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Effects of *Cordyceps* Mushroom Powder on Nursery Pig Performance

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Summary

One hundred sixty crossbred pigs (Duroc × (York × Landrace)) weaned at 18.8 d of age and weighing an average of 13.1 lb were used in a 35-day growth trial to evaluate *Cordyceps* mushroom powder as potential alternative to carbadox in nursery pig diets. Pigs were divided by weight, sex, litter, and assigned to body weight (BW) blocks. Within BW blocks, sex ratios were constant in each pen. Each pen within a BW block was randomly assigned a dietary treatment. Growth performance was analyzed using BW, average daily gain (ADG), average daily feed intake (ADFI), and feed conversion as feed-to-gain (F:G). Pigs were blocked by weight with 5 or 6 pigs per pen and there were 6 pens per treatment. There were 5 diets used in the study: a negative diet or a positive control (carbadox, 50 g/ton); 300 or 600 ppm mushroom powder, and a step-down treatment (900, 900, 450, 300, and 150 ppm mushroom powder during weeks 1, 2, 3, 4, and 5, respectively). At various points of the study, pigs fed the 300 ppm and the step-down mushroom powder treatments tended to have improved ($P < 0.10$) growth performance compared with those fed the negative control diet. During Phase 4 of the study, pigs fed carbadox had greater ADG ($P < 0.02$) and improved feed efficiency ($P < 0.09$) over pigs fed the negative control diet. However, overall data showed that there were no statistical differences among treatments ($P > 0.05$). In summary, pigs fed 300 ppm mushroom powder or the step-down treatment showed comparable results to pigs fed carbadox. However, future research is needed under a greater disease pressure to show mushroom powder's full potential as an alternative to antibiotics.

Introduction

Swine production is moving further away from antibiotics, following the trend of consumer desires. Antibiotics are an important aspect of swine production for disease prevention and treatment. Antimicrobials used in feed post-weaning, such as carbadox, are under heavy scrutiny due to the growing concerns about antibiotic resistant pathogens. The effects of feeding carbadox to nursery pigs has traditionally shown improved growth performance and feed efficiency compared to pigs fed diets without antimicrobial agents. This has led to research in alternatives to antibiotics such as carbadox due to industry concern over potential monetary losses. One of these possible alternatives is

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a Chinese herbal mushroom blend of *Cordyceps militaris* and *Cordyceps sinensis*.² These mushrooms have long been used by the Chinese as a human health promoting additive. The particular compound, cordycepin, found in these mushrooms is currently being studied as a possible anti-cancer agent by many research institutes. The mushroom itself has antimicrobial and antiviral characteristics.³ Based on a previous study with this mushroom⁴ showing positive results, we decided to perform a titration study to determine the most optimal levels to feed to nursery pigs.

Procedures

One hundred sixty weanling pigs (18.8 d of age) weighing an average of 13.1 lb with US purebred genetics (Duroc × (York × Landrace)) were used in a 35 day growth trial. Growth performance was analyzed using BW, ADG, ADFI, and F:G. Pigs were allotted by BW with 5 or 6 pigs per pen. There were 5 dietary treatments: a negative control diet without a feed antimicrobial; a positive control diet containing 55 ppm carbadox; 300 or 600 ppm mushroom powder; and a step down treatment containing 900, 900, 450, 300, and 150 ppm mushroom powder for weeks 1, 2, 3, 4, and 5, respectively. The 300 ppm mushroom dose was equivalent to the daily recommended human dose by Aloha Medicinals (2300 Arrowhead Drive, Carson City, NV). Pigs were divided by weight, sex, litter, and assigned to BW blocks. Within BW blocks sex ratios were constant in each pen. Each pen within a BW block was then assigned a diet via a random number generator with pens that had the lowest random number being assigned diet 1, to diet 5 for the highest random number. The experiment was conducted at the Purdue University Swine Farm, West Lafayette, IN.

The pigs were fed four dietary phases over a 35-day period (Table 1). Phase 1 was d 0-7, Phase 2 was d 7-14, Phase 3 was d 14-21, Phase 4 was d 21-35. Phase 1 and 2 were made with a basal diet which was split then remixed with the treatment premixes added for each diet. Phase 3 and 4 were made as individual diet treatment batches. All diets were formulated to meet or exceed the nutrient requirements based on the swine NRC.⁵

Feed and water were provided *ad libitum* access to each pen through a five-hole stainless steel feeder and one cup waterer. Feeders and waterers were checked daily, with the idea of having partial pan coverage (40 to 50% coverage) for feed flow while also minimizing feed wastage. Pigs were individually treated with injectable antibiotics when signs of disease were detected and recorded for later treatment rate analysis. Pigs and feeders were weighed on day 0, 7, 14, 21, 28, and 35. The individual body weights and pen feed intake were recorded, then transferred to Microsoft Excel (2016, Redmond, WA) to determine pen ADG, ADFI, and F:G.

²Shen et. al. 2017. Antimicrobials from Mushrooms for Assuring Food Safety. Comprehensive Reviews in Food Science and Food Safety. Vol.16:316-329.

³Zhou et. al. 2008. Cordycepin is an immunoregulatory active ingredient of *Cordyceps sinensis*. Am J Chin Med 36:967–980.

⁴Cheng et al. 2016. South African Journal of Animal Science 2016, 46 (No. 2):121-128

⁵National Research Council. Nutrient Requirements of Swine. 2012.

Growth data were analyzed as a randomized complete block design using the GLM procedure in SAS (9.4, SAS Institute, Inc., Cary, NC) with pen being the experimental unit. Individual single degree of freedom contrasts were used to test for linear, quadratic, and cubic responses of the mushroom product when appropriate, as well as the positive vs. negative control, and on the overall (d 0-35) data, the effect of the constant 300 ppm dose vs. the step-down mushroom dose. The parameters measured were BW, ADG, ADFI, and feed efficiency every week and summarized by dietary phase and overall. Differences among treatments were considered significantly different at $P \leq 0.05$, or a tendency for difference at $0.05 < P \leq 0.10$.

Results and Discussion

During Phase 1 of the trial (d 0 to 7) there was a tendency for a linear reduction in BW ($P < 0.07$) as the mushroom concentration increased in the diet (Table 2). During Phase 2 (d 7-14) there was a trend for a cubic mushroom response ($P < 0.07$) in ADFI and ADG ($P < 0.11$), resulting in a cubic mushroom response in BW at d 14 of age ($P < 0.04$). These cubic responses were caused by the pigs fed the 300 ppm dose having an 8.7% increase in ADG and 9.8% increase in ADFI above the 0 ppm negative control followed by the lowest ADG and ADFI at the 600 ppm level and the 900 ppm dose having a partial recovery of the pig growth performance. Phase 3 (d 14-21) showed no statistical differences in performance among treatments ($P > 0.10$). During the first week of Phase 4 (d 21 to 28), pigs fed carbadox were statistically improved in ADG ($P < 0.04$) and increased feed efficiency ($P < 0.02$) over pigs fed the negative control. There was also a tendency for a linear increase in ADG ($P < 0.10$) and improvement in feed efficiency ($P < 0.08$) as mushroom concentration increased to 600 ppm. During the second week of Phase 4 (d 28 to 35) there was a tendency for cubic ADFI response ($P < 0.10$) for mushroom inclusion with a 13% increase in ADFI at the lowest 150 ppm inclusion followed by a 10.7% decrease in ADFI at the 300 ppm level and ADFI then increasing at the 600 ppm level close to the negative control. Overall (d 0 to 35), pigs fed the 300 ppm diet tended ($P < 0.10$) to have better feed efficiency compared to those fed the step-down treatment. However, there were no other dietary treatment effects for the overall nursery study.

Carbadox has been well documented in its effects in post-weaning performance. Most industry professionals tend to use some form of antimicrobial in the post-weaning diet. In this current study, carbadox primarily only improved pig growth performance during Phase 4, the last 2 weeks of the study, resulting in about a 1.1 lb heavier pig over the negative control. It should also be noted that the growth performance of pigs in general was very good in this study and is likely related to the small response to the antimicrobial.

It is worth noting that the heaviest pigs in this study were fed the constant level of 300 ppm mushroom (41.62 lb) similar to the carbadox fed pigs. As the mushroom level declined to 150 ppm in the last week of the study, the greatest growth performance of all treatments was observed. The poorer growth performance earlier in the study by pigs fed 600 and 900 ppm mushroom powder may indicate that these levels may have been too high and may require future evaluation with doses below 300 ppm. When considering the economics of feeding this human-grade mushroom product, the 300 ppm mushroom product is slightly more expensive at \$35/ton compared \$26/ton for the carbadox treatment. When feeding the 150 ppm level at the end of the study, feed costs were less than the carbadox positive control. In conclusion, the 300 ppm mushroom and step-down treatments were both comparable in results to carbadox. Therefore, mushroom powder could serve as a possible antimicrobial replacement to carbadox.

Table 1. Basal diet formulations

Ingredient, %	Phase 1	Phase 2	Phase 3	Phase 4
Corn	36.140	42.290	46.390	54.055
Soybean meal, 48% crude protein	14.000	16.950	26.500	28.925
Dried distillers grains with solubles, 7% fat	0.000	5.000	7.500	10.000
Choice white grease	0.000	0.000	0.000	3.000
Soybean oil	5.000	4.000	3.000	0.000
Limestone	0.650	0.810	0.890	1.415
Monocalcium phosphate, 21% P	0.480	0.530	0.180	0.560
Vitamin premix	0.250	0.250	0.250	0.250
Trace mineral premix	0.125	0.125	0.125	0.125
Selenium premix	0.050	0.050	0.050	0.050
Phytase	0.100	0.100	0.100	0.100
Salt	0.250	0.250	0.300	0.350
Plasma protein	5.000	2.500	0.000	0.000
Spray-dried blood meal	1.500	1.000	0.000	0.000
Soy concentrate	5.000	3.250	0.000	0.000
Fish meal	4.650	4.500	5.000	0.000
Dried whey	25.750	17.150	8.600	0.000
Lysine-HCL	0.130	0.275	0.300	0.435
DL-Methionine	0.230	0.210	0.160	0.150
L-Threonine	0.060	0.110	0.110	0.140
L-Tryptophan	0.010	0.025	0.015	0.015
Copper sulfate	0.000	0.000	0.000	0.08
Zinc oxide	0.375	0.375	0.375	0.000
Banminth-48	0.000	0.000	0.000	0.100
Corn premix	0.250	0.250	0.250	0.250
Total	100.00	100.00	100.00	100.00

continued

Table 1. Basal diet formulations

Ingredient, %	Phase 1	Phase 2	Phase 3	Phase 4
Calculated nutrients				
Metabolizable energy, kcal/kg	3529	3472.9	3427.3	3401.5
Net energy, kcal/kg	2743.3	2658.4	2567.4	2516.8
Crude protein, %	24.46	23.22	23.12	21.53
Total lysine, %	1.727	1.62	1.52	1.43
Standardized ileal digestible amino acids, %				
Lysine	1.55	1.45	1.35	1.25
Methionine	0.54	0.53	0.50	0.44
Methionine+cystine	0.91	0.85	0.79	0.73
Threonine	0.97	0.90	0.84	0.78
Tryptophan	0.28	0.26	0.24	0.23
Isoleucine	0.86	0.81	0.82	0.75
Valine	1.08	0.97	0.91	0.83
Ca, %	0.85	0.85	0.80	0.75
P, %	0.76	0.72	0.62	0.55
Available P, %	0.55	0.50	0.38	0.28

Table 2. Growth performance of nursery pigs fed *Cordyceps* mushroom powder

Diet	Negative control	300 ppm mushroom	600 ppm mushroom	Step-down ¹	Carbadox	Probability, <i>P</i> <				
						SE	Linear mushroom	Quadratic mushroom	Cubic mushroom	Negative vs. positive control
Pens/diet	6	6	6	6	6					
Initial wt, lb	13.11	13.08	13.01	13.02	13.09	0.503	0.143	0.639	0.599	0.7713
Day 7 wt, lb	15.07	15.05	14.49	14.69	14.89	0.197	0.066	0.581	0.147	0.525
Day 14 wt, lb	19.91	20.34	18.88	19.32	19.76	0.38	0.072	0.986	0.036	0.793
Day 21 wt, lb	25.67	25.88	24.46	25.49	25.09	0.610	0.216	0.224	0.885	0.506
Day 28 wt, lb	32.37	33.30	31.92	32.61	32.77	0.69	0.655	0.257	-	0.683
Day 35 wt, lb	40.41	41.62	40.45	41.35	41.48	0.868	0.902	0.231	0.976	0.393
Day 0 to 7										
ADG, lb	0.28	0.28	0.24	0.24	0.26	0.024	0.137	0.938	0.453	0.511
ADFI, lb	0.29	0.28	0.25	0.27	0.30	0.028	0.402	0.708	0.619	0.879
F:G	1.14	1.00	1.18	1.17	1.23	0.089	0.527	0.495	0.257	0.463
Day 7 to 14										
ADG, lb	0.69	0.75	0.63	0.66	0.70	0.046	0.310	0.752	0.103	0.936
ADFI, lb	0.82	0.90	0.74	0.90	0.87	0.066	0.839	0.569	0.072	0.590
F:G	1.21	1.19	1.18	1.33	1.26	0.099	0.458	0.398	0.705	0.742
Day 14 to 21										
ADG, lb	0.82	0.79	0.80	0.88	0.76	0.046	0.956	0.772	0.144	0.344
ADFI, lb	1.28	1.32	1.21	1.35	1.25	0.072	0.725	0.230	0.462	0.823
F:G	1.57	1.69	1.52	1.54	1.68	0.056	0.371	0.104	0.180	0.213
Day 21-28										
ADG, lb	0.96	1.06	1.07	1.02	1.10	0.043	0.092	0.548	-	0.032
ADFI, lb	1.59	1.68	1.65	1.68	1.63	0.048	0.407	0.208	-	0.539
F:G	1.67	1.58	1.54	1.67	1.48	0.048	0.079	0.662	-	0.012

continued

Table 2. Growth performance of nursery pigs fed *Cordyceps* mushroom powder

						Probability, $P <$				
						SE	Linear mushroom	Quadratic mushroom	Cubic mushroom	Negative vs. positive control
Diet	Negative control	300 ppm mushroom	600 ppm mushroom	Step-down ¹	Carbadox					
Day 28-35										
ADG, lb	1.15	1.19	1.22	1.25	1.24	0.045	0.512	0.510	0.199	0.153
ADFI, lb	2.43	2.17	2.34	2.75	2.36	0.222	0.446	0.884	0.096	0.828
F:G	2.16	1.80	1.96	2.21	1.86	0.179	0.291	0.447	0.214	0.256
Day 21-35 (Phase 4)										
ADG, lb	1.05	1.12	1.14	1.13	1.17	0.032	0.109	0.272	0.383	0.016
ADFI, lb	2.01	1.92	2.00	2.22	2.00	0.117	0.543	0.893	0.093	0.937
F:G	1.92	1.70	1.76	1.96	1.69	0.094	0.114	0.488	0.138	0.088
Day 0-35										
Treatments; contrasts						SE	Linear mushroom	Quadratic mushroom	Stepdown vs. 300 mushroom	Negative vs. positive control
ADG, lb	0.78	0.82	0.78	0.81	0.81	0.024	0.907	0.269	0.858	0.372
ADFI, lb	1.28	1.27	1.24	1.37	1.28	0.058	0.580	0.906	0.212	0.996
F:G	1.65	1.56	1.59	1.70	1.57	0.057	0.399	0.380	0.093	0.310

¹Step-down treatment contained 900, 900, 450, 300, and 150 ppm mushroom product during weeks 1, 2, 3, 4, and 5, respectively.

ADG = average daily gain. ADFI = average daily feed intake. F:G = feed conversion as feed-to-gain.