of organic matter, crude fat and nitrogen-free extractives, metabolizity coefficient for apparent metabolizable energy corrected for nitrogen retention, and balances of nitrogen, calcium, phosphorus and zinc were calculated using the obtained data.

After completion of the balance trial, 3 hens each from groups I, III, IV, V, VI, VIII, X and XI were killed by cervical dislocation. Whole intestines were removed and total intestinal contents from the upper parts of the intestines (between the gizzard and Meckel's diverticulum) were collected and centrifuged at 5000 *g* for 10 min. Viscosity of the supernatant was measured on a capillary viscometer at 37ºC.

In DDGS samples the contents of simple sugars (arabinose, xylose, mannose, galactose and glucose) in NSP were determined using a gas HP 5890 chromatograph (Englyst and Cummings, 1984). Total and insoluble β-glucans were analysed using the Aman and Graham procedure (1987).

Data were subjected to one-way analysis of variance. The significance of differences between means was determined by Duncan's multiple range test with the use of the Statistica 5.0 PL software package. Two statistical analyses were performed separately for evaluation of the effects of mDDGS and rDDGS on the studied parameters.

RESULTS AND DISCUSSION

Maize DDGS contained 26.5% total non-starch polysaccharides (3.55% soluble and 23.5 insoluble NSP), 21.5% arabinoxylans and 0.32% β-glucans. The level of NSP in rDDGS was higher: 29.0% total non-starch polysacaccharides (4.65% soluble and 24.4 insoluble NSP), 23.3% arabinoxylans and 1.17% β-glucans. The DDGS used in the experiment, especially rDDGS, contained considerable amounts of NSP. For comparison the level of total NSP and arabinoxylans in rye grain, analysed in our earlier experiment (Świątkiewicz et al., 2001), was 2-3 times lower than in the studied DDGS.

The average laying rate during the balance assay was 96.5%, daily mass of eggs, 59.5 g/hen/day, feed conversion for 1 kg of eggs, 1.97 kg, and feed conversion for 1 egg, 121 g of feed (Table 2). Dietary inclusion levels of mDDGS had no effect on these parameters, but in hens fed the diet with 20% rDDGS, worsening of laying performance and feed conversion was noted ($P \leq 0.05$). The results of our previous experiments (Świątkiewicz and Koreleski, 2006 a,b), obtained for

Table 2. Effect of maize distillers dried grains with solubles (mDDGS) and rye distillers dried grains with solubles (rDDGS) on performance indices during balance study, 39-40 weeks of age

Item	mDDGS, % of diet							rDDGS, % of diet						
	0	5	10	15	20	20+ E[1]	SEM	0	5	10	15	20	20+ E[1]	SEM
Laying rate, %	96.7	96.4	97.8	97.7	96.7	96.9	0.205	96.7[b]	96.7[b]	96.9[b]	95.5[ab]	94.4[a]	96.1[ab]	0.216
Daily mass of eggs, g per hen	59.4	60.1	59.8	60.3	59.8	59.7	0.221	59.4[b]	60.8[b]	60.0[b]	58.7[ab]	56.7[a]	58.9[ab]	0.230
Feed, kg per 1 kg of eggs	1.96	1.95	1.96	1.96	1.94	1.96	0.008	1.96[a]	1.94[a]	1.95[a]	2.00[ab]	2.05[b]	1.99[ab]	0.008
Feed, g per 1 egg	120	121	120	121	120	120	0.312	120	122	121	123	123	122	0.325

[1] - addition of NSP hydrolysing enzymes

[a,b] - within groups fed diets with mDDGS and rDDGS values in the same rows with different letters differ significantly at $P \leq 0.05$

the whole laying cycle (26-68 weeks of age) show that the decrease in laying performance could also have been caused by 20% mDDGS and 15% rDDGS in the diet, especially in the second phase of the laying cycle. Lumpkins et al. (2005) found no significant difference in laying performance when hens were fed diets containing 0 or 15% mDDGS.

The results from the balance assay are summarized in Table 3. There was no difference between treatments in apparent digestibility of nitrogen-free extractives in total digestive tract. The dietary inclusion level of mDDGS had no effect on organic matter digestibility, but in the treatment with 20% mDDGS, a decrease in crude fat digestibility and metabolizable energy of the diet in comparison with the control group was found ($P \leq 0.05$). In contrast with our findings, Spiehs et al. (1999) reported an increase in metabolizable energy when 10 or 20% mDDGS was included in a pig diet, but in a later experiment (Spiehs et al., 2000), a dietary level of 20% mDDGS had no effect on energy utilization in pigs.

In hens fed the diet with 20% rDDGS, the digestibility of organic matter was significantly reduced as compared with the control group (Table 3). A decrease in fat digestibility and in the percentage of AME_N in gross energy was observed when the diet contained 15 or 20% rDDGS ($P \leq 0.05$). In an experiment on growing pigs, Nyachoti et al. (2005) showed that wheat DDGS had a significantly lower digestibility of dry matter, gross energy and crude protein as compared with wheat. This may correspond with the decrease in nutrient digestibility in treatments with a high dietary level of rDDGS observed in our experiment.

Addition of NSP hydrolyzing enzymes to the diet positively affected nutrient utilization and there was no difference in nutrient digestibility and metabolizability coefficients between the control treatment and hens fed diets with 20% mDDGS or rDDGS supplemented with the enzyme preparation (Table 3). Dietary inclusion levels of mDDGS or rDDGS did not significantly affect intestinal digesta viscosity, however, viscosity was numerically higher in treatments with 20% DDGS than in the control group. Supplementation of 20% DDGS diets with enzymes numerically decreased digesta viscosity, but this effect was not confirmed statistically (Table 3).

The results of chemical analysis of NSP fractions in DDGS and the positive effect of enzymes could suggest that the main reason for reduced nutrient digestibility of diets with high levels of DDGS is the considerable amount of non-starch polysaccharides in this by-product. Similar results were obtained by Pan et al. (1998) and Lazaro et al. (2003), who reported that supplementation of diets containing high levels of cereals rich in NSP with NSP-hydrolysing enzymes had a positive influence on dry matter and fat digestibility, dietary AME_N content and digesta viscosity. Jaroni et al. (1999) found, however, no beneficial effect on digesta viscosity or protein and fat digestibility in hens when diets containing 8 or 16% of wheat middlings were supplemented with xylanase. Smulikowska et al.

Table 3. Effect of maize distillers dried grains with solubles (mDDGS) and rye distillers dried grains with solubles (rDDGS) on nutrient digestibility, metabolizable energy of diet, viscosity of intestinal content and balance of N, Ca, P and Zn

Item	mDDGS, % of diet							rDDGS, % of diet						
	0	5	10	15	20	20+E[1]	SEM	0	5	10	15	20	20+E[1]	SEM
Apparent digestibility, %														
organic matter	74.7	74.0	72.6	73.4	73.3	74.6	0.265	74.7^{c}	74.5^{c}	74.2^{bc}	71.8^{ab}	70.9^{a}	73.6^{abc}	0.280
crude fat	84.9^{b}	83.2^{ab}	83.6^{ab}	83.4^{ab}	82.3^{a}	85.1^{b}	0.259	84.9^{c}	83.4^{bc}	83.2^{bc}	81.5^{ab}	79.8^{a}	83.3^{bc}	0.275
N- free extractives	78.9	77.5	77.5	78.1	77.1	77.2	0.290	78.9	77.3	78.2	76.2	76.7	78.0	0.298
Metabolizability coefficient														
AME_N[2]	0.687^{b}	0.683^{b}	0.684^{b}	0.686^{b}	0.671^{a}	0.688^{b}	0.003	0.687^{b}	0.687^{b}	0.683^{b}	0.666^{a}	0.659^{a}	0.681^{b}	0.003
viscosity, cPs	2.61	n.d.[3]	2.48	n.d.[3]	2.98	2.35	0.123	2.61	n.d.[3]	2.57	n.d.[3]	3.03	2.40	0.110
N intake, mg/hen per day	2642	2662	2673	2621	2641	2639	13.3	2647	2642	2635	2636	2547	2630	15.5
N excretion, mg/hen per day	1363	1368	1384	1327	1390	1363	7.21	1363	1362	1350	1356	1320	1345	7.39
N retained, % of N intake	48.5	48.6	48.2	49.4	47.3	48.3	0.287	48.5	48.5	48.8	48.5	45.9	48.9	0.298
Ca intake, mg/hen per day	4157	4182	4198	4116	4149	4150	20.9	4157	4158	4141	4140	4116	4133	16.5
Ca excretion, mg/hen per day	2011	2036	2070	1910	1953	1856	18.2	2011	1952	1964	1966	1959	1917	18.5
Ca retained, % of Ca intake	51.7	51.3	50.7	53.6	52.9	55.2	0.416	51.7	53.1	52.6	52.5	53.3	53.6	0.430
P intake, mg/hen per day	537	543	545	534	536	537	3.10	537	537	535	535	532	534	1.75
P excretion, mg/hen per day	423^{b}	416^{ab}	416^{ab}	399^{a}	399^{a}	400^{a}	2.01	423^{b}	413^{ab}	405^{ab}	411^{ab}	401^{a}	400^{a}	2.09
P retained, % of P intake	21.3^{a}	23.4^{ab}	23.6^{ab}	25.2^{b}	25.5^{b}	25.6^{b}	0.317	21.3^{a}	23.1^{ab}	24.3^{ab}	23.1^{ab}	24.6^{b}	25.1^{b}	0.327
Zn intake, mg/hen per day	10.14	10.19	10.24	10.04	10.12	10.12	0.081	10.14	10.13	10.10	10.09	10.04	10.08	0.075
Zn excretion, mg/hen per day	9.13	9.24	9.02	9.05	9.17	9.10	0.108	9.13	8.93	9.19	9.08	9.11	9.14	0.099
Zn retained, % of Zn intake	9.90	9.36	11.79	9.86	9.24	10.04	0.891	9.90	11.90	8.96	10.03	9.23	9.39	0.921

[1] - addition of NSP hydrolysing enzymes

[2] - AME_N - for apparent metabolizable energy corrected for nitrogen retention

[3] - not determined

[a,b,c] - within groups fed diets with mDDGS and rDDGS values in the same rows with different letters differ significantly at $P \leq 0.05$

(1997) found that NSP-hydrolysing enzymes decreased intestinal digesta viscosity of hens fed a diet with 30% whole rye, but the enzyme was not effective when ground rye was used. Supplementation of a diet containing 30% brewer's dried grains with xylanase positively affected performance and nutrient utilization in broilers (Iyayi and Davies, 2005).

The results of the balance study did not show any significant effect of dietary inclusion level of DDGS or supplementation of the diet containing 20% DDGS with NSP-hydrolizing enzymes on retention (as % of intake) and excretion of N, Ca and Zn (Table 3). In diets with 0, 5, 10, 15 and 20% DDGS, the balances of N, Ca and Zn were similar. In contrast with our results, Spiehs et al. (1999) reported that inclusion of 10 or 20% mDDGS in diets for growing and finishing swine tended to increase N excretion. In another study, these authors showed that inclusion of 20% mDDGS in the diet had no effect on nitrogen retention (as % of N intake), but increased N excretion (Spiehs et al., 2000).

There was a significant influence of dietary treatment on P balance (Table 3). Dietary inclusion levels of 15 and 20% mDDGS or 20% rDDGS decreased P excretion and positively affected P retention ($P \leq 0.05$). It could be speculated, based on literature data, that fermentation increases P availability in DDGS, possibly through synthesis of microbial phytase (Lumpkins and Batal, 2005). The higher P availability of diets with 15 and 20% DDGS could be important due to environmental concerns and for economic reasons (phosphorus is an expensive component of poultry diets). Our results correspond with data from experiments on pigs (Spiehs et al., 1999), where inclusion of 10 or 20% DDGS in a maize-soyabean based diet increased P retention (as % of P intake) and decreased P excretion. In a later experiment by Spiehs et al. (2000), inclusion of DDGS into a diet had no effect on P retention, but urinary P excretion in pigs fed a diet with 20% mDDGS tended to decrease as compared with a control group ($P \leq 0.15$). Apparent total tract digestibility of P in DDGS fed to growing pigs amounted to 59.1% and was significantly greater than in maize (Pedersen et al., 2007). Whitney et al. (2001) suggested that DDGS could be an excellent source of available P for growing swine. They showed in slope-ratio analysis, that P availability in mDGGS was 87.5 and 92.2%, based on P excretion and P retention, respectively, as compared with P availability from dicalcium phosphate. In a study with broiler chickens, Martinez-Amezcua et al. (2004) reported that relative P availability in DDGS was higher than the value estimated from NRC (1994), but there was substantial variability in P availability among different DDGS samples. In a later study, Martinez-Amezcua and Parsons (2007) showed that P bioavailability in DDGS (relative to P in KH_2PO_4) increases with the duration of heating DDGS.

CONCLUSIONS

The results of our study indicate that high dietary level of DDGS could decrease dietary nutrient digestibility and metabolizable energy content, but positively affect phosphorus balance in laying hens. Addition of NSP-hydrolysing enzymes reduces the negative effect of high dietary levels of DDGS on nutrient digestibility.

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