Zootechnical performance and carcass characteristics of broiler chicks fed different kinds and concentrations of distillers dried grains with solubles (DDGS)

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Einfluss unterschiedlicher Arten und Mengen von Trockenschlempe (DDGS) auf die Mast- und Schlachtleistung von Broilern

1 Introduction

The Austrian government shows increasing interest in producing ethanol from cereals for use as a substitute to motor fuels. As a result, the process of cereal based ethanol production generates a by-product, distiller's dried grain with solubles (DDGS), which is now available in rapidly increasing quantities for livestock feed in Austria. Product variability in terms of nutrient content and lack of information about the nutritional value of DDGS from different sources, as well as the reduced amino acid (AA) digestibility and AA pattern, are reasons for the initial reluctance of using DDGS in diets for monogastrics (Nyachoti et al., 2005; Widyaratne and Zijlstra, 2007; Lan et al., 2008; Bandegan et al., 2009). Nevertheless DDGS offers high nutrient density, especially concerning energy, crude protein (CP), AA, and nonphytate phosphorus; hence it has the potential for being used as livestock feed (Nyachoti et al., 2005; Widyaratne and Zijlstra, 2007). Of special interest seems the possibility to reduce soybean meal in livestock diets, as DDGS offers a national gene modified organism free alternative to soybean meal. In this context, two growth performance studies were conducted to explore the application of DDGS of different sources and concentrations in diets for broiler chicks.

Zusammenfassung

In zwei Experimenten wurde der Einfluss unterschiedlicher Arten und Mengen von Trockenschlempe (DDGS) auf die Mast- und Schlachtleistung von Broilern getestet. Die Fütterungsversuche basierten auf isokalorischen und isonitrogenen Futtermischungen. In Experiment I beinhalteten die Futtermischungen vom Starterfutter (Tag 0–14; 12,3 MJ AME_N/kg; 21,4 % Rohprotein (XP)), Hühnermastfutter I (Tag 15–28; 12,8 MJ AME_N/kg; 21,0 % XP) und Hühnermastfutter II (Tag 29–36; 12,7 MJ AME_N/kg; 19,5 % XP) 0, 3, 6, 9, 12 sowie 15 % Weizen-DDGS. In Experiment II wurden 0, 8, 16 und 24 % DDGS, bestehend aus Weizen, Mais und Triticale (51,0:40,5:8,5), in die Futterrationen für Starterfutter (Tag 0–14; 13,1 MJ AME_N/kg; 23,0 % XP), Hühnermastfutter I (Tag 15–28; 13,6 MJ AME_N/kg; 22,0 % XP) und Hühnermastfutter II (Tag 29–36; 13,2 MJ AME_N/kg; 20,0 % XP) eingemischt. In der Starterphase (Tag 1–14) von beiden Experimenten konnte bis zu 15 % DDGS ohne Einfluss auf die Mastleistung eingesetzt werden. In der zweiten Mastphase (Tag 15–28) zeigte sich eine lineare Verschlechterung der Leistungsparameter in Experiment I und in Experiment II ab einem DDGS Gehalt von 8 % (linear, $p < 0{,}05$). Die dritte Mastphase (Tag 29–36) zeigte eine lineare Verschlechterung (linear, $p < 0{,}05$) der Leistungsdaten mit Ausnahme der Futterverwertung in Experiment I. Die Schlachtmassen zeigten eine starke Korrelation mit der Lebendmasse der Tiere. Die Ergebnisse unserer Studien zeigen die Wichtigkeit der genauen Nährstoffkenntnis über die eingesetzten Futtermittel, um so bedarfsgerechte leistungsorientierte Rationen kalkulieren zu können. Trockenschlempen unterschiedlicher Herkunft variieren vor allem in den Gehalten an umsetzbarer Energie, Aminosäuren, Phosphor und Natrium. Zusätzlich gibt es beträchtliche Schwankungen bezüglich der Verdaulichkeit der Aminosäuren und des Phosphors. Broilerfutterrationen mit hohen Gehalten an DDGS sollten daher so kalkuliert werden, dass sämtliche Nährstoffbedürfnisse gedeckt werden.

Schlagwörter: Trockenschlempe DDGS, Broiler, Eiweißquelle, Mast- und Schlachtleistung.

Summary

Two experiments were conducted to evaluate the use of different kinds of distillers dried grains with solubles (DDGS) in broiler diets. The diets were formulated to be isocaloric and isonitrogenous. In experiment I, diets of starter (day 0–14; 12.3 MJ AME_N/kg; 21.4 % crude protein (CP)), grower (day 15–28; 12.8 MJ AME_N/kg; 21.0 % CP), and finisher feed (day 29–36; 12.7 MJ AME_N/kg; 19.5 % CP) contained 0, 3, 6, 9, 12 or 15 % wheat-DDGS. In experiment II, inclusion level of DDGS originated from wheat, corn and triticale (51.0:40.5:8.5) was 0, 8, 16 and 24 % for starter (day 0–14; 13.1 MJ AME_N/kg; 23.0 % CP), grower (day 15–28; 13.6 MJ AME_N/kg; 22.0 % CP) and finisher (day 29–36; 13.2 MJ AME_N/kg; 20.0 % CP) diets. In starter phase (day 1–14) of both experiments no negative effect on zootechnical performance up to an inclusion level of 15 % DDGS was observed. In our studies, zootechnical performance declined linearly by increasing DDGS content in diets of experiment I and in experiment II at an inclusion level of more than 8 % DDGS in the grower phase (day 15–28; linear, $p < 0.05$). The finisher phase (day 29–36) showed a linear decline (linear, $p < 0.05$) in performance in both experiments, except feed to gain (g:g) in experiment I. Weight of eviscerated carcass, chilled carcass and carcass for grilling showed similar differences between treatment groups as compared to body weight at slaughter in both experiments. Results obtained in the present studies demonstrate the importance of the correct nutrient and digestibility knowledge of the different used feed stuffs, to meet nutrient requirement and optimal performance. DDGS from various sources differ concerning the amount of metabolizable energy, amino acids, phosphorous and sodium. Furthermore, notable variation can also be found in the digestibility of amino acids and phosphorus. Thus, broiler feed containing high amounts of DDGS should be calculated carefully to meet all nutrient requirements.

Key words: Distillers dried grains with solubles, broiler, alternative feed, zootechnical performance, carcass yield.

2 Materials and Methods

2.1 Animals and housing

2.1.1 General

Animals were housed in the poultry trial station (Wimitz, Austria). Each of the 24 pens was equipped with an automatic waterer, infrared warming lamp and size-adjusted feed troughs. Grounded feed and water were provided *ad libitum.* Diets provided all nutrients according to the recommendations of the GfE (1999). During the experimental period the temperature at the fully air-conditioned stable was initially adjusted to 28 °C and then subsequently lowered to 20 °C. Lightening schedule was 24 hours/day for day one to three, followed by 23 hours/day until day 21 and then 22 hours/day until the end of the studies. The trials were divided into starter (day 1–14), grower (day 15–28) and finisher (day 29–36) period.

2.1.2 Experiment I

The study was carried out with a total of 384 broiler chicks (Ross 308) with an initial body weight of 43 ± 0.04 g. One-day-old chicks were distributed equally among 24 pens and 6 dietary treatments considering initial body weight. Starter (12.3 MJ AME_N/kg; 21.4 % CP), grower (12.8 MJ AME_N/kg; 21.0 % CP), and finisher (12.7 MJ AME_N/kg; 19.5 % CP) diets were mainly based on corn, wheat, and soybean meal. Experimental diets (Table 1) were formulated to contain rising amounts of DDGS at the expense of corn and soybean meal. Thus, DDGS originating from wheat was included into the diet at 6 levels (0, 3, 6, 9, 12, and 15 %).

Experimental diets within each phase of growth were formulated to contain similar concentrations of total AME_N, digestible lysine, digestible methionine, and digestible threonine. Experimental diet composition and analyzed nutrient concentrations for starter, grower and finisher diets are presented in tables 1 and 2. Wheat-DDGS was obtained from an Austrian bio ethanol-plant (AGRANA, Pischelsdorf, Austria). Analyzed composition of the DDGS (as-fed basis) was: dry matter (DM) 91.2 %, CP 33.2 %, ether extracts (EE) 8.7 %, crude fiber (CF) 5,7 %, crude ash (CA) 5.4 %, neutral detergent fiber (NDF) 46.4 %, acid detergent fiber (ADF) 10.9 %, acid detergent lignin (ADL) 5.4 %, starch 2.5 %, sugar 4.6 %, lysine 0.58 %, methionine 0.93 %, methionine+cysteine 1.60 %, threonine 0.87 %, and tryptophan 0.34 %. Digestibility values for DDGS were taken from Kluth and Rodehutscord (2010).

Table 1: Composition of the experimental starter, grower and finisher diet in experiment I in percent
Tabelle 1: Zusammensetzung von Starterfutter, Hühnermastfutter I und Hühnermastfutter II in Prozent bei Experiment I

Feed components	Trial group						Trial group						Trial group					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
	Starter diet						Grower diet						Finisher diet					
Wheat-DDGS	0.00	3.00	6.00	9.00	12.00	15.00	0.00	3.00	6.00	9.00	12.00	15.00	0.00	3.00	6.00	9.00	12.00	15.00
Soybean meal	37.78	35.71	33.65	31.58	29.52	27.46	35.47	33.41	31.35	29.28	27.22	25.15	28.21	26.17	24.13	22.09	20.05	17.99
Corn	45.43	44.19	42.95	41.71	40.48	39.24	45.03	43.79	42.55	41.31	40.07	38.83	50.34	49.09	47.83	46.58	45.33	44.09
Wheat	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Dried grass meal	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00
Corn gluten	-	-	-	-	-	-	-	-	-	-	-	-	3.00	3.00	3.00	3.00	3.00	3.00
Fat	2.35	2.68	3.01	3.34	3.67	4.00	4.24	4.57	4.90	5.23	5.56	5.89	2.59	2.92	3.26	3.59	3.93	4.26
Feed lime	1.352	1.440	1.528	1.615	1.703	1.791	1.185	1.272	1.360	1.448	1.535	1.623	1.206	1.294	1.382	1.470	1.558	1.646
Dicalciumphosphat	0.946	0.810	0.675	0.539	0.404	0.268	1.021	0.885	0.750	0.614	0.479	0.343	0.815	0.679	0.543	0.406	0.270	0.134
Salt	0.338	0.306	0.275	0.244	0.213	0.182	0.338	0.307	0.276	0.245	0.213	0.182	0.340	0.308	0.277	0.246	0.215	0.184
Vitamin premix[1)]	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.025	0.025	0.025	0.025	0.025	0.025
Trace element premix[2)]	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
L-lysine	0.278	0.331	0.383	0.436	0.488	0.540	0.247	0.299	0.352	0.404	0.456	0.509	0.176	0.228	0.280	0.331	0.383	0.435
DL-methionine	0.254	0.241	0.227	0.213	0.200	0.186	0.236	0.222	0.209	0.195	0.182	0.168	0.193	0.179	0.166	0.152	0.138	0.125
L-threonine	0.047	0.060	0.073	0.086	0.100	0.113	0.010	0.023	0.036	0.049	0.063	0.076	0.000	0.000	0.000	0.000	0.001	0.015
Cholin-Cl	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.040	0.040	0.040	0.040	0.040	0.040
Elancoban	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	-	-	-	-	-	-
Sanor Endox	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
ZY-Phytase	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010

[1)] 1 kg vitamin premix includes: 40,000,000 i.U. Vitamin A, 16,500,000 i.U. Vitamin D, 165,000 mg Vitamin E, 13,500 mg Vitamin K, 10,000 mg Vitamin B1, 25,000 mg Vitamin B2, 15,000 mg Vitamin B6, 75 mg Vitamin B12, 230,000 mg Nicotinic acid, 65,000 mg Pantothenic acid,, 6,500 mg Folic acid, 400 mg Biotin

[2)] 1 kg trace element premix includes: 120 g Fe, 10 g Zn, 180 g Mn, 30 g Co, 2 g J, 2 g Co, 0.8 g Se

2.1.3 Experiment II

In contrast to experiment I, AA were calculated on total basis. Hence, total dietary contents of lysine, methionine, and threonine were kept constant by respective additions of pure AA. DDGS originated from wheat, corn and triticale (51.0:40.5:8.5) was included into the diet at 4 levels (0, 8, 16, and 24 %). Experimental diet composition and analyzed nutrient concentrations for starter, grower and finisher diets are presented in tables 3 and 4. DDGS was sourced from an Austrian bio ethanol plant (AGRANA, Pischelsdorf, Austria). Analyzed composition of the DDGS (as-fed basis) was: DM 92.6 %, CP 32.2 %, EE 9.0 %, CF 6,7 %, CA 5.8 %, 5.4 %, starch 4.5 %, sugar 2.6 %, lysine 0.70 %, methionine 0.45 %, methionine+cysteine 0.94 %, threonine 1.03 %, and tryptophan 0.31 %.

The study included 388 broiler chicks (Ross 308) with an initial body weight of 41 ± 0.11 g. One day old chicks were distributed equally among 24 pens and 4 dietary treatments considering initial body weight. On live day 8, chicks within one pen weighing less than 75 % of the average pen body weight were removed from the trial. The individual weight and pen-number were recorded of all died and eliminated chicks. Starter (13.1 MJ AME_N/kg; 23.0 % CP), grower (13.6 MJ AME_N/kg; 22.0 % CP), and finisher (13.2 MJ AME_N/kg; 20.0 % CP) diets were mainly based on corn and soybean meal. Experimental diets were formulated to contain rising amounts of DDGS at the expense of corn and soybean meal.

2.2 Measurements, and chemical analysis

Feed samples were obtained from each batch of feed, vacuum packed and stored at – 20 °C until analysis. All diets were analyzed for DM, CP, EE, CF, CA, starch, sugar, as well as for detergent fiber (NDF, ADF, ADL) according to standard procedures of VDLUFA (NAUMANN and BASSLER, 1997). AA composition was analyzed applying the methods of Altmann (1992).

Chicks' body weights and feed consumption were evaluated per pen, on day 14, 28 and 36. Growth rate, feed intake, and feed : gain were calculated for the starter, grower, finisher and the whole fattening period.

Table 2: Analyzed nutrient and amino acid content (in g/kg fresh matter) in the diets of experiment I
Tabelle 2: Analysierte Nährstoff- und Aminosäuregehalte (in g/kg Frischmasse) der Versuchsmischungen in Experiment I

% DDGS	0	3	6	9	12	15	0	3	6	9	12	15	0	3	6	9	12	15
Trial group	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Nutrient	**Starter diet**						**Grower diet**						**Finisher diet**					
Dry matter	892	893	894	893	896	894	890	894	895	896	899	897	884	887	890	891	892	894
AME_N, MJ/kg	12.3	12.2	12.3	12.4	12.4	12.4	12.8	12.7	12.7	12.7	12.9	12.8	12.6	12.5	12.8	12.7	12.6	12.7
Crude protein	215	216	214	211	218	208	202	205	208	218	214	210	194	198	199	193	195	198
Ether extracts	51	56	61	68	73	79	72	77	79	88	92	96	54	60	68	70	77	82
Crude fiber	28	29	30	31	30	30	30	33	32	34	32	33	31	32	31	31	32	34
Crude ash	58	57	55	58	56	55	54	53	52	56	53	51	48	49	47	48	48	47
Starch	393	382	375	371	355	355	393	375	367	338	354	341	431	407	408	407	389	379
Sugar	47	46	46	45	46	44	48	47	47	47	44	44	41	41	41	37	37	38
NDF	165	173	180	172	180	190	158	176	177	160	170	196	160	164	184	150	169	192
ADF	58	44	49	69	61	66	49	48	56	58	39	50	54	54	52	67	59	67
ADL	19	12	14	21	20	21	9	10	15	17	20	15	12	10	12	21	16	22
Lysine	12.53	13.36	13.09	13.23	13.56	13.87	11.83	12.07	12.72	13.30	12.43	12.48	9.89	10.59	10.49	10.20	10.05	10.51
Methionine	5.23	5.13	4.91	5.15	5.02	4.71	5.00	4.80	4.94	5.10	4.60	4.39	4.83	4.79	4.52	4.35	4.29	4.15
Cystine	3.43	3.48	3.45	3.51	3.61	3.71	3.32	3.31	3.40	3.70	3.47	3.51	3.38	3.43	3.48	3.36	3.54	3.56
Methionine + Cysteine	8.66	8.61	8.36	8.66	8.63	8.42	8.32	8.11	8.34	8.80	8.07	7.90	8.21	8.22	8.00	7.71	7.83	7.71
Threonine	8.46	8.06	7.92	8.28	8.16	9.01	7.39	7.42	7.59	8.05	7.57	7.71	6.89	7.28	6.66	6.50	6.40	6.93
Tryptophan	2.00	2.02	1.87	2.00	2.11	2.09	2.08	1.97	1.66	2.11	2.09	1.99	1.77	1.77	1.88	1.82	1.78	1.79
Valine	9.92	9.74	9.41	8.76	8.96	9.81	9.17	9.26	9.40	9.31	8.80	9.34	8.85	8.64	8.82	8.10	8.51	8.98
Isoleucine	8.90	8.63	8.28	7.67	7.83	8.51	8.13	8.28	8.33	8.14	7.68	8.07	7.71	7.48	7.57	6.97	7.25	7.64
Arginine	13.11	12.71	11.88	11.64	11.44	12.57	12.09	12.02	12.05	12.10	11.03	11.04	10,92	10,97	10,18	9.52	9.45	9.94
Ca	7.57	7.88	7.68	8.78	8.49	7.92	7.61	7.59	7.50	7.90	7.55	7.08	6.45	6.59	6.60	6.84	7.18	6.44
P	6.42	6.16	6.05	5.98	5.86	5.73	6.51	6.45	6.03	6.32	5.88	5.87	5.50	5.54	4.83	4.73	4.50	4.50
Na	2.63	2.52	2.64	2.74	2.49	2.29	1.64	1.70	1.60	1.68	1.36	1.35	1.43	1.47	1.25	1.24	1.22	1.25

The animals were slaughtered under standardized conditions in the slaughter house of the poultry trial station at the 36^{th} fattening day. At the day of slaughter and the following day, carcass characteristics like dressing, eviscerated carcass (weight of the slaughtered animals without blood, feathers, oil sac, viscera, abdominal fat, and giblets), chilled carcass (weight of eviscerated carcass after 16 h storage in a cooling chamber at + 3 °C), carcass for grilling (weight of chilled carcass without head and neck and legs at the hock joints), and giblets (weight of empty gizzard, liver without gall bladder and heart immediately after slaughter) were assessed.

2.3 Statistical analyses

All experimental data were statistically analyzed by the GLM procedure of SAS 9.1.3 (SAS, Inst., Inc., Cary, NC, USA). Treatment effects were determined by analysis of variance (ANOVA) using the Student-Newman-Keuls test for each variable. The tables 5–8 present the mean values of the different dietary treatments and the standard error of means (SEM). Significant differences among means ($p < 0.05$) are indicated by different superscripts $^{a, ab, b}$. Additionally orthogonal polynomials were used to determine the effects of increasing DDGS.

3 Results

3.1 Nutrient and AA contents of the experimental diets

The analyzed nutrient and AA contents of the experimental diets are shown in tables 2 and 4. Diets increasing in DDGS showed rising EE and NDF contents. In contrast, starch and phosphorus decreased by enhanced DDGS levels. In experiment I lysine and threonine showed increasing, methionine and arginine decreasing values by DDGS supplementation. Furthermore, sodium showed decreasing

Table 3: Composition of the experimental starter, grower and finisher diet in experiment II in percent
Tabelle 3: Zusammensetzung von Starterfutter, Hühnermastfutter I und Hühnermastfutter II in Prozent bei Experiment II

	Trial group				Trial group				Trial group			
Feed components	1	2	3	4	1	2	3	4	1	2	3	4
	Starter diet				Grower diet				Finisher diet			
DDGS	0.00	8.00	16.00	24.00	0.00	8.00	16.00	24.00	0.00	8.00	16.00	24.00
Soybean meal	38.38	33.38	28.39	23.39	36.01	31.02	26.02	21.02	28.74	23.73	18.73	13.75
Corn	53.64	50.22	46.80	43.37	54.73	51.31	47.89	44.47	61.25	57.88	54.49	50.99
Corn gluten	-	-	-	-	-	-	-	-	3.00	3.00	3.00	3.00
Fat	4.41	4.90	5.38	5.87	5.84	6.33	6.82	7.31	3.96	4.44	4.93	5.44
Feed lime	1.162	1.447	1.732	2.019	1.008	1.292	1.582	1.869	1.061	1.350	1.635	1.854
Dicalciumphosphat	1.307	0.885	0.461	0.037	1.379	0.955	0.531	0.110	1.164	0.741	0.316	0.000
Salt	0.271	0.186	0.100	0.014	0.273	0.187	0.102	0.016	0.275	0.190	0.104	0.018
Vitamin premix[1)]	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.025	0.025	0.025	0.025
Trace element premix[2)]	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
L-lysine	0.310	0.430	0.549	0.669	0.284	0.403	0.523	0.643	0.212	0.331	0.451	0.570
DL-methionine	0.258	0.258	0.257	0.256	0.240	0.240	0.239	0.238	0.197	0.197	0.196	0.195
L-threonine	0.028	0.058	0.089	0.119	0.000	0.027	0.057	0.088	0.000	0.000	0.007	0.037
L-tryptophan	0.000	0.000	0.006	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cholin-Cl	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.040	0.040	0.040	0.040
Elancoban	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	-	-	-	-
Sanor Endox	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
ZY-Phytase	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010

1) 1 kg vitamin premix includes: 40,000,000 i.U. Vitamin A, 16,500,000 i.U. Vitamin D, 165,000 mg Vitamin E, 13,500 mg Vitamin K, 10,000 mg Vitamin B1, 25,000 mg Vitamin B2, 15,000 mg Vitamin B6, 75 mg Vitamin B12, 230,000 mg Nicotinic acid, 65,000 mg Pantothenic acid,, 6,500 mg Folic acid, 400 mg Biotin
2) 1 kg trace element premix includes: 120 g Fe, 120 g Zn, 180 g Mn, 30 g Co, 2 g J, 2 g Co, 0.8 g Se

values by increasing DDGS contents, which is in contrast to experiment II where sodium contents increased by DDGS supplementation. In experiment II, lysine, arginine, isoleucine, and valine showed decrease, whereas methionine, threonine and tryptophan had similar values by increasing DDGS concentration.

3.2 Experiment I

The performance of broilers during the experimental period is shown in table 5. Starting with homogenous distribution of body weights final body weight (BW), average daily gain (ADG), average daily feed intake (ADFI) and feed to gain (F:G) did not differ among treatment groups ($p > 0.05$) in the starter period. In the grower period polynomial analysis showed a linear decrease for BW, ADG, ADFI and an increase for F : G (linear, $p < 0.05$), affected by DDGS supplementation. Similar results were observed in the finisher period except for F:G, where no differences between the trial groups were seen. Over the whole fattening period ADG and ADFI decreased linearly ($p < 0.05$) by DDGS addition, while F : G was unaffected.

Carcass characteristics are shown in table 7. Weight of eviscerated carcass, chilled carcass, carcass for grilling, and heart showed a linear decrease (liner, $p < 0.05$) by increasing DDGS content. Dressing percentage was highest in the treatment including 6 % DDGS (79.8 %) and lowest in the treatment with 15 % DDGS addition and resulted in a significant difference ($p < 0.05$) between these treatments. Weight of abdominal fat differed significantly ($p < 0.05$) between the treatments including 15 % DDGS and 6 % DDGS (– 15 %). Nevertheless polynomial analysis showed a linear increase by rising DDGS supplementation for abdominal fat ($p < 0.05$). Relative liver weights (= liver weight in % of live weight at slaughter) decreased linearly (p <

Table 4: Analyzed nutrient and amino acid content (in g/kg fresh matter) in the diets of experiment II
Tabelle 4: Analysierte Nährstoff- und Aminosäuregehalte (in g/kg Frischmasse) der Versuchsmischungen in Experiment II

% DDGS	0	8	16	24	0	8	16	24	0	8	16	24
Trial group	1	2	3	4	1	2	3	4	1	2	3	4
Nutrient	Starter diet				Grower diet				Finisher diet			
Dry matter	893	896	903	908	899	904	907	907	889	892	897	898
AME_N, MJ/kg	13.0	13.1	13.1	13.0	13.6	13.5	13.5	13.7	13.1	13.1	13.1	13.4
Crude protein	231	229	233	228	221	223	218	219	200	203	202	207
Ether extracts	70	84	99	111	85	97	113	130	66	75	9	105
Crude fiber	24	27	30	30	19	20	23	26	20	25	27	28
Crude ash	55	53	55	54	53	52	53	53	49	48	48	49
Starch	379	362	330	310	395	365	341	323	434	416	390	376
Sugar	50	46	43	38	49	45	40	39	38	35	25	25
NDF	140	147	163	202	114	140	152	181	256	262	277	285
ADF	31	46	31	57	27	36	40	50	46	50	47	67
ADL	6	15	7	6	12	11	11	17	15	14	15	28
Lysine	17.4	16.4	16.4	16.0	15.2	15.7	14.8	14.8	12.7	13.0	12.8	12.8
Methionine	6.1	5.9	5.9	6.0	5.7	5.5	5.6	5.6	5.2	5.0	5.0	5.2
Cystine	3.7	3.6	3.8	3.9	3.4	3.5	3.6	3.6	3.4	3.4	3.6	3.7
Methionine + Cystine	9.8	9.5	9.7	9.9	9.1	9.0	9.2	9.2	8.6	8.4	8.6	8.9
Threonine	9.5	9.3	9.5	9.4	8.2	8.6	8.5	8.5	7.7	7.4	7.2	7.4
Tryptophan	2.7	2.6	1.2	2.6	2.5	2.5	2.4	2.4	2.5	2.1	2.1	2.0
Valine	12.0	11.5	11.5	11.2	10.8	11.1	10.6	10.6	10.5	10.1	10.1	9.7
Isoleucine	11.0	10.3	10.3	9.8	9.8	9.9	9.3	9.2	9.4	8.9	8.7	8.2
Arginine	16.0	14.7	14.3	13.0	14.2	13.9	12.7	12.0	12.6	11.6	10.8	9.7
Ca	8.3	8.5	8.3	8.2	8.3	7.9	7.8	7.8	7.3	7.3	7.4	7.6
P	5.8	5.4	5.1	4.8	5.7	5.5	5.0	5.0	5.3	4.9	4.4	4.3
Mg	1.8	1.9	2.0	2.0	1.7	1.8	1.9	1.9	1.6	1.7	1.7	1.9
K	10.0	10.0	10.0	9.0	9.0	10.0	9.0	9.0	8.0	8.0	8.0	7.0
Na	1.4	1.6	1.9	2.3	1.5	1.7	2.0	2.0	1.3	1.6	1.9	2.2

[1)] 1 kg vitamin premix includes: 40,000,000 i.U. Vitamin A, 16,500,000 i.U. Vitamin D, 165,000 mg Vitamin E, 13,500 mg Vitamin K, 10,000 mg Vitamin B1, 25,000 mg Vitamin B2, 15,000 mg Vitamin B6, 75 mg Vitamin B12, 230,000 mg Nicotinic acid, 65,000 mg Pantothenic acid,, 6,500 mg Folic acid, 400 mg Biotin
[2)] 1 kg trace element premix includes: 120 g Fe, 120 g Zn, 180 g Mn, 30 g Co, 2 g J, 2 g Co, 0.8 g Se

0.05) from treatment with the highest content of DDGS (2.21 %) to diet without DDGS (2.04 %)

3.3 Experiment II

The performance data of broilers during the experimental period are shown in table 6. At the end of the starter period, lowest BW was observed for birds fed diets without and 24 % DDGS, while treatment including 8 % DDGS affected the highest body weight. The same picture was found for the ADG. ADFI of birds fed diets including 8 % DDGS was significantly higher ($p < 0.05$) than all other treatments. Furthermore, the most favorable feed conversion ratio showed the treatment with 8 % DDGS supplementation. Hence, it resulted in significant difference ($p < 0.05$) of F : G compared to the diet including 24 % DDGS. The polynomial analysis

Table 5: Zootechnical performance experiment I
Tabelle 5: Mastleistungsparameter von Experiment I

	Trial group						*SEM	p-value		
	1	2	3	4	5	6				
Wheat DDGS, %	**0**	**3**	**6**	**9**	**12**	**15**		**ANOVA**	**Linear**	**Quadratic**
Fattening performance day 1 to 14 (starter phase)										
Animals, n	64	64	65	60	63	63	-			
Body weight, day 1, g	43	43	43	43	43	43	0.04	0.275	0.985	0.500
Body weight, day 14, g	426	428	430	426	421	431	0.09	0.983	0.943	0.917
Daily weight gain, g/day	27	27	28	27	27	28	0.27	0.891	0.802	0.701
Daily feed intake, g/day	41	41	41	40	40	41	0.28	0.843	0.310	0.744
Feed conversion ratio, g/g	1.52	1.50	1.50	1.52	1.51	1.48	0.01	0.787	0.445	0.704
Fattening performance day 14 to 28 (grower phase)										
Animals, n	63	64	64	60	63	62	-			
Body weight, day 28, g	1472	1455	1477	1430	1388	1384	11.6	0.079	0.006	0.442
Daily weight gain, g/day	74[ab]	73[ab]	75[a]	71[bc]	69[ab]	68[b]	0.72	0.014	0.001	0.209
Daily feed intake, g/day	114	114	115	112	110	110	0.73	0.276	0.041	0.543
Feed conversion ratio, g/g	1.54[b]	1.55[b]	1.54[b]	1.58[ab]	1.60[ab]	1.63[a]	0.01	0.005	0.001	0.831
Fattening performance day 28 to 36 (finisher phase)										
Animals, n	63	64	64	60	63	62	-			
Body weight, day 36, g	2196[a]	2143[a]	2117[a]	2103[a]	2026[b]	1990[b]	16.9	0.001	<0.0001	0.641
Daily weight gain, g/day	89[a]	86[ab]	77[bc]	84[abc]	80[bc]	74[c]	1.41	0.003	0.001	0.882
Daily feed intake, g/day	180[a]	175[a]	170[ab]	171[ab]	165[ab]	151[b]	2.67	0.024	0.001	0.390
Feed conversion ratio, g/g	2.03	2.04	2.20	2.03	2.07	2.08	0.04	0.791	0.821	0.554
Fattening performance day 1 to 36										
Animals, n	63	64	64	60	63	62	-			
Daily weight gain, g/day	59[a]	58[a]	57[ab]	56[abc]	55[bc]	53[c]	0.49	0.002	<0.0001	0.682
Daily feed intake, g/day	100[a]	99[ab]	98[ab]	96[ab]	95[ab]	92[b]	0.81	0.039	0.001	0.520
Feed conversion ratio, g/g	1.70	1.70	1.72	1.72	1.73	1.73	0.01	0.879	0.273	0.738

* SEM = standard error of means

showed a curve linear effect for BW, ADG, ADFI and F : G (quadratic, $p < 0.05$). In the grower period, BW was similar for treatments without and 8 % DDGS supplementation. However, a DDGS supplementation from 8 to 24 % resulted in a linear decrease (linear $p < 0.0001$, quadratic $p < 0.05$) of BW. Same declines were observed for ADG, ADFI and F:G. During the finisher period, performance trend between the treatments continued. Hence no differences of the BW and ADG were recorded between treatment with 0 % and 8 % DDGS supplementation. Diets including higher contents of DDGS showed a linear decline (linear, $p < 0.05$) for these parameters. The lowest ADFI showed the treatment with the highest DDGS supplementation, which differs significantly from all other feeding groups. Treatments with low (0 % and 8 % DDGS) DDGS contents showed a significantly more favorable F : G ($p < 0.05$) than diets including high DDGS contents (16 % and 24 % DDGS). Over the whole fattening period a linear decline in BW, ADG and F:G was observed in diets including more DDGS than 8 % (linear $p < 0.05$, quadratic $p < 0.05$).

Carcass characteristics of experiment II are shown in table 8. Dressing percent, weight of eviscerated carcass, chilled carcass, and carcass for grilling, showed a linear decrease (linear $p < 0.05$, quadratic $p < 0.05$) if more than 8 %

Table 6: Zootechnical performance, experiment II
Tabelle 6: Mastleistungsparameter von Experiment II

	Trial Group				*SEM	p-value		
	1	2	3	4				
DDGS, %	0	8	16	24		ANOVA	Linear	Quadratic
Fattening performance day 1 to 14 (starter phase)								
Animals, n	97	97	97	97	-			
Body weight, day 1, g	41	41	41	41	0.1	0.947	0.791	0.629
Body weight, day 14, g	377^{c}	414^{a}	397^{b}	362^{c}	5.0	<0.0001	0.014	<0.0001
Daily weight gain, g/day	23^{c}	27^{a}	25^{b}	23^{c}	0.39	<0.0001	0.150	<0.0001
Daily feed intake, g/day	32^{b}	35^{a}	33^{b}	32^{b}	0.33	0.004	0.630	0.001
Feed conversion ratio, kg/kg	1.37^{ab}	1.28^{b}	1.32^{ab}	1.40^{a}	0.01	0.015	0.267	0.003
Fattening performance day 14 to 28 (grower phase)								
Animals, n	87	96	94	93	-			
Body weight, day 28, g	1395^{a}	1431^{a}	1325^{b}	1198^{c}	20.1	<0.0001	<0.0001	<0.0001
Daily weight gain, g/day	72^{a}	73^{a}	67^{b}	59^{c}	1.19	<0.0001	<0.0001	0.001
Daily feed intake, g/day	102^{ab}	105^{a}	100^{b}	94^{c}	1.05	<0.0001	<0.0001	0.001
Feed conversion ratio, kg/kg	1.43^{c}	1.45^{c}	1.49^{b}	1.58^{a}	0.01	<0.0001	<0.0001	0.004
Fattening performance day 28 to 36 (finisher phase)								
Animals, n	86	96	93	93	-			
Body weight, day 36, g	2162^{a}	2171^{a}	2020^{b}	1830^{c}	13.4	<0.0001	<0.0001	0.001
Daily weight gain, g/day	96^{a}	93^{a}	86^{b}	79^{c}	1.67	<0.0001	<0.0001	0.145
Daily feed intake, g/day	158^{a}	157^{a}	154^{a}	147^{b}	1.70	0.01	0.002	0.179
Feed conversion ratio, kg/kg	1.66^{b}	1.69^{b}	1.79^{a}	1.87^{a}	0.02	0.001	<0.0001	0.411
Fattening performance day 1 to 36								
Animals, n	86	96	93	93	-			
Daily weight gain, g/day	57^{a}	59^{a}	55^{b}	49^{c}	0.85	<0.0001	<0.0001	<0.0001
Daily feed intake, g/day	87^{b}	89^{a}	85^{b}	81^{c}	0.73	<0.0001	<0.0001	<0.0001
Feed conversion ratio, kg/kg	1.50^{c}	1.50^{c}	1.57^{b}	1.65^{a}	0.01	<0.0001	<0.0001	0.007

* SEM = standard error of means

DDGS was supplemented in the diet. Gizzard and heart weight were not affected by the addition of DDGS to the diets ($p > 0.05$).

4 Discussion

Soybean meal is the most widely used source of protein in broiler production and is the common standard used to assess any alternative protein source. DDGS application in poultry diets serves not only as alternative ingredient supplying protein and AA, but also effects diet composition in general. The higher NDF content up to 45 % limits its proportion in the whole diet (SPIEHS et al., 2002; STEIN and SHURSON, 2009). The obtained nutrient composition of DDGS showed that analyzed DDGS had high levels of DM, CP, NDF and EE, which resulted in linear increasing NDF and decreasing starch concentrations in diets of both experiments. The increasing EE contents are a result of rising DDGS and fat inclusion to the diets. Between the two DDGS sources, the CP, EE, CF, and CA contents were similar, however the amino acid pattern differed considerable, which is in accordance to other authors (SPIEHS et al., 2002; STEIN and SHURSON, 2009). Hence, the linear decrease of methionine affected by rising DDGS concentration in diets of experiment I can be considered as overrated methionine content in DDGS. Nevertheless, in experiment I, AA contents reached recommended values of the GfE (1999) ex-

Table 7: Carcass characteristics of experiment I
Tabelle 7: Schlachtleistungsparameter von Experiment I

	Trial group							p-value		
	1	2	3	4	5	6	*SEM			
Wheat DDGS, %	0	3	6	9	12	15		ANOVA	Linear	Quadratic
Carcass parameters										
Animals, n	51	52	52	48	51	50	-			
Dressing, %	79.3[ab]	79.4[ab]	79.8[a]	79.3[ab]	79.3[ab]	79.2[b]	0.06	0.026	0.187	0.026
Eviscerated carcass, g	1742[a]	1703[a]	1699[a]	1681[a]	1603[b]	1575[b]	10.0	<0.0001	<0.0001	0.265
Chilled carcass, g	1727[a]	1690[a]	1680[a]	1669[a]	1587[b]	1568[b]	9.99	<0.0001	<0.0001	0.319
Carcass for grilling, g	1558[a]	1521[a]	1520[a]	1507[a]	1436[b]	1415[b]	9.00	<0.0001	<0.0001	0.241
Abdominal fat, g	23[ab]	24[ab]	24[ab]	22[b]	24[ab]	26[a]	0.36	0.047	0.045	0.094
Heart, g	10.1[a]	9.5[ab]	9.8[ab]	9.5[ab]	9.6[ab]	9.0[b]	0.09	0.044	0.004	0.875
Liver, g	45	43	43	43	42	44	0.30	0.136	0.262	0.030
Gizzard, g	32	32	32	32	31	31	0.25	0.658	0.180	0.672

* SEM = standard error of means

Table 8: Carcass characteristics of experiment II
Tabelle 8: Schlachtleistungsparameter von Experiment II

	Trial group					p-value		
	1	2	3	4	*SEM			
DDGS, %	0	8	16	24		ANOVA	Linear	Quadratic
Carcass parameters								
Animals, n	74	84	81	81	-			
Dressing, %	79.4[a]	79.5[a]	78.9[b]	77.9[c]	0.087	<0.0001	<0.0001	0.001
Eviscerated carcass, g	1717[a]	1731[a]	1587[b]	1420[c]	11.6	<0.0001	<0.0001	<0.0001
Chilled carcass, g	1673[a]	1691[a]	1555[b]	1384[c]	11.3	<0.0001	<0.0001	<0.0001
Carcass for grilling, g	1523[a]	1537[a]	1410[b]	1244[c]	11.7	<0.0001	<0.0001	<0.0001
Abdominal fat, g	25[ab]	26[a]	25[ab]	23[b]	0.39	0.028	0.053	0.078
Heart, g	9.3	9.6	9.4	9.1	0.07	0.051	0.152	0.057
Liver, g	48[a]	47[a]	46[a]	43[b]	0.36	<0.0001	<0.0001	0.244
Gizzard, g	28	27	27	27	0.24	0.805	0.283	0.241

* SEM = standard error of means

cept methionine in all diets and arginine in treatments including 12 and 15 % DDGS of grower phase. Methionine + cysteine values failed requirement in treatment including 24 % DDGS in the grower phase and in all finisher diets. Furthermore arginine in finisher diets failed requirement from an inclusion level of 6 % DDGS. In experiment II, arginine did not reach demand in grower diet with highest DDGS supplementation and from a DDGS inclusion level of 16 % in finisher phase. All diets of grower and finisher phase failed valine requirement. In all diets of both experiments DDGS supplementation decreased phosphorous content linearly. Moreover, phosphorous contents of all diets in both experiments were lower than the GfE (1999) recommendations. Additionally, sodium content decreased in experiment I and increased in experiment II. In summary our studies show the importance of an accurate knowledge about the nutrient contents of the used DDGS concerning energy, CP and AA to calculate diets which achieve requirement.

4.1 Growth Performance

4.1.1 Starter phase

The main objective of the present study was to observe the possibility to replace soybean meal via DDGS. Both experiments showed an inclusion level of DDGS up to 15 % without a negative effect on zootechnical performance in the starter phase. Similar results were reported from other authors feeding high-density diets (LUMPKINS et al., 2004; WANG et al., 2007a;b; MIN et al., 2008). In experiment II, the higher ADG of treatment including 8 % DDGS can be explained by the increased ADFI compared to the other treatments. Hence it could be concluded that DDGS inclusion up to 15 % may be safely used in commercial starter diets for broilers, if all nutrient requirements are covered.

4.1.2 Grower and finisher phase

In both experiments, birds showed similar performance trends in grower and finisher phase. Nevertheless ADFI was higher in experiment I. Diets in experiment I showed lower AME_N contents compare d to experiment II. Hence this energy deficit was compensated by an increased ADFI. The nutrient compensation by an enhanced feed intake is well established in poultry nutrition (HADORN and WENK, 1996; PETER et al., 1997). In our studies, zootechnical performance declined linearly by increasing DDGS content in diets of experiment I. Also in experiment II, an inclusion level of more than 8 % DDGS affected a linear decline in performance in the grower phase. The finisher phase showed a linear decline in performance in both experiments, except F : G in experiment I. The drop in feed intake observed in diets including high contents of DDGS may be interpreted as a lower bulk density, which may induce the feeling of fullness before meeting their energy needs (WANG et al., 2007a). Furthermore, it is well known that methionine and phosphorus imbalances between diets can affect feed intake and/or weight gain (CAREW et al., 2003; SINGH et al., 2003; KARIMI, 2006). Indeed, our trials showed unbalanced nutrient values or nutrients below requirement. Phosphorus and arginine imbalances were observed in both studies and differences in methionine content in experiment I. Hence, that imbalance seems a possible explanation for the decline in performance in both experiments in grower and finisher phase. DDGS contains a high level of CP, however the AA profile is not ideal to meet the broilers requirements (BANDEGAN et al., 2009). Furthermore DDGS has relatively low digestibility of CP and AA compared to other ingredients in poultry feeds especially soybean meal (NYACHOTI et al., 2005; LAN et al., 2008; KLUTH and RODEHUTSCORD, 2010). Therefore it can be concluded, that independent from DDGS source, broiler diets including more DDGS without impact on performance, were based on ileal digestible amino acids and reached nutrient requirements of broilers in every fattening period (PARSONS and BAKER, 1983; THACKER, 2006; WANG et al., 2007b;a). As the contribution of the grower and finisher period to the whole fattening period was more pronounced, the differences in performance found in the grower and finisher period were observed over the whole fattening period as well.

4.2 Carcass composition

Weight of eviscerated carcass, chilled carcass, and carcass for grilling showed a similar difference between treatment groups as compared to body weight at slaughter in both experiments. In experiment II weight of abdominal fat and liver decreased by DDGS supplementation. This is in contrast to experiment I were abdominal fat mass increased and liver weight did not differ between treatments. Changes in liver weight and body fat are often an index of various nutrient deficiencies including AA (NOBLET et al., 1987; CAREW et al., 2003). Liver weights remained unchanged by DDGS supplementation, however, body weight decreased. Indeed, a linear increase in relative liver weight was observed in experiment I. Hence, those observations support the theory of a possible methionine deficiency in diets including rising DDGS content in experiment I. Dressing percentage decreased linearly when increasing DDGS in experiment II. Experiment I showed quadratic difference between treatment with 6 % and 15 % DDGS for dressing. Similar trends in reduced dressing percentage with higher levels of DDGS have been seen in previous studies (WANG et al., 2007a;b; MIN et al., 2008). The reasons for the reduced dressing percentage can be the inclusion of fiber rich feed stuffs to broiler and other monogastric animals' feed, affected by increasing gut fill and intestinal mass (HANSEN et al., 1992; JORGENSEN et al., 1996; MCDONALD et al., 2001). Nevertheless Widmer et al. (2008) assumed a relation between the quality of DDGS and dressing percentage. For detailed information on that phenomenon, more research work in this field seems necessary.

5 Conclusion

The present study indicates that, to maintain bird performance, diets containing DDGS must be formulated carefully to take the variation of nutrients in consideration.

Variations may exist among samples of DDGS for metabolizable energy, content and availability of essential amino acids, content and bioavailability of phosphorus and variation in sodium content. The acceptance of high levels of DDGS as seen in other studies may be associated with diet formulations which are more tailored to broiler chicks' requirement.

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Submitted: September 17, 2010
Accepted: July 14, 2011